

# An Extended Case Study Using SWOT Analysis on the Impact of Multi-lane Free Flow on Vehicle Operating Costs

Hally Hanafiah<sup>1</sup>, Ratna Palupi<sup>2</sup>, Muhammad Emyr Ilham<sup>3</sup>, Liswandi<sup>4</sup>, Pandu Adi Cakranegara<sup>5</sup>

<sup>1,4</sup>Management Department, President University, Bekasi, Indonesia 17550

<sup>2</sup>SIMT Department, Institute Teknologi Sepuluh Noverber, Surabaya, Indonesia 60264

<sup>3</sup>Transportation Department, Institute Transportation & Logistic Trisakti, Jakarta, Indonesia 13410

<sup>5</sup>School of Business Management, Universitas Ciputra, Jakarta, Indonesia 11610

**Abstract**— growth and competitiveness, especially in manufacturing, trade, and export sectors. Road transport, contributing 8.5%, suffers from poor infrastructure and congestion, raising vehicle operating costs (VOC). This study, *An Extended Case Study Using SWOT Analysis on the Impact of Multilane Free Flow on Vehicle Operating Costs in Indonesia*, evaluates MLFF, a barrier-free toll system, as a strategic solution. Results show MLFF significantly reduces VOC compared to E-Toll, improving cost efficiency and performance. Policymakers and stakeholders should pursue phased MLFF adoption with regulatory support, public outreach, and technology standardization to strengthen Indonesia's logistics sector.

**Keywords**— Multi-lane Free Flow, Transportation, Logistic Cost, Vehicle Operating Cost, SWOT Analysis.

## I. INTRODUCTION

### A. Importance of Transportation in Supply Chain

Transportation is a critical component of supply chain management, as products are rarely manufactured and consumed in the same location. The effective management of transportation is critical for the successful execution of supply chain strategies. The movement of goods between locations within the supply chain is referred to as transportation operations [1]. The significance of transportation has increased in line with the expansion of e-commerce and the globalization of supply chains. Transportation is the most readily recognized activity within logistics. Customers can track the movement of goods across various modes of transportation, including trucks and trains (land), ships (sea), airplanes (air), or multimodal systems that integrate multiple transport methods.

In supply chain management, transportation is essential to in facilitating logistics services, including product movement and storage. It facilitates the transportation of goods, whether they are raw materials, parts, work-in-progress items, or finished goods. The economic value of transportation lies in its ability to move goods from the point of origin to a designated destination within a company's supply chain management system. Transportation performance directly impacts procurement, production, and customer relationship management. Without reliable transportation performance, key supply chain activities cannot function effectively or efficiently.

### B. Current Logistics Costs in Indonesia

According to the Ministry of Finance (2019-2020), logistics costs in Indonesia remain relatively high at 23.5% of GDP equivalent to billions of USD annually, which raises consumer prices, reduces profit margins for businesses, and limits Indonesia's competitiveness in regional trade. With land transportation contributing the second-largest share at 8.5%, followed by inventory costs (8.9%), sea transportation (2.8%), administration (2.7%), and other expenses (0.8%) [2]. Furthermore, recent data from the Indonesian Employers Association (Apindo) highlights that Indonesia's logistics costs are significantly higher than neighboring economies, such as Malaysia (13% of GDP), Singapore (8% of GDP), and China (16% of GDP). This gap means Indonesian exporters face higher operational costs, making goods less competitive in international markets. Highlighting the pressing need for systemic changes to improve competitiveness [3]. Many argue that logistics inefficiency is a major contributor to Indonesia's low international competitiveness.

### C. Challenges in the Logistics Sector

There are several key factors contributing to the high logistics costs in Indonesia, four of which are [4]:

#### *Subsidies are temporary*

Temporary government subsidies are ineffective and should instead be allocated to improving transportation infrastructure. For example, subsidies given in the shipping sector should be diverted to ports.

#### *The volume of goods being transported is imbalanced, particularly between Java and other regions*

There is a clear disparity in the volume of goods sent to and from Java. For instance, the cost of shipping goods from Sorong to the United States remains higher than shipping from Java, despite the longer distance.

#### *Illegal Levies*

The economic impact of thuggery and illegal levies not only increases the operational costs borne by logistics companies but also contributes to the overall deterioration of the logistics system. These illegal levies affect the logistics system through opportunity costs, loading and unloading delays, land transport disruptions, and other domino effects.

### *Infrastructure is inadequate*

The prompt delivery of products is hampered by inadequate infrastructure and subpar facilities. Infrastructure varies across regions, with some roads either nonexistent or not extending beyond Java. The existing roads are in such poor condition that they require longer travel times, despite the presence of a toll fee collection system. The use of e-tolls still results in queues and presents additional issues that require further attention.

One of the most visible inefficiencies occurs at toll gates, where vehicle queues increase operating costs and travel times. Addressing this bottleneck could yield immediate cost savings, and MLFF offers a direct technological solution.

