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Policy Issues and Challenges in the Introduction of Electronic Toll Collection in Indonesia: A Qualitative System Dynamics Approach

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Abstract

Objective: This study aims to analyze the policy issues and challenges involved in the implementation of Electronic Toll Collection (ETC) systems in Indonesia using a Qualitative System Dynamics (QSD) approach.

Theoretical Framework: The research utilizes the System Dynamics framework, focusing on the qualitative phase, which involves constructing Causal Loop Diagrams (CLDs) to visually represent relationships and feedback loops in the ETC system.

Method: The research applies a comprehensive literature review to identify key variables, causal relationships, and feedback loops relevant to ETC in Indonesia, followed by constructing CLDs based on the literature and validating these through expert consultations and stakeholder feedback.

Results and Conclusion: The study develops a CLD tailored to the Indonesian context, identifying key policy issues and challenges in ETC implementation. These challenges are categorized into technology adoption, public acceptance, regulatory frameworks, and financing. The research underscores the need for a coordinated, holistic approach in addressing the various policy issues simultaneously to ensure successful ETC implementation in Indonesia. It highlights the importance of stakeholder collaboration, public acceptance, adequate financing, and robust regulatory frameworks. The findings provide valuable insights for policymakers, transportation agencies, and other stakeholders in Indonesia and contribute to the broader literature on transportation policy analysis.

Keywords: *Electronic Toll Collection (ETC), Qualitative System Dynamics (QSD), Causal Loop Diagram (CLD), policy issues and challenges, transportation policy analysis.*

INTRODUCTION

The rapid growth of urbanization and economic development in Indonesia has resulted in an increasing demand for an efficient and sustainable transportation infrastructure. Among the various components of transportation infrastructure, toll roads play a vital role in driving economic growth (Faturachman, 2017) and promoting equitable development across the country (Astutik and Dewanti, 2020). The presence of toll roads can serve as a

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measure of both micro and macroeconomic progress, and demonstrates a nation's commitment to establishing a modern, efficient society (Siswoyo, 2020).

Under President Joko Widodo’s leadership, the Indonesian government has significantly increased its efforts to build toll roads. Between 2014 and February 2022, 1,569 km of new toll roads were constructed, a figure that surpasses the total 928 km of toll roads built from Indonesia's independence in 1945 until 2014 (Arief, 2022). By 2022, Indonesia planed to have 2,955 km of toll roads (Arief, 2022), which represents less than 40% of the country's planned 6,000 km of toll road infrastructure. This figure still lags behind other Southeast Asian countries with more advanced economies, such as Malaysia, which had 3,800 km of toll roads in 2019 (Badan Pengatur Jalan Tol, 2020), despite being smaller in size than Indonesia.

Not only in terms of number and length, the Indonesian government has been working to improve toll roads in terms of service and technology aspects. Traditional toll collection systems that rely on cash payments and involve many officers at toll booths had been implemented in the first stage of toll development in Indonesia from 1978 to 2017. Then since october 2017, the government implemented a policy of using toll cards (e-money), considering several drawbacks in the previous transaction system, such as congestion at toll plazas, increased air pollution, and higher transaction costs. Although this has resulted in an improvement, the payment system using e-toll cards is considered to have the same problems at toll plazas, especially congestion during rush hour because toll users still need to stop their vehicles to tap the card to the reader device. In this regard, the Indonesian government has recently initiated efforts to introduce Electronic Toll Collection (ETC) systems on its toll roads as a means of improving traffic flow and overall efficiency. This initiative was later embodied in the Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia Number 18 Year 2020 regarding Cashless Touchless Toll Transactions on Toll Roads.

In the face of rapidly evolving transportation needs and increasing environmental concerns, there is a growing global interest in implementing electronic toll collection (ETC) systems that can improve traffic management and contribute to infrastructure development. ETC systems are considered to offer a more convenient, efficient, and environmentally friendly alternative to cash- and card-based tolling. ETC, a technological solution for collecting tolls on highways, bridges, and tunnels, enables vehicles to pass through toll facilities without stopping, thus reducing traffic congestion, fuel consumption, and greenhouse gas emissions (Coelho et al., 2005; Tseng et al., 2014; Pérez-Martnez et al., 2011). Countries such as Belgium, Russia, Hungaria, the United States, and Taiwan have demonstrated the successful implementation of ETC systems, which has led to increased efficiency in traffic management and the generation of sustainable revenue for infrastructure development (Tseng & Pilcher, 2022).

