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Analytical hierarchy process on the implementation of multi lane free flow toll road transaction system in Indonesia

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Abstract: The Indonesian government, through the Indonesia Toll Road Authority and the Ministry of Public Works and Housing, has established a policy for implementing an electronic toll transaction system for Multi-Lane Free Flow Toll Roads in Indonesia as an effort to improve the speed of toll transaction services. However, since it was first launched in 2016, until the beginning of 2024, this policy has not been implemented due to various problems. Therefore, this research will evaluate the key factors affecting the implementation of the electronic toll transaction system for Multi-Lane Free Flow Toll Roads in Indonesia and develop the best alternative strategy for its implementation. This research will use a combination of qualitative and quantitative research methods with the application of the Analytical Hierarchy Process (AHP). The analysis found that there are seven main factors: public acceptance, legal framework, investment cost, technology, toll road performance, data, and stakeholders. The three factors that are considered the most influential based on AHP analysis are the legal framework at 25.7%, toll road performance at 18.18%, and public acceptance at 14.28%. At the indicator level, the top two rankings are the toll transaction time indicator at 12.38% and privacy and data protection at 8.34%. The results of the analysis recommend the best alternative strategy, which is the selection of the best electronic toll transaction system technology, with a value of 22.23%, outperforming four other alternative strategies.

Keywords: *Electronic toll transaction system, Key factors, Multi lane free flow, Strategy development.*

1. Introduction

Toll road infrastructure development in Indonesia in the 2014-2024 period has accelerated, namely by increasing the length of operating toll roads from the original 822.42 km (2014) to 2,835.71 km (April 2024) or an increase of 2,013.29 km within 10 years based on updated data from [1]. The growth of toll roads is accompanied by growth in traffic volume and toll transactions every year. Based on data from the Toll Road Regulatory Agency, Ministry of Public Works and Housing in 2023 there were 4.9 million vehicles passing on toll roads every day with an annual toll transaction amount of Rp 31.56 trillion, this figure is already higher than the 2019 data before the Covid-19 Pandemic. This raises the challenge of services on toll roads related to toll transactions at toll gates which is the background for the instruction of the President of the Republic of Indonesia Mr. Joko Widodo in 2016 to the Minister of Public Works and Housing to eliminate queues at toll gates by applying a sensory system that is directly connected to banking accounts. follow up on this by stipulating Public Works and Housing Minister Regulation 16/PRT/M/2017 on Cashless Toll Transactions on Toll Roads which broadly divides the two stages of toll transaction electronification in Indonesia, namely the first stage by implementing cashless toll transactions with electronic money that is currently used and the second stage with contactless cashless toll transactions with Multi Lane Free Flow which has an initial target to be implemented in 2018.

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The plan to implement the electronification of the second phase of toll transactions did not run smoothly, only in 2018 there was a proposal for the Multi Lane Free Flow implementation project initiative on the Indonesian Toll Road by Roatex, a Hungarian Business Entity. This was followed up with the implementation of the Feasibility Study of the Multi Lane Free Flow implementation project on the Indonesian Toll Road in 2019 until the project procurement process was carried out by Ministry of Public Works and Public Housing [2] along with the enactment of the Public Works and Housing Ministerial Regulation No. 18/PRT/M/2020 concerning Contactless Cashless Toll Transactions on Toll Roads. Furthermore, in 2021, the Minister of Public Works and Housing officially determined the winner of the procurement of the Multi Lane Free Flow implementation project on the Indonesian Toll Road with the Public Private Partnership (PPP) scheme, which was won by PT Roatex Indonesia Toll System (PT RITS). This collaboration began on March 15, 2021 with an investment value of IDR 4.4 Trillion and a concession period of 9 years since commercial operation.

The signing of the cooperation is a new hope for the realization of the implementation of a contactless cashless electronic toll transaction system with Multi Lane Free Flow on Indonesian Toll Roads. The system has various benefits in terms of service techniques on toll roads as well as in terms of toll road users and the environment around the toll road. Milenković, et al. [3] found that the implementation of the MLFF system compared to the manual system can reduce CO2 levels by 25-45% and Nox by 32-98% depending on the type of vehicle and scenario which is the result of a case study in Serbia. The study also calculated the projected ecological benefits of 1.35-1.49 million euros. Rizal [4] found that toll gates with a free flow transaction system have a higher capacity and can eliminate queues at toll gates when compared to Automatic Toll Boards (GTO) and Semi-Automatic Boards (GSO) currently in operation.

However, until early 2024, the implementation of a contactless cashless electronic toll transaction system with Multi Lane Free Flow has not yet been realized. A small-scale implementation trial was conducted on the Bali Mandara Toll Road in December 2023, but various media reported notes that still needed to be evaluated on the implementation of the system [5]. The Minister of Public Works and Housing has also acknowledged that there are internal problems at the Implementing Business Entity, which was conveyed to the media on June 7, 2023 [6]. This delay is also accompanied by the missed implementation target that was previously stated in Minister of Public Works and Housing Regulation No. 18/PRT/M/2020 concerning Contactless Cashless Toll Transactions on Toll Roads which specifically states that the system is targeted to be implemented gradually starting January 31, 2022.