## II. LITERATURE REVIEW

### *A. Alternative Solutions*

To address the issue of high logistics costs in Indonesia, the government, through relevant transportation and logistics agencies, must collaborate with industry stakeholders to develop integrated and sustainable solutions. In this context, the focus of this discussion is on addressing infrastructure challenges, specifically by minimizing toll queues through the implementation of a digital toll collection system powered by Multilane Free Flow (MLFF) technology.

Traffic congestion in Jabodetabek contributes significantly to economic losses, caused not only by travel delays but also by toll gate congestion. Proposals to implement contactless cashless toll systems using Multilane Free Flow (MLFF) technology highlight potential efficiency gains, such as reducing transaction times by seconds to minutes per vehicle. When scaled across toll roads, these improvements could mitigate cumulative delays and associated costs, though challenges in implementation and systemic bottlenecks remain unresolved.

Logistics is a strategic process involving the movement and storage of goods, spare parts, and finished products from suppliers to company facilities. In addition, it alludes to the procedure of designing and managing the movement and storage of commodities [5], as well as associated data and services from. with the objective of meeting customer needs, from the source to the final consumer. It also encompasses the coordinated flow of materials, information, and financial resources between consumers and suppliers. Furthermore, logistics encompasses the planning, execution, and management of the efficient movement of costs, the location of raw materials, inventory management, completed products, and other factors. and related information from the source to the point of consumption in order to satisfy customer requirements.

Transportation refers to the act, process, or system of transporting or being transported [6]. The term "to transport" specifically means moving something from one location to another. Furthermore, transportation is characterized as a process of relocating people or goods from one place to another using a structured system to meet human needs by enabling connectivity and interaction. Its primary function is to link individuals to land use, integrate activities, and provide spatial and temporal access to essential commodities.

Transportation plays a crucial role in the supply chain process. The movement of a product from one location to

another throughout the supply chain process, from its inception to the consumer, is referred to as transportation. Transportation plays an important role because a product is rarely produced and used in the same location. Transportation is a significant cost component in the supply chain process.

Transportation challenges in urban areas involve the interaction of transport systems, land use, population, and economic activities. Transportation is essential for promoting economic development, generating job possibilities, and revitalizing cities. In tackling transportation issues, the choice of transportation mode is primarily influenced by the need to move the largest volume of goods and people over the shortest distances [7]. In this context, mass transportation is considered more effective than individual transportation. Transportation infrastructure serves two primary purposes: as a tool for guiding urban development and as a means of facilitating the movement of goods and people generated by urban activities [8]. The first role, as outlined above, is often utilized by regional planners to shape development in alignment with strategic plans. Furthermore, transportation strategies that incorporate modal shifts, particularly for perishable goods such as seafood, have been proven effective in reducing logistics costs while maintaining product quality during transit [6].

The number of vehicles in Indonesia continues to grow, outpacing the development of supporting infrastructure. Congestion often occurs on the roads, especially in urban areas. Travel time will increase due to obstacles on the road. A freeway, commonly referred to as a toll road, was developed. Toll itself means a certain amount of money paid for the use of a toll road [9].

Toll roads in Indonesia are regulated by the Toll Road Regulatory Agency (BPJT), an institution established by the Minister that operates under the Ministry's authority. The primary goal of toll roads is to improve the efficiency of transportation services, supporting economic growth, particularly in areas with significant development. Access to toll roads requires users to pay a fee, which in Indonesia is currently processed through E-Toll transactions. This system requires users to tap a card with a balance, which is then deducted according to the toll rates set for each road.

During periods of heavy traffic, toll gates often face long queues of vehicles waiting to make payments to access toll roads [10]. The payment process for each vehicle contributes to these delays, with some drivers occasionally encountering issues when tapping their cards. To address this, adopting advanced technology such as Multilane Free Flow (MLFF) is essential. MLFF enables a seamless, non-stop payment process, allowing users to complete transactions without halting their vehicles [11].

### *B. Evolution of Toll Payment Systems in Indonesia*

A look back at the development of toll road payment transactions in Indonesia has gone through several times and is currently under development, namely:

#### *Pay cash*

Pay cash is a payment method made at toll gates with cash. This method was introduced in 1987, coinciding with the establishment of Indonesia's first toll road. Road users must

provide a certain amount of money to pay at the toll gate [12]. This method takes a long time, especially if road users do not have the right money.

*Electronic cards*

Since October 31, 2017, all toll payments in Indonesia must be made using an e-money card. Road users no longer need to prepare cash for toll payments. Just provide an electronic card containing a balance to be able to use the toll road [13]. Electronic cards are cards that function as digital money [14]. This prepaid card stores monetary value electronically, either on a server or a chip. The balance on the card is the value of money stored, which can be used for various payments at shops that accept payments by e-money.

While the implementation of e-Toll has reduced the reliance on cash payments and improved transaction efficiency, it still faces limitations. Vehicles are required to stop at toll gates, leading to congestion and delays during peak hours, particularly on major toll roads. Previous research has shown the positive impact of MLFF in addressing these issues. Budiharjo and Margarani (2019), for example, highlighted how MLFF helped solve the problem of long queues at toll gates in Indonesia [15]. This study broadens the focus by exploring MLFF's impact on logistics costs through a quantitative approach that is relevant to support more effective national transportation policies [16].