The ETC technology that will be implemented on several toll roads in Indonesia is planed to utilize the Global Navigation Satellite System (GNSS) and adopt the Multi Lane Free Flow (MLFF) system mechanism that enable seamless and without stop movement of vehicles through toll gates. In order to implement this technology system, the government through Badan Pengelola Jalan Tol (BPJT, the Toll Road Regulatory Agency) is working with Roatex Indonesia Toll System (RITS), a subsidiary of Roatex Ltd. designated as the winner of the tender and the initiator of the MLFF system project in Indonesia, in a Kerjasama Publik dan Badan Usaha (KPBU – Public-Private Partnership) framework. The planned project scope is Design-Build-Finance-Operate-Transfer (DBFOT), with a project concession period of 10 years. The project return scheme is to use a user charge (tariff) with an investment value of IDR 4.4 trillion (Kantor Bersama KPBU, 2022). Previously planed at the end of 2022, the MLFF system in Indonesia will instead hold its first trial in June 2023 in Bali-Mandara toll road in June 2023 due to the preparation of the system and the determination of the trial location (Saputro, 2022).

The adoption of ETC systems, a global trend in transportation infrastructure, promises a more convenient, efficient, and environmentally friendly alternative to conventional tolling methods. This technological shift is not without challenges, encompassing issues like technology adoption, financing, public acceptance, and regulatory frameworks. The successful implementation and integration of ETC systems also require the involvement of various stakeholders, including government agencies, private companies, and international partnerships, as well as the adoption of appropriate technology and infrastructure. However, ETC adoption and expansion face multiple challenges, such as financial and technical constraints, public awareness and acceptance, interoperability and standardization of ETC systems across different toll roads, and security and privacy concerns. To overcome these challenges and reap the potential benefits of ETC systems, it is necessary to understand the dynamics of ETC system by examining how one variable interacts with others and in what pattern the interaction forms. In this regard, System Dynamics can be a useful analytical approach.

System Dynamics is an approach used to study complex systems and their underlying structures, feedback loops, and causal relationships (Sterman, 2000). In its qualitative phase of modelling, System Dynamics involves construction of Causal Loop Diagrams (CLDs) to visually represent the relationships between variables in the system and identify feedback loops that either reinforce or balance the system's behavior (Sterman, 2000). CLDs can help policymakers and stakeholders gain insights into the underlying dynamics of transportation systems and identify potential leverage points for interventions.

Although there is a growing body of literature on ETC systems and their implementation, there are limited studies that specifically apply Qualitative System Dynamics (QSD) to analyze the policy issues and challenges related to ETC adoption. Some studies have explored the broader context of transportation policy and infrastructure development using QSD. These studies provide valuable insights into the general principles and methodologies of QSD applied to transportation systems, but they do not focus on the unique dynamics and challenges of policy-related ETC systems.

This study aims to develop a CLD specifically tailored to the context of ETC systems in Indonesia, using a literature-based approach to identify key variables, causal relationships, and feedback loops that shape the system’s behavior. By constructing and validating the CLD with expert and stakeholder input, this study seeks to provide insights that can inform policy decisions and support the successful implementation of ETC systems in Indonesia.

The results of this study have significant implications for policymakers, transportation agencies, and other stakeholders involved in the identifying the key policy issues and challenges, stakeholders can develop more informed strategies and interventions to ensure the successful adoption and operation of ETC systems. Furthermore, this study contributes to the broader literature on transportation policy analysis, providing valuable insights for other countries considering the implementation of ETC systems.

THEORETICAL FRAMEWORK

After establishing the context and significance of implementing Electronic Toll Collection (ETC) systems in Indonesia, it is essential to delve into the theoretical foundation that guides this study. This research is rooted in the field of system dynamics, a discipline that provides a powerful lens through which the complexities and interdependencies inherent in such large-scale infrastructural projects can be examined and understood. System dynamics, with its dual emphasis on qualitative and quantitative modeling, offers a robust framework for analyzing the multifaceted challenges and dynamic interactions involved in the implementation of ETC systems.

The choice of system dynamics as the theoretical bedrock for this study is particularly pertinent given its proven effectiveness in exploring and elucidating the nuances of policy and strategy analysis, especially in contexts involving intricate systems like transportation and infrastructure management. By utilizing this approach, we aim to construct a comprehensive model that not only captures the various elements and stakeholders involved in the ETC implementation process but also reflects the dynamic interplay of these elements over time. This approach aligns with our objective of providing a deep and nuanced understanding of the policy issues and challenges in introducing ETC in Indonesia.

The field of system dynamics emerged in the 1950s, focusing on the study of information feedback characteristics within industrial activities. It demonstrates how organizational structure, policy amplification, and time delays in decisions and actions influence an enterprise's success (Forrester, 1958). System dynamics simplifies the endogenous structure of systems, identifies interrelationships between elements, and facilitates the simulation of various alternatives (Sterman, 2001; Musango & Brent, 2011).