*Single-lane free flow (SLFF)*

Single-lane Free Flow is a non-stop payment system in every transaction lane. This system enables vehicles to pass through toll gates without stopping to tap an e-money card [17]. It is expected that this system will reduce queue buildup at toll gates. Travel time is also faster because vehicles no longer need to stop and queue to make transactions at toll gates. However, for SLFF there is only one lane that uses a free flow system.

*Multilane Free Flow (MLFF)*

MLFF as a form of ETC is a new method of paying tolls where vehicles do not need to stop and stop their vehicles at the toll gate. The existing system identifies the vehicle so that the vehicle can continue to drive at high speed [18]. MLFF technology offers several key features and advantages. First, the system is easy to install on existing roads, and it does not require additional space for toll booths. Then, it helps reduce traffic congestion by eliminating barriers that would otherwise cause vehicles to stop. In other words, vehicles do not need to slow down to pay the toll.

Apart from highway tolls, MLFF can also be used for various Intelligent Transport Systems (ITS) applications such as vehicle monitoring for traffic management, violation control, and vehicle tax management. In addition, its compact design, featuring an integrated antenna and processor, ensures efficient installation and maintenance. Additionally, MLFF can communicate with high-speed automobiles at an output of 2 WERP or lower, which is the threshold set by wireless radio legislation in several significant Asian nations. Toll booths and MLFF systems may both use toll collection systems with dual-use designs.

MLFF also has ethernet cable connectivity for easy installation. Additionally, the robust security design allows for the storage of three generations of security keys. As Radio Frequency Identification (RFID) for equipment in vehicles,

MLFF is compliant with ISO18000-6C, an international standard that will be coming soon. It is no less important to know that this tool works with vehicles traveling at very high speeds (180 km/hour).

*Advantages of MLFF*

Unlike e-Toll, which requires vehicles to stop, and SLFF, which applies only to a single lane, MLFF enables all lanes to process transactions seamlessly without barriers.

When compared to other payment options, multilane free flow (MLFF) has a lot of benefits. Travel time can be done more quickly and efficiently, there are no queues and delays at toll gates, it is environmentally friendly and can speed up the mobility of delivery of goods and services. The MLFF function are detect vehicles passing through toll gates, the system processes transaction information to management for transaction processing, supervision and monitoring of status and activities at toll gates and protect data so that data manipulation does not occur or data can be lost.

III. RESEARCH METHOD

Numerous countries worldwide have implemented MLFF, including Slovakia, Germany, the Czech Republic, Russia, Hungary, and Belgium. In the Asia-Pacific region, Malaysia, Singapore, and Australia have also adopted this system. Several types of technology support the implementation of MLFF.

*A. Criteria for Technology Selection*

Selecting the appropriate technology requires consideration of its reliability and the accuracy with which the installed equipment can detect data from passing vehicles. Investment costs must be carefully evaluated to prevent financial losses for business entities and other stakeholders. Apart from that, both the Toll Road Regulatory Agency and business entities need to consider the capabilities of the users who will use the toll road, If the selected technology burdens drivers, they may avoid using toll roads altogether. Alternative technologies that can be used are ANPR, DSRC, RFID, and GNSS.



Figure 1. An example of an Automatic Number Plate Recognition (ANPR) system that captures vehicle license plates using Optical Character Recognition (OCR) technology for identification and monitoring purposes.

*Technologies Supporting Multilane Free Flow Implementation Automatic Number Plate Recognition (ANPR)*

ANPR is a commonly used method for vehicle identification in the modern era. The method used for vehicle monitoring uses optical character recognition in images by reading vehicle number plates [19]. Number plate recognition systems can utilize CCTV installed in traffic zones or areas designated for specific monitoring tasks. To provide a clearer illustration of how ANPR operates in practice, Figure 1 below

demonstrates an example of a system capturing and recognizing vehicle license plates using OCR for identification and monitoring.

*Dedicated Short-Range Communication (DSRC)*

DSRC is a short-to-medium-range wireless communication channel, supporting both one-way and two-way transmission, and is designed for automotive applications, enabling high-speed data transmission [20]. This is particularly important for communication-based active safety applications designed to prevent accidents. There are two types of DSRC, namely vehicle-to-vehicle and vehicle-to-infrastructure. Both need a stable wireless interface that can withstand extreme weather and brief interruptions, all of which DSRC can provide. To provide an overview of how DSRC enables crucial high-speed wireless data transmission, Figure 2 below illustrates the technology facilitating both vehicle-to-vehicle and vehicle-to-infrastructure communication in modern transportation systems.

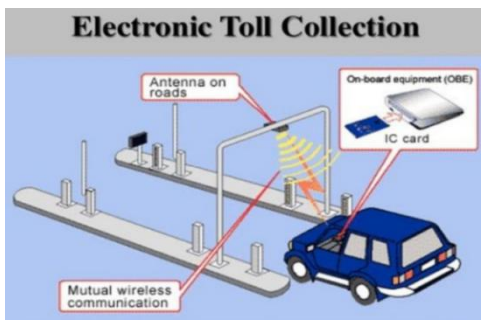


Figure 2. Illustration of Dedicated Short-Range Communication (DSRC) technology enabling high-speed wireless data transmission for vehicle-to-vehicle and vehicle-to-infrastructure communication in transportation systems

*Radio Frequency Identification (RFID)*

RFID is a wireless identification system that enables data collection without physical contact, unlike traditional methods such as barcodes or magnetic stripe cards [21]. This tool uses an electromagnetic radiation system to transmit codes. Radio waves are used in the RFID identification system. A Tag and a Reader are the two essential components. A thing that will be recognized by an RFID Reader is an RFID tag, which is a device that is attached to the object. To illustrate how RFID technology employs radio waves for wireless identification, Figure 3 below demonstrates the interaction between a tag and a reader in various applications.

*Global Navigation Satellite System*

GNSS or Global Navigation Satellite System is a constellation of satellites that provides signals from space that transmit positioning and timing data to GNSS receivers [22]. These recipients then use this data to determine their location. To provide a clearer understanding of how GNSS delivers positioning and timing data, Figure 4 illustrates how satellite signals are received by GNSS receivers to determine accurate locations.

In Indonesia, MLFF implementation is already underway and is currently in the trial phase utilizing RFID technology. In the future, it is planned to use GNSS technology that uses satellites with plans to implement it in stages starting in 2022 Q3.

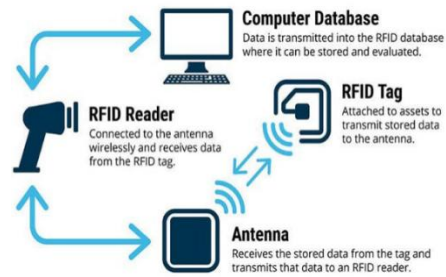


Figure 2. Illustration of Radio Frequency Identification (RFID) technology utilizing radio waves for wireless identification through tag and reader interaction in various applications.

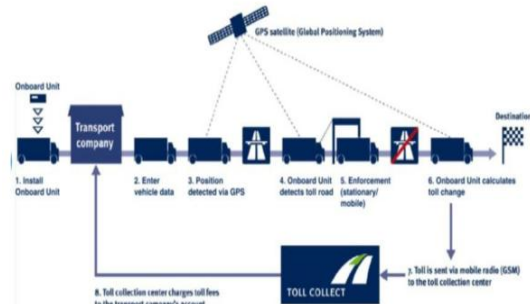


Figure 3. Illustration of Global Navigation Satellite System (GNSS) technology providing positioning and timing data through satellite signals received by GNSS receivers for location determination.

TABLE 1. Comparison of Alternative Electronic Toll Collection (ETC) Technologies, including ANPR, DSRC, RFID, and GNSS, highlighting their characteristics, performance, and implementation in various regions.

Automatic Number Plate Recognition	Dedicated Short-Range Communication
Camera technology to detect number plates	Contactless Technology with 5.8 GHz Frequency Using OBU DSRC
Performance is stable but does not provide real-time location data	Performance tends to be stable and reliable
Used on roads in the cities of London, Milan, Stockholm and Toronto	It has been implemented in Japan, Korea, and across various European countries

Radio Frequency Identification	Global Navigation Satellite System
Contactless Technology with 860-960 MHz GHz Frequency Using Tag	A satellite-based strategy for tracking user journeys via GNSS-enabled OBUs
High performance and reliability and is not disturbed by weather factors	The technology enables real-time access to user data
Used in America and Asian countries, Taiwan and Malaysia	Used on motorways in Germany and Slovakia

*Comparative Analysis of Technologies*

To offer a detailed overview of how these four MLFF technologies perform and are implemented, Table 1 below provides a comparative look at ANPR, DSRC, RFID, and GNSS in various region.

*Quantitative Approach for VOC Analysis*

The data for this study were sourced from the journal “Analysis of Multilane Free Flow Implementation at Toll Gates in Indonesia” [16], which included vehicle operating costs (VOC) for various vehicle types related to the implementation of Multilane Free Flow (MLFF). The Ministry of Public Works' methodology for VOC computations served as the basis for the study, which quantitatively examined the performance of E-

Toll and MLFF systems. VOC was determined by summing fixed and non-fixed costs to compare expenses between the two systems. The results showed that MLFF implementation significantly reduced VOC across all vehicle types, highlighting its efficiency and impact.

*Application of Center of Gravity Method*

Similarly, the Center of Gravity method has been demonstrated to optimize logistics distribution by reducing transportation costs and travel distances, as shown in the case study of PT Kimia Farma in West Java, which achieved a cost reduction of 6.91% through this approach [23].

To provide a clearer overview of the methodological stages, the research process is summarized in a systematic flowchart (Figure 5). This flowchart outlines the sequential steps, starting from problem identification and literature review, followed by technology selection and comparative analysis, data collection, and quantitative VOC evaluation.

It further incorporates the SWOT analysis and the application of the Center of Gravity method, before arriving at the study’s conclusions and policy recommendations.