System dynamics models enhance the understanding of system structures, policy and strategy analysis, theory testing, and support public policy analysis and evaluation (Winz et al., 2009). Numerous studies have established guidelines and strategies for system dynamics modeling, all containing similar iterative activities that involve both qualitative and quantitative modeling (Winz et al., 2009; Probst & Bassi, 2014; Davies et al., 2016).

Quantitative modeling allows the visualization of different intervention strategies through simulations (Sterman, 2000). It requires explicit statements about assumptions, identification of uncertainties and gaps in data availability, and aims to promote transparency. Quantitative modeling has been advocated for its ability to use mental models and structural elements of problems, identify and integrate soft and hard variables, simulate dynamic behavior, and assist in problem understanding and management (Sterman, 2000).

However, quantitative modeling has faced challenges in devising and quantifying soft and uncertain variables, which qualitative modeling addresses (Davies et al., 2016). While qualitative modeling is considered essential, some scholars emphasize the importance of quantitative modeling in achieving dynamic knowledge (Wolstenholme, 1999; Coyle, 2000). The debate over the superiority of quantitative models versus qualitative models continues, with the choice depending on the nature of the variables involved (Wolstenholme &Coyle, 1983).

To understand how a system behave, constructing Causal loop diagrams (CLDs) serves as an entry point, especially in qualitative phase. CLDs serve several purposes and benefits, including combining ideas, knowledge, and opinions, defining boundaries, and allowing stakeholders to understand systemic properties of an issue. CLDs, therefore, facilitate problem understanding, stimulate discussion, identify feedback loops, and provide context for modeling tasks. The effectiveness of CLDs relies on the quality of the process, which influences the conceptualization (Probst & Bassi, 2014).

CLDs consist of variables, links/arrows, direction of influence, and types of feedback loops. Variables represent conditions, situations, actions, or decisions that can influence and be influenced by other variables, and can be quantitative or qualitative. Links/arrows illustrate the relationship and direction of influence or causation among variables. The direction of influence is denoted by the symbols S/(+) for "same direction" or O/(-) for "opposite direction", indicating how one variable changes in relation to another. Feedback loops can be either balancing, which pursue equilibrium and are represented by 'B', or reinforcing, which amplify changes and are represented by 'R' (Probst & Bassi, 2014; Davies et al., 2016).

CLDs can support all decision-making phases. In the problem identification phase, they help identify the causal chain of the problem from an endogenous perspective. During the strategy/policy assessment phase, they help identify key entry points for interventions and support the evaluation of selected interventions, including short-term vs. long-term and direct and indirect impacts. In the decision-making and implementation phase, and the monitoring and evaluation phase, CLDs bring together diverse stakeholders to promote synergies, coordination, integrated strategies and action plans, and identify unintended consequences of implemented interventions (Probst & Bassi, 2014).

METHODOLOGY

Using a Qualitative System Dynamics (QSD) approach, the methodology of this study consists of two main steps: literature-based CLD construction and validation of the CLDs. A comprehensive review of the literature was conducted to gather information on ETC systems, their implementation in different countries, policy issues and challenges, and the application of QSD in transportation policy analysis. The review helped to identify the key variables, causal relationships, and feedback loops relevant to the ETC system in Indonesia.

Based on the literature review, a list of key variables was compiled that represent the critical elements of the ETC system. These variables were chosen based on their relevance to the policy issues and challenges identified in the literature and their potential impact on the successful implementation of ETC systems in Indonesia. Causal relationships between the identified key variables were established based on the findings from the literature review. These relationships represent the direct and indirect effects of one variable on another, helping to understand the underlying dynamics of the ETC system and the potential consequences of policy interventions.

Feedback loops were identified by examining the causal relationships between the key variables and determining whether they form self-reinforcing or balancing loops. Self-reinforcing loops amplify changes in the system, while balancing loops counteract changes and stabilize the system. Understanding the feedback loops in the ETC system can provide insights into the system's behavior and help identify potential leverage points for policy interventions.

To ensure the validity and reliability of the constructed CLDs, expert consultations were conducted with academics who have experience in ETC systems, transportation policy, and system dynamics. These experts provided feedback on the key variables, causal relationships, and feedback loops included in the CLDs, as well as suggestions for improvements or additions.

Stakeholder feedback was also gathered from relevant actors involved in the implementation of ETC systems in Indonesia, such as BPJT, PT RITS, and toll road operators. Their input helped to validate the CLDs by confirming the relevance and accuracy of the identified variables, causal relationships, and feedback loops, as well as providing insights into the local context and specific challenges faced in the Indonesian ETC system.

RESULTS AND DISCUSSION

ETC-Related Issues Considered in Literatures

By employing electronic devices to detect vehicles and debit the appropriate toll fees from users' accounts, Electronic Toll Collection (ETC) systems automate the process of collecting toll charges. They have a number of benefits over conventional cash-based toll collecting techniques, including fewer idling cars, reduced traffic jams at toll plazas, lower transaction costs, and improved traffic flow. According to Iseki and Demisch (2012) and Vats et al. (2014), ETC systems can be implemented utilizing a variety of technologies, including Radio Frequency Identification (RFID), Dedicated Short-Range Communications (DSRC), Automatic Number Plate Recognition (ANPR), and Global Navigation Satellite System (GNSS). The choice of technology is influenced by a number of variables, including budget, cost, and compatibility with current infrastructure.

Many nations throughout the world, notably the United States (with E-ZPass), Japan (with ETC), and some European nations (with EETS), have successfully adopted ETC systems. Based on regional requirements, available resources, and technical breakthroughs, each nation has created a distinct ETC system (Tseng & Pilcher, 2022). In order to allow for a gradual transition to fully electronic toll collection, ETC systems often require a transition period during which users have access to both cash and electronic payment options.

Numerous difficulties arise while implementing Electronic Toll Collection (ETC) systems. Complex hardware and software configurations are required to build an ETC system with effective assessment and guaranteed quality (Chu et al., 2013). According to Iseki and Demisch (2012), this technology should integrate road usage measurement, execute a tariff schedule, and effectively transmit data. For payment processing, quality control, and assuring security and privacy (Riley, 2008), accurate data collecting is essential. Data security, enforcement, and record usage are privacy concerns in the context of ETC (Ogden, 2001).

Due to context-specific topological differences and governmental policy objectives, choosing the right ETC technology and implementing it might be challenging (Levinson & Chang, 2003). In Singapore, for instance, DSRC is used instead of GNSS technology (Kramberger & Curin, 2011), however in the US, the choice of road tolling technology may rely on the size of the road networks and the complexity of the fee calculation (Iseki & Demisch, 2012).

Government policy goals and political divergence are important factors, with revenue generation for infrastructure development being crucial in some nations, technology costs being crucial in others (Vats et al., 2014), and environmental efficiency optimization being crucial in other nations (Odeck & Welde, 2017). Additionally, priorities can shift over time, with environmental issues becoming more crucial in many nations, such as Taiwan (Lai et al., 2021). These many underlying objectives are taken into account while deciding on the road pricing system (May, 1992).

With many studies (such as Chiou et al., 2013) concentrating on users' Willingness To Pay (WTP), governments' approaches to ETC also address marketing and publicity elements associated to road users' travel decisions. However, some nations (such as Singapore) may put customer preferences second to the decrease of congestion, or they may charge greater tolls for infrastructure development (such as Austria). The technology's usability may also have an impact on adoption, as was the case in Taiwan. Additionally, some countries (like the US (Ogden, 2001)) may place a higher priority on privacy and data usage issues than others (Lerouge, 1999).

Road pricing may be opposed by many parties, and while political and technical issues can be worked out (May, 1992), equitable issues may be more challenging to resolve (Di Ciommo & Lucas, 2014). A common strategy for addressing equity issues is to divert toll money to other initiatives, such as enhancing public transit (Di Ciommo & Lucas, 2014) to help low-income passengers (Hensher & Bliemer, 2014). Getting the public to accept road pricing systems while persuading governments of the benefits that the majority or all users will receive is a significant challenge (Hensher & Bliemer, 2014). A number of methods have been suggested to increase public acceptance of road pricing, including providing financial incentives or providing evidence of environmental enhancements, traffic congestion reductions, and travel time savings (Hensher & Bliemer, 2014).

Contexts unique to each country are also essential. The levels of willingness to pay (WTP) range between nations, even on the same continent as Europe (Glavi et al., 2021), and the effects of road pricing schemes might vary between cities even within the same nation (Santos & Rojey, 2004). If tolls are thought to be overly expensive, users may stop paying them and stop using the roads (Hensher et al., 2016). Vehicle type and speed should also be considered when determining charges, particularly with regards to congestion reduction (Button, 2004). Choosing between Time-Based (TB) vignette systems charging or Distance-Based (DB) charging systems is essential, with DB charging necessitating greater roadside infrastructure (Glavić et al., 2021).

In addition, cost-benefit analyses are commonly considered by policymakers in relation to ETC's practical applicability, often concerning social welfare (Levinson & Chang, 2003). For ETC, "costs" can include initial investment, ongoing operations and maintenance, and updates and reconstruction, while "benefits" could involve time savings (Chang & Hsueh, 2006), energy savings, emission reductions, and service improvements (Li et al., 1999).