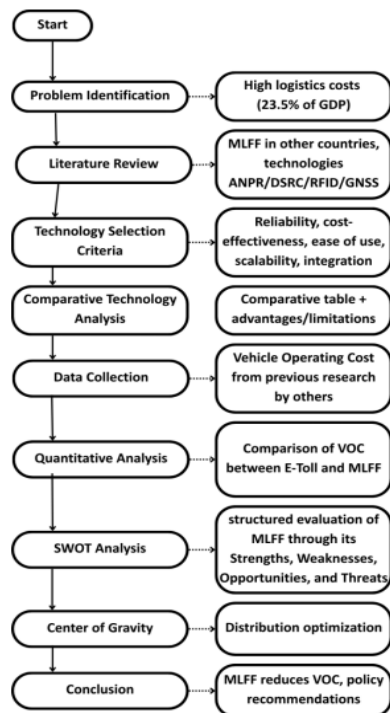


Figure 4. Research Flowchart of MLFF Study

IV. RESULT AND DISCUSSION

*Toll Road Network Overview*

According to primary data from the Indonesian Toll Road Services Authority, the toll road network in Indonesia currently spans 1,713 km, with ongoing construction and development projected to expand it beyond 6,000 km in the coming years. The concentration of toll and express roads in Java and South Sumatra mirrors the population distribution, as around 60% of Indonesia’s population resides on Java. Considering the extensive toll road network, it is crucial to carefully select toll payment technology by evaluating all relevant factors.

The proposed toll payment system must provide economic benefits, such as improved traffic flow and reduced capital and operational costs. Various factors were evaluated to identify the most suitable technology that aligns with local conditions and ensures economic feasibility. These include the initial investment costs for roadside infrastructure, annual operating expenses, and requirements and costs for vehicle-mounted equipment. Expansion costs, including additional investments and operational expenses required to extend the toll network, were also considered. The evaluation further addressed the efficiency of the system based on toll road characteristics, the longevity of the system’s equipment, and the communication technologies used with vehicles. Additionally, central database requirements for registered vehicles, the primary toll collection scheme, and compatibility with distance-based tolling systems were reviewed. Finally, the system’s capacity for dynamic traffic management, such as implementing congestion charges, was analyzed to ensure it meets the requirements for effective toll management.

*Economic Benefits of MLFF*

The vehicle operating cost (VOC) analysis shows that the implementation of MLFF substantially reduces costs per kilometer compared to E-Toll, with passenger vehicles experiencing a 50% reduction [16]. These cost reductions across various vehicle types are depicted in Figure 6. Similar savings are observed in heavy vehicles, such as large trucks. These results confirm that the implementation of MLFF can support logistics cost efficiency, especially for commercial vehicles. Additionally, the application of Vehicle Routing Problem (VRP) methods in logistics optimization, as demonstrated in disaster relief operations, has proven effective in minimizing travel time and enhancing distribution efficiency through heuristic and local search algorithms [24].

*SWOT Analysis*

Apart from that, it is also necessary to carry out a SWOT analysis to describe the situation and conditions currently being faced. The following is a SWOT analysis regarding MLFF users:

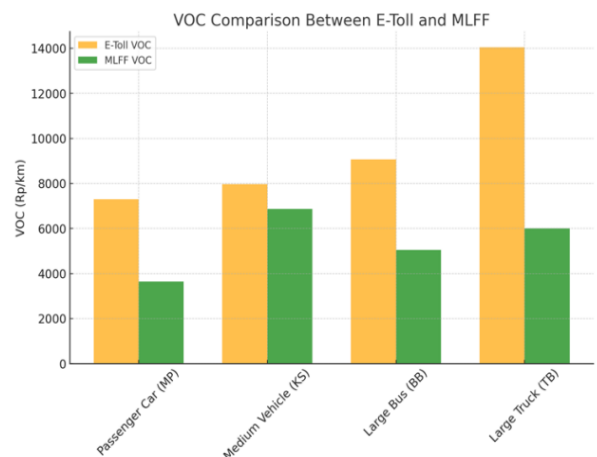


Figure 5. Comparison of Vehicle Operating Costs (VOC) between E-Toll and MLFF, demonstrating the cost reduction achieved through MLFF implementation across different vehicle types.

### *Strength*

- Multilane Free Flow provides many positive impacts on society, including:
- Mobility for the delivery of goods and services can be carried out more quickly, thereby increasing revenue for the company
- Queues for vehicles carrying out transactions at toll gates can be eliminated because users no longer need to stop the vehicle to make transactions.
- Since there are no longer queues of vehicles at toll booths, travelers may experience fewer delays in travel time.
- Congestion can be resolved by reducing the queue of vehicles at the toll gate.

### *Weakness*

- It costs a lot of money to replace the existing transaction system, and it needs to be implemented nationally.
- Consideration of suitable technology to be applied must also be appropriate and standardization/uniformity of technology is carried out for all toll roads in Indonesia.

### *Opportunities*

- MLFF, a technological improvement to toll transactions, may aid in speeding up the country's progress.
- Creating new business opportunities in the form of technology installed on gantries and vehicles.