However, cost prediction is highly complex, as evidenced by one study (Morgan, 1997) that found 13 of 14 newly implemented road tolls in the US had lower than predicted traffic flow levels. Consequently, the Public-Private Partnerships (PPPs) employed by many to fund toll collection systems and technology may be overly optimistic, potentially leading to failure and a need for public government intervention (Tseng & Pilcher, 2022). Financing tolling infrastructure is another complexity for governments, who may resort to Private Finance Initiatives (PFI) and Public-Private Partnerships (PPP) when public resources are limited. However, these are often more expensive than public construction (Acerete et al., 2009).

In terms of environmental benefits, ETC has been reported to decrease CO_2 emissions by 61-84% compared to manual one (Coelho et al., 2005), and both CO_2 emissions and transaction times can be reduced by switching to ETC (Tseng et al., 2014), consequently lowering energy consumption (Pérez-Martínez et al., 2011).

One approach to tolling aimed at reducing congestion is to increase charges during peak hours or reduce them during off-peak hours. This strategy, widely used in the United States, effectively decreases congestion during peak times. Some studies argue that such approaches should consider user WTP and equity issues, suggesting that revenue could be used to enhance public transportation during peak hours (May, 1992; Di Ciommo & Lucas, 2014).

Additionally, it is generally found that ETC, even when combined with MTC (Komada et al., 2009), is safer than MTC alone, as drivers can pass through an open road without changing lanes or stopping, although they may need to slow down for recognition (Dell'Asin & Monzón, 2011).

In the context of ETC system introduction and implementation in Indonesia, some studies highlighted similar issues. Congestion on toll roads, especially at toll booths, has been one of the main concerns of the community and expected to be resolved through the application of appropriate technology (Harnanda et al., 2022). Regarding the toll collection technology, Multi-Lane Free Flow (MLFF)-based ETC system has been studied to potentially reduce queues, delays, fuel consumption, and emissions (Munawar et al., 2020). However, its implementation in Indonesia is considered to face some challenges mainly concerning regulatory framework, financing, technology standardization, and socialization (Budiharjo & Margarani, 2019). In terms of technology selection, road conditions, driving behavior, and supporting infrastructure need to be considered (Recky, 2021).

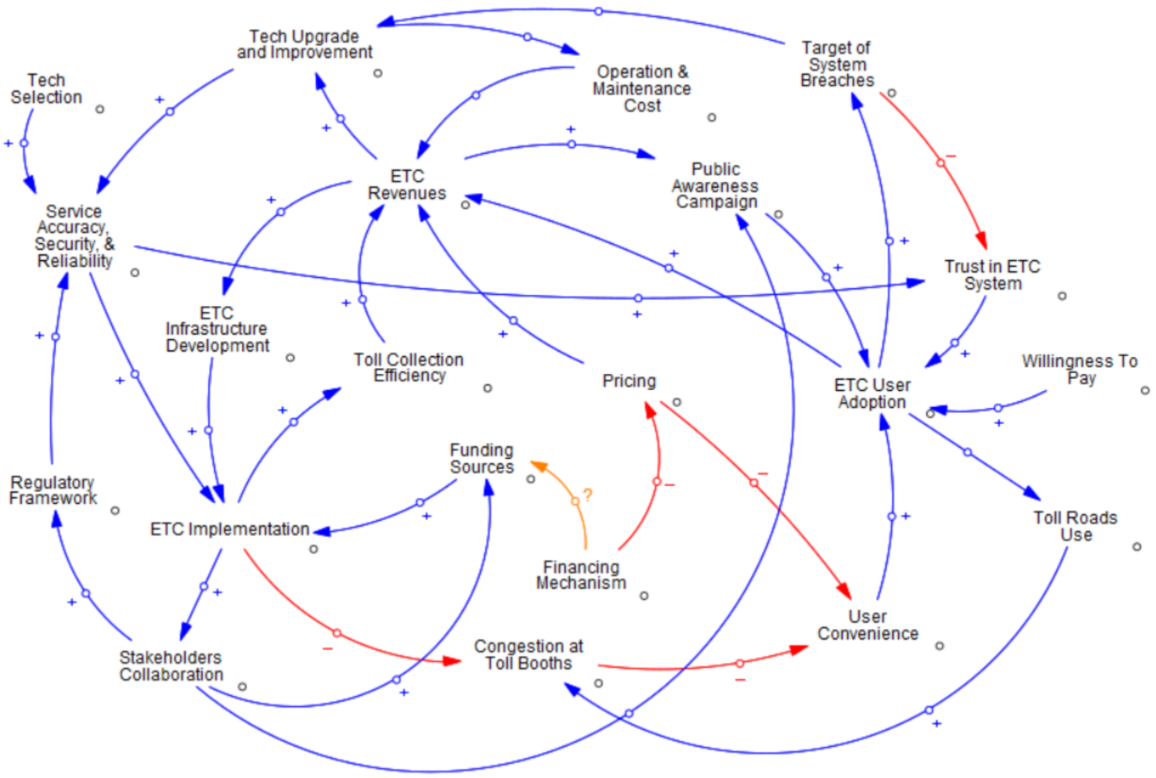
To sum up, governments and transportation agencies face numerous complexities regarding ETC, relating to practical application, technological development, political variations, and publicity and marketing of the schemes. To successfully implement ETC systems, these challenges must be carefully considered and addressed, keeping in mind the unique context of each country and the differing priorities and objectives that influence decision-making in the pricing systems.

Causal Loop Diagrams (CLDs) of the ETC system

Based on the literature review, Causal Loop Diagrams (CLDs) were constructed to represent the key variables, causal relationships, and feedback loops in the ETC system in Indonesia (Figure 1). The CLDs presented in the article offers a nuanced understanding of the dynamics involved in the implementation of Electronic Toll Collection (ETC) systems in Indonesia, focusing on key feedback loops that highlight the interconnected nature of various policy issues and challenges.

One of the primary feedback loops pertains to technology adoption. This loop illustrates the critical role of choosing the right ETC technology, which not only needs to be compatible with existing infrastructure but also must align with user behavior and preferences. The success of technology adoption is closely tied to user satisfaction, which in turn influences the overall effectiveness of the ETC system. The challenges in this loop are centered around ensuring technological compatibility, addressing user behavior, and securing widespread acceptance, all of which are essential for the smooth functioning of the ETC system.

Figure 1. CLDs of the ETC System



Source: Prepared by the authors (2023)

Another significant feedback loop is related to public acceptance. The success of the ETC system is heavily dependent on how well the public receives and adapts to it. This loop takes into account various factors that can influence public acceptance, such as concerns about privacy, data security, and the cost implications of ETC devices. Addressing these concerns is crucial, as they directly impact the willingness of the public to adopt this new system. The challenge for policymakers here is to devise strategies that not only increase awareness but also address the concerns that might hinder public acceptance.

The regulatory frameworks loop underscores the importance of having clear and comprehensive legal and regulatory guidelines for the operation of ETC systems. This aspect is critical for protecting user rights, ensuring the interoperability of the system across different jurisdictions, and establishing operational rules. The main challenge in this loop is the development of these regulations and ensuring coordination among various stakeholders, including government agencies, private sector partners, and regulatory bodies.

Financing is another crucial loop that deals with the financial aspects of implementing ETC systems. This includes securing the initial investment for setting up the systems and managing the ongoing operational costs. The financing loop highlights the need for risk-sharing arrangements and securing adequate financing, often through public-private partnerships. The challenge here lies in balancing the financial responsibilities between the public and private sectors and ensuring the financial sustainability of the ETC system in the long run.

These loops are not isolated but are deeply interconnected, illustrating the complex nature of ETC system implementation. For instance, successful technology adoption relies heavily on public acceptance, which is influenced by the regulatory frameworks and financing strategies. This interdependency suggests that a holistic approach is necessary for the successful implementation of ETC systems. Integrated policy interventions that consider all these aspects are more likely to yield successful outcomes. The dynamic nature of these feedback loops also highlights the need for strategic planning and careful consideration of various factors, including technological options, public engagement, regulatory development, and financial planning.

Key policy issues and challenges

The analysis of the CLDs revealed several policy issues and challenges which can be grouped into several categories:

a. Technology adoption

The selection of an appropriate ETC technology is crucial to ensure system effectiveness and user satisfaction. Policy makers need to consider various factors, including technological, social, and economic, in the adoption of ETC as a new technology in Indonesia. Considering only the technical aspects can lead to the failure of the adopted new technology to work effectively and optimally. Due to different socio-economic conditions, the appropriate and suitable criteria to be considered in technology adoption in different countries may vary, hence, they may come across with various choices. Vats et al., (2014), for instance, considered thirteen criteria for suitable technology selection of ETC system for India, resulting RFID-based ETC as the best alternative. RFID-based ETC system was also recommended as the most suitable technology to be adopted in Bangladesh in the short term, especially considering its relatively low cost and ease of implementation, but in the long run satellite-based ETC system was projected to be the most promising option (Zoy et al., 2020).

However, there's a growing trend in many countries to introduce ETC systems, leveraging Global Navigation Satellite Systems (GNSS) and Global Positioning Systems (GPS), which do not require gantries to register passing vehicles and, thus, support free-flow tolling systems (Tseng & Pilcher, 2022).