### *Threats*

- With no more toll gates installed on every toll road, it is possible that deviant behavior from the public may arise, for example, vehicles that do not have a balance can still enter the toll road or vehicles that do not have transaction equipment installed on their vehicles can enter the toll road. So there is a need for clear law enforcement and in-depth study regarding the implementation of MLFF looking at the culture of Indonesian society.

SWOT analysis is a strategic tool for assessing project performance and planning in various fields. This analysis was originally intended for corporate management and has now become an important tool [25] and [26]. The success of this analysis in various fields, ranging from health technology assessment [27] to construction industry planning [28] and sustainable agriculture evaluation [29] is due to the flexibility of this framework.

SWOT analysis has been particularly useful in infrastructure development for assessing innovation systems [30] and implementing new technologies [31]. Managers can use this framework to identify and address key factors that influence the success and sustainability of projects [32].

Although widely used in business plans, this analysis has recently been used to evaluate issues and policies related to decision-making and to evaluate sustainable highway infrastructure development [25], [33] and [34].

An understanding of these four aspects is expected to help maximize strengths, minimize weaknesses, reduce threats, and create opportunities moving forward. In order to minimize weaknesses and reduce threats so that the implementation of MLFF, including the transition from the old system, runs smoothly, the Government needs to pay attention to the following matters:

### *Social Factors*

Public outreach is necessary to ensure that the community can quickly adapt to the new system. This outreach should be conducted effectively during the transition period to minimize any foreseeable issues once the system becomes fully operational. Additionally, the outreach should include a clear timeline and information on law enforcement measures that will be implemented in the event of violations.

### *Economic Factors*

A separate organization with clear policies and standard operating procedures is needed to manage toll tariff collection at uniform rates. Previously, this task was carried out by individual toll road business entities, each setting its own rates based on sectional divisions. Regarding the equipment that will be installed on the vehicle, it is very necessary to look for equipment that is cheap so that it does not burden toll road consumers. If it is deemed unaffordable for some groups, incentive mechanisms or ownership assistance should be considered, or the devices could potentially be provided free of charge, particularly for small-scale businesses.

### *Technological Factors*

A clear and accurate database containing vehicle identity and ownership information is essential, as a signal is transmitted to the passing vehicle via an OBU, RFID, or other installed technology when it passes through the MLFF system. This device will store a road user database. If the data from the unit installed on a vehicle cannot be read, the MLFF system includes a backup camera that can capture and identify the vehicle's license plate, type, dimensions, and owner. The toll charges will then be assigned to the registered owner of the vehicle. Meanwhile, in Indonesia, the sale of used cars is quite widespread. However, many buyers do not immediately update the ownership records, resulting in the vehicle data still being linked to the previous owner's identity.

By identifying these factors, the implemented system is expected to enhance service quality—making it faster, safer, easier, and more user-friendly for toll road users. It should also support operational effectiveness, improve data accuracy and security, and deliver tangible added value to both stakeholders and the wider community.

### *Suggestions for Implementation*

Based on the SWOT analysis, the implementation of MLFF requires not only technological readiness but also strong regulatory, institutional, and social support. One critical challenge lies in the development of a centralized database system that ensures interoperability among toll operators while maintaining robust data privacy and security protections. Weaknesses such as limited public awareness can be addressed through targeted outreach strategies, including community workshops, informational campaigns, and collaboration with local organizations to build trust and understanding of the system. At the same time, regulatory threats can be mitigated through the establishment of clear legal frameworks and uniform tariff-setting mechanisms. Opportunities such as accelerating Indonesia's digital transformation in transportation can be leveraged by providing incentives for early adoption and integrating MLFF into broader smart mobility initiatives. These strategies, if well-coordinated, will ensure that MLFF achieves

its potential in reducing logistics costs and improving operational efficiency.

### V. CONCLUSION

High logistics costs remain a critical barrier to Indonesia's economic competitiveness, as they directly affect supply chain efficiency, consumer prices, and the ability of businesses to expand. Addressing this challenge requires integrated solutions that go beyond infrastructure development and target systemic inefficiencies.

The phased implementation of Multilane Free Flow (MLFF), initiated in 2022, offers a strategic pathway to reduce congestion, streamline toll collection, and significantly lower vehicle operating costs (VOC). Beyond cost reduction, MLFF also improves traffic flow, minimizes toll gate queues, reduces emissions, and enhances the overall performance of Indonesia's logistics sector.

Ensuring the success of MLFF requires clear operational standards, comprehensive public outreach, and strong regulatory support. Key enablers include the availability of affordable on-board equipment, incentives for small businesses, and a secure, integrated vehicle ownership database. These measures will support both fairness and consistency in implementation.

Looking ahead, future research should focus on longitudinal assessments of MLFF's long-term impact on logistics costs, environmental sustainability, and user adoption. Case studies across different regions could provide deeper insights into variations in effectiveness and help refine policies. By combining rigorous monitoring with stakeholder collaboration, MLFF can become a cornerstone in Indonesia's efforts to build a more efficient, sustainable, and competitive logistics system.