The MLFF-based ETC system that applies GNSS technology was also recommended by Roatex Ltd. in the feasibility study it presented. It is considered the most attractive option for Indonesia because, among other things, the users can use an e-OBU (electronic on-board unit) on their own smartphone, hence, minimizing the cost of additional equipment from the user's side. In addition, the implementation of this GNSS technology requires no exposure to roadside infrastructure (unlike DSRC, ANPR, and RFID based system), except for enforcement purposes (Roatex, 2020).

However, the ETC technology recommendations place more emphasis on considerations of technological and economic aspects. The complexity of the GNSS-based MLFF system demands more collaboration and coordination efforts between stakeholders, not only toll road authority (BPJT), banks, toll road operators, but also police and court institutions, for instance, in enforcement against toll violations. In this regard, clear guidelines and protocols, derived from comprehensive regulations, are key in dealing with the complexity of the GNSS-based ETC system having been selected for adoption.

Policy makers also need to plan the implementation of new technologies by considering existing infrastructure and seamless transitions among groups of community. In the context of ETC introduction in Indonesia, careful planning and precise execution are crucial to support the GNSS technology's launch. Pre-registering users and vehicles are required facilitate a seamless transition to the new system. A comprehensive and successful system integration test must be conducted before the official launch date, covering not only registration, declaration, data collection, and payment procedures, but also back-end functions like settlement with BLU and TROs, as well as testing the entire enforcement process. Consequently, such a system test involves all MLFF service stakeholders and requires them to provide the necessary resources.

Policymakers should also plan for a seamless transition process, considering the new system compatibility with existing infrastructure and its accuracy as well as reliability. In the context of MLFF-based ETC system introduction in Indonesia, it is planed that deconstruction of existing toll booths will be carried out in stages, allowing time for system design, integration, testing and transition. Beside that, factors relating to user behavior must also be considered to ensure widely user acceptance.

b. Public acceptance

The successful implementation of ETC systems depends on the acceptance of users, who must be willing to adopt the new technology and comply with the associated rules and regulations. Policymakers should design strategies to increase public awareness of the benefits of ETC systems and address potential concerns related to privacy, security, and fairness.

The cost of ETC devices and installation can be a barrier for some people, especially those with low incomes, and further affect their convenience. Even though the proposed ETC technology will offer the advantage of not needing a physical device that users need to provide for applying e-OBU, they still need to have a smartphone as a substitute for an electronic toll card. This may be an obstacle for drivers of transportation and logistics companies who are not equipped with smartphones. Providing subsidies can be considered to be one of the policy options implemented by the government, although this will also affect revenues of ETC implementation, thus careful calculations are needed.

Public awareness campaign to inform users about the benefits, usage, and requirements of ETC systems can be a useful action to promote acceptance and adoption. Utilizing various campaign approach, especially social media and motorist community, should be optimized to gain wide public attention.

Public acceptance may also relate with privacy concerns as ETC system collects data about their travel habits. In addition, there is a risk of ETC devices being hacked or stolen, which could lead to fraud or identity theft, hence, raising concerns about security data. In this case, the government needs to provide a regulatory framework that is able to assure and guarantee ETC system users of their data privacy and security.

In addition, activated customer service channels have to be provided to help toll users. It is vital to address any additional support requests from toll road users before and during the launch of the new technology, which may necessitate allocating extra resources to this task.

c. Regulatory frameworks

Implementing ETC systems requires the development of appropriate legal and regulatory frameworks to govern their use, ensure interoperability between different jurisdictions, and protect user rights. Policymakers should work together with relevant stakeholders to establish clear rules and guidelines for the operation of ETC systems.

In the context of Electronic Toll Collection (ETC) systems, a regulatory framework would include the set of laws, policies, and standards enacted by the government or relevant regulatory bodies to oversee the planning, implementation, and operation of ETC systems. This may involve aspects such as licensing and permitting requirements for ETC operators; privacy and data protection regulations to safeguard user information; technical standards and specifications for ETC equipment and infrastructure; security requirements to prevent fraud, hacking, and other threats; pricing structures, including toll rates and fees; interoperability guidelines to ensure seamless integration across different toll systems and regions; and compliance monitoring and enforcement mechanisms.

The regulatory framework formulation above requires collaboration between stakeholders, including government agencies, Badan Usaha Pelaksana (BPU – Special Purpose Vehicle, in this case, RITS), and toll road operators, in order to obtain comprehensive results.

d. Financing

Implementing an ETC system requires substantial initial investment, as well as ongoing maintenance and operational costs. To support the development and operation of the ETC system, the government has been conducting a KPBU (public-private partnership) with Design-Build-Finance-Operate-Transfer (DBFOT) scheme, by designating PT RITS as the BPU. Regarding this financing mechanism, several challenges are faced, such as, risk allocation, financing availability, long term-financial sustainability, and capacity building.

Determining an appropriate risk-sharing arrangement between the government and the private sector partner can be a challenge. The public and private sectors need to agree on how to allocate risks such as demand risk, construction risk, operation risk, and financial risk to create a balanced partnership. On the other hand, securing adequate financing for the project can be a challenge, as the government might need to consider providing guarantees or other financial support mechanisms to attract private investment.

Strengthening the capacity of public institutions involved in the PPP process is vital. This includes building expertise in project management, contract negotiation, and monitoring and evaluation of the ETC system.

Recommendation for Policy Implementation

This finding underscores the need for a holistic approach to ETC system implementation, as addressing individual policy issues in isolation may not lead to the desired level of success. By adopting an integrated policy intervention, policymakers and stakeholders can better address the complex interactions between technology adoption, financing, public acceptance, and regulatory frameworks, ultimately leading to a more efficient and sustainable transportation system in Indonesia. This will ensure that all key policy issues and challenges are addressed and their complex interactions are taken into consideration, leading to more efficient and sustainable transportation systems in Indonesia. Some strategic recommendations are presented as follows:

a. Integrated Policy Intervention

Policymakers should adopt an integrated policy intervention as it leads to the most probably successful outcomes for the ETC system. This approach involves the simultaneous implementation of advanced technology adoption, comprehensive financing mechanisms, effective public awareness campaigns, and comprehensive regulatory frameworks. This will ensure that all key policy issues and challenges are addressed and their complex interactions are taken into consideration, leading to more efficient and sustainable transportation systems in Indonesia.

b. Coordination and Collaboration

Successful implementation of an integrated policy intervention requires close coordination and collaboration among various stakeholders, including policymakers, transportation agencies, private sector partners, and the public. Establishing a multi-stakeholder working group or task force responsible for overseeing the ETC system's implementation can help facilitate communication, knowledge sharing, and joint decision-making, ensuring that the interests and concerns of all stakeholders are taken into account.

c. Monitoring and Evaluation

To ensure the effectiveness of policy interventions, policymakers and stakeholders should establish a robust monitoring and evaluation (M&E) system that tracks the progress of ETC implementation and assesses the impact of different policy measures. This will enable stakeholders to identify potential bottlenecks or unintended consequences, adjust their strategies accordingly, and continuously improve the ETC system's performance. The M&E system should be based on clear performance indicators, such as the level of technology adoption, the amount of funding secured, public acceptance rates, and the effectiveness of regulatory frameworks.

d. Capacity Building and Knowledge Transfer

Policymakers and stakeholders should invest in capacity building and knowledge transfer initiatives to ensure that all actors involved in the ETC system's implementation have the necessary skills and expertise to effectively carry out their roles. This may include training programs, workshops, and study tours to learn from the experiences of other countries that have successfully implemented ETC systems.

e. Flexibility and Adaptability

As the ETC system evolves and new challenges emerge, policymakers and stakeholders must remain flexible and adaptable in their approach to policy implementation. This may involve regularly reviewing and updating technology adoption strategies, financing mechanisms, public awareness campaigns, and regulatory frameworks, as well as being open to learning from new experiences and incorporating best practices from other countries.

By taking these implications and recommendations into account, policymakers and stakeholders can address the complex interactions between technology adoption, financing, public acceptance, and regulatory frameworks, ultimately leading to a more efficient and sustainable transportation system in Indonesia. The findings serve as a valuable guide for designing and implementing effective policy interventions that support the successful introduction of ETC systems.

CONCLUSION

The results of the analysis highlighted the importance of addressing technology adoption, financing, public acceptance, and regulatory frameworks for the successful implementation of ETC systems. The scenario analysis demonstrated that a coordinated approach, addressing all policy issues simultaneously, is likely to lead to the most successful outcomes.

The findings of this study have several implications for policymakers and stakeholders involved in the implementation of ETC systems in Indonesia. It emphasizes the need for well-informed decision-making processes, securing adequate financing, promoting public awareness and acceptance, and developing clear legal and regulatory frameworks. By addressing these policy issues and challenges, policymakers can support the successful implementation of ETC systems, leading to more efficient and sustainable transportation systems in Indonesia.

This study also acknowledges its limitations, such as the reliance on existing literature for the construction of the CLD and potential biases in the validation process. Future research could address these limitations by conducting in-depth case studies, interviews with stakeholders, and applying quantitative system dynamics models to simulate the impact of policy interventions over time.

This study contributes to the understanding of policy issues and challenges in the introduction of ETC systems in Indonesia and provides valuable insights for policymakers and stakeholders to support successful implementation. By adopting a QSD approach, this research demonstrates the potential of systems thinking and modeling techniques to analyze complex transportation policy issues and inform decision-making processes.

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