### REFERENCES

- [1] M. G. Mnif and S. Bouamama, "Multi-Objective Optimization Methods for Transportation Network Problems: Definition, Taxonomy, and Annotation," *International Journal of Operations Research and Information Systems*, vol. 11, no. 1, pp. 1–36, 2020, doi: 10.4018/IJORIS.2020010101.
- [2] Office of Assistant to Deputy Cabinet Secretary for State Documents & Translation, "Gov't Creates National Logistics Ecosystem to Reduce Cost to 17%," CABINET SECRETARIAT OF THE REPUBLIC OF INDONESIA.
- [3] S. Masitoh, "Apindo Sebut Biaya Logistik Perdagangan Indonesia Termahal di ASEAN-5," KONTAN.CO.ID.
- [4] "Causes of High Logistics Costs in Indonesia," Mitra Pradhana Consultingindo.
- [5] A. Szmelter-Jaros, B. Chmiel, D. Weiland, P. Wierzbowski, and L. Reszka, "DEBATE ON THE DEFINITION OF URBAN LOGISTICS," vol. 18, no. 2, pp. 32–54, 2023, doi: 10.2307/27212585.
- [6] W. Kartika, "MODEL TRANSPORTASI PENGIRIMAN PRODUK PERISHABLE DENGAN MULTI KENDARAAN," *Jurnal Manajemen Industri dan Logistik*, vol. 3, no. 1, pp. 57–74, May 2019, doi: 10.30988/jmil.v3i1.72.
- [7] X. Sun and S. Wandelt, "Transportation mode choice behavior with recommender systems: A case study on Beijing," *Transp Res Interdiscip Perspect*, vol. 11, Sep. 2021, doi: 10.1016/j.trip.2021.100408.
- [8] Z. Han and H. Li, "Transportation infrastructure and trade," *Japan World Econ*, vol. 64, Dec. 2022, doi: 10.1016/j.japwor.2022.101162.
- [9] M. O. Karpushko, I. L. Bartolomei, E. N. Karpushko, A. V. Zhidelev, and V. I. Bryzgalov, "Analysis of Efficiency of Toll Road Network Development," *IOP Conf Ser Mater Sci Eng*, vol. 1079, no. 3, p. 032096, Mar. 2021, doi: 10.1088/1757-899x/1079/3/032096.
- [10] H. P. Astutik and D. Dewanti, "The Effect of Toll Gate Type on the Queue of Vehicles in Connecting Roads: A case study of Bawen – Yogyakarta Toll Road," *Journal of the Civil Engineering Forum*, vol. 6, no. 1, p. 1, Jan. 2020, doi: 10.22146/jcef.43975.
- [11] F. A. Hidayat and T. Kurniawan, "Multilane Free Flow Policy Analysis Based On Public Service And Public Administration Legal Studies," *Jurnal Ilmu Hukum*, vol. 9, pp. 116–122, doi: 10.30596/dll.v9i1.18492.
- [12] R. H. Karsaman, Y. Mahendra, H. Rahman, and S. Sulaksono, "Measuring the capacity and transaction time of cash and electronic toll collection systems," *Journal of Engineering and Technological Sciences*, vol. 46 B, no. 2, pp. 180–194, 2014, doi: 10.5614/j.eng.technol.sci.2014.46.2.5.
- [13] F. Sudirjo, M. R. Tawil, S. Imanirubiarko, L. Judijanto, and T. R. Fauzan, "The Influence of Insecurity, Perceived of Technology Innovativeness, Perceived Ease of Use and Perceived Usefulness on Consumers Intention to Use Electronic Toll Payment Cards," *Jurnal Informatika dan Teknologi*, pp. 92–97, Nov. 2023, doi: 10.60083/jidt.v5i4.421.
- [14] A. Matar and A. M. Alkhalwaldeh, "Adoption of electronic cards using Wi-Fi platform services by clients of banking sector during COVID-19 pandemic," *International Journal of Engineering Business Management*, vol. 14, Jul. 2022, doi: 10.1177/18479790221112797.
- [15] A. Budiharjo and S. R. Margarani, "KAJIAN PENERAPAN MULTILANE FREE FLOW (MLFF) DI JALAN TOL INDONESIA," *Jurnal Keselamatan Transportasi Jalan*, 2019.
- [16] F. Nur Azizah, S. Novriani, N. Budiswanto, and N. Shefa Salsabila, "Analysis Of Multilane Free Flow Implementation At Toll Gates In Indonesia (Case Study Of Cililitan Toll Gate 2)."
- [17] R. Septi Nurdiana and R. Haratama, "Peluang Penggunaan Sistem Single-lane Free Flow (SLFF) Untuk Mereduksi Tundaan Pada Gerbang Tol Exit Kejapanan Utama I N F O A R T I K E L A B S T R A K," 2024.
- [18] A. Y. Harnanda, S. Priyanto, and M. Z. Irawan, "DETERMINING FACTORS OF INTEREST IN THE USE OF TECHNOLOGY READNESS BASED MULTILANE FREE FLOW (MLFF)," *Business and Accounting Research (IJEBAR) Peer Reviewed-International Journal*, vol. 6, [Online]. Available: <https://jurnal.stie-aas.ac.id/index.php/IJEBAR>
- [19] S. Tripathi and S. Jain, "Automatic Number Plate Recognition System (ANPR): The Implementation," *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, no. 10, pp. 2278–3075, 2021, doi: 10.35940/ijitee.H9257.0610821.
- [20] Aleksandar Gogic, "SAFETY EVENT MESSAGE TRANSMISSION TIMING IN DEDICATED SHORT - RANGE COMMUNICATION ( DSRC )," 2015.
- [21] M. A. Baballe, M. B. Ahmad, and F. A. Nababa, "The need of using a Radio Frequency Identification (RFID) System," 2021. [Online]. Available: <https://www.researchgate.net/publication/353763092>
- [22] Clark Emerson Cohen, "PERFORMANCE AND COST GLOBAL NAVIGATION SATELLITE SYSTEM ARCHITECTURE," 2015.
- [23] R. Soesilo (Sekolah Tinggi Teknologi Mutu Muhammadiyah), Y. Firmansyah (Sekolah Tinggi Teknologi Mutu Muhammadiyah), and S. (Sekolah Tinggi Teknologi Mutu Muhammadiyah), "PENENTUAN LOKASI EXTERNAL WAREHOUSE DENGAN MENGGUNAKAN METODE CENTER OF GRAVITY (STUDI KASUS DI PT. RPZ SURABAYA)," *Jurnal Manajemen Industri dan Logistik*, vol. 4, no. 1, pp. 58–66, Jun. 2020, doi: 10.30988/jmil.v4i1.372.
- [24] P. Denny Sentia, "Jurnal Manajemen Industri dan Logistik PENENTUAN RUTE KENDARAAN PADA SISTEM DISTRIBUSI LOGISTIK PASCA BENCANA (STUDI KASUS)," *Syekh Abdurauf As Sinkili*, no. 7, [Online]. Available: <http://jurnal.poltekapp.ac.id/>
- [25] Cheng, B., Huang, J., Guo, Z., Li, J., & Chen, H. (2023). Towards sustainable construction through better construction and demolition waste management practices: A SWOT analysis of Suzhou, China. *International Journal of Construction Management*, 23(15), 2614–2624. <https://doi.org/10.1080/15623599.2022.2081406>
- [26] Hosseini Dehshiri, S. J., Amiri, M., & Hosseini Bamakan, S. M. (2024). Evaluating the blockchain technology strategies for reducing renewable energy development risks using a novel integrated decision framework. *Energy*, 289, 129987. <https://doi.org/10.1016/j.energy.2023.129987>
- [27] Behzadifar, M., Ghanbari, M. K., Azari, S., Bakhtiari, A., Rahimi, S., Ehsanzadeh, S. J., Sharafkhani, N., Moridi, S., & Bragazzi, N. L. (2023). A SWOT analysis of the development of health technology assessment

- in Iran. *PLOS One*, 18(3), e0283663. <https://doi.org/10.1371/journal.pone.0283663>
- [28] Lu, W. (2010). Improved SWOT approach for conducting strategic planning in the construction industry. *Journal of Construction Engineering and Management*, 136(12), 1317–1328. [https://doi.org/10.1061/\(ASCE\)CO.1943-7862.0000240](https://doi.org/10.1061/(ASCE)CO.1943-7862.0000240)
- [29] Das, K. P., Sharma, D., & Satapathy, B. K. (2022). Electrospun fibrous constructs towards clean and sustainable agricultural prospects: SWOT analysis and TOWS based strategy assessment. *Journal of Cleaner Production*, 368, 133137. <https://doi.org/10.1016/j.jclepro.2022.133137>
- [30] Awuzie, B., Ngowi, A. B., Omotayo, T., Obi, L., & Akotia, J. (2021). Facilitating successful smart campus transitions: A systems thinking-SWOT analysis approach. *Applied Sciences*, 11(5), 2044. <https://doi.org/10.3390/app11052044>
- [31] Zima, K., Plebankiewicz, E., & Wieczorek, D. (2020). A SWOT analysis of the use of BIM technology in the polish construction industry. *Buildings*, 10(1), 16. <https://doi.org/10.3390/buildings10010016>
- [32] Montgomery, R., Schirmer, H., Jr., & Hirsch, A. (2014). *A Sustainability Rating System for Roads in Developing Countries* [Paper presentation]. ICSI, 1086–1096. <https://doi.org/10.1061/9780784478745.10>
- [33] Leandri, P., Rocchio, P., & Losa, M. (2020). A SWOT analysis of innovative high sustainability pavement surfaces containing crumb rubber modifier. *Road Materials and Pavement Design*, 21(sup1), S103–S122. <https://doi.org/10.1080/14680629.2020.1736132>
- [34] Qayyum, M., Yuyuan, Y., Bhatti, U. A., & Shijie, L. (2023). Evaluation of the one belt and one road (OBOR) in economic development and suggestions analysis based on SWOT analysis with weighted AHP and entropy methods. *Multimedia Tools and Applications*, 82(10), 14985–15006. <https://doi.org/10.1007/s11042-022-13565-w>