Based on these data, there has been a problem of delayed implementation of the contactless cashless electronic toll transaction system with Multi Lane Free Flow on Indonesian Toll Roads which aims to increase the speed of toll transaction services since it was first instructed in 2016 until the implementation target of 2022 was not met and has not been implemented until now. So, an evaluation is needed related to the key factors that affect the implementation of the contactless cashless electronic toll transaction system with Multi Lane Free Flow on Indonesian Toll Roads and the development of the best alternative strategy through a mixed qualitative and quantitative research approach with the *Analytical Hierarchy Process* (AHP) method.

2. Research Methodology

This research will be conducted using a combination of qualitative and quantitative methods. Data collection will be carried out using interview and questionnaire techniques involving resource persons with predetermined criteria, namely:

1. Is a State Civil Apparatus (ASN) of the Ministry of Public Works and Housing;
2. Have a minimum work experience of 5 (five) years; and
3. Specifically assigned to the implementation of the *Multi-Lane Free Flow* Toll Road Public Private Partnership (PPP) Project.

Furthermore, based on the collected data, an analysis will be carried out using the *Analytical Hierarchy Process* (AHP) method developed by Saaty [7] to compile a hierarchical structure of critical

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factors affecting the implementation of the *Multi-Lane Free Flow* Toll Road electronic toll transaction system in Indonesia which aims to increase the speed of toll transaction services. The research questions that will be answered in this study are:

1. What are the variables and indicators that influence the implementation of the *Multi Lane Free Flow* Toll Road electronic toll transaction system in Indonesia?
2. What are the key factors affecting the implementation of the *Multi Lane Free Flow* Toll Road electronic toll transaction system in Indonesia based on the weighting of these variables and indicators?
3. How to develop alternative strategies to these key factors to influence the implementation of the *Multi Lane Free Flow* Toll Road electronic toll transaction system in Indonesia?
4. What are the best alternative strategies on the implementation of electronic toll transaction system of *Multi Lane Free Flow* Toll Road in Indonesia?

The implementation of the research begins with identifying a *long list of* factors and alternative strategies that have the potential to influence the implementation of the *Multi Lane Free Flow* Toll Road electronic toll transaction system in Indonesia, through a literature review of previous research. The results of the literature review for the identification of factors that will become variables in this study are summarized in Table 1 below which consists of 7 (seven) variables, namely public acceptance, legal framework, investment costs, technology, toll road performance, data, and stakeholders. In previous studies on the topic of electronic toll transaction systems, there were still few that discussed the relationship with stakeholder involvement, so in this study the variable was added based on research on the role of stakeholders in managing a project. In addition, from the seven variables, 32 indicators were also developed to detail the related derivative factors.

Furthermore, for the results of the identification of alternative strategies for implementing the electronic toll transaction system, there are 5 (five) alternative strategies that have been previously researched which are summarized in Table 2 which include selecting the best electronic toll transaction system technology, preparing a legal framework specifically related to toll road user data privacy, marketing policies by providing discounts on OBU installations and toll tariff discounts for users who use electronic toll transaction systems, approaching technology acceptance by toll road users through ease of use and benefits, and prioritizing stakeholder collaboration, public acceptance, funding, and regulatory framework.

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Table 1.
AHP Variables of Toll Road MLFF Implementation.

Reference	Variables						
	Public Acceptance	Legal Framework	Investment Costs	Technology	Toll Road Performance	Data	Stakeholders
Kamiliah and Wijaya [8]	✓	✓	✓	✓			
Sumardi, et al. [9]	✓		✓	✓	✓	✓	
Harnanda, et al. [10]	✓			✓	✓		
Hidayat and Kurniawan [11]		✓					
Papandreou [12]	✓			✓	✓		
Budiharjo, et al. [13]	✓	✓	✓	✓	✓		
Hermawan and Aruan [14]	✓			✓			
Lixia, et al. [15]		✓					
Vats, et al. [16]	✓	✓		✓	✓	✓	
Li, et al. [17]				✓			
Recky [18]				✓	✓		
Hidayatul [19]					✓		
Mavi and Standing [20]	✓		✓	✓			✓
Nara, et al. [21]		✓	✓	✓			✓

Table 2.
Alternative Strategies for Implementing Toll Road MLFF in Indonesia.

Code	Reference	Implementation Strategy
S.1	Vats, et al. [16]	Selection of the best electronic toll transaction system technology.
S.2	Lixia, et al. [15]	Preparation of a legal framework specifically related to toll road user data privacy.
S.3	Chiou, et al. [22]	Marketing policy with OBU installation discount and toll tariff discount for users who use electronic toll transaction system.
S.4	Hermawan and Aruan [14]	Approach technology acceptance by toll road users through ease of use and benefits.
S.5	Kamiliah and Wijaya [8]	Prioritization of stakeholder collaboration, community buy-in, funding, and regulatory framework.

Furthermore, based on the results of the identification of factors and alternative strategies that have the potential to influence the implementation of the *Multi Lane Free Flow* Toll Road electronic toll transaction system in Indonesia, a hierarchical structure model is developed as a basis for conducting the *Analytical Hierarchy Process* presented in Figure 1 below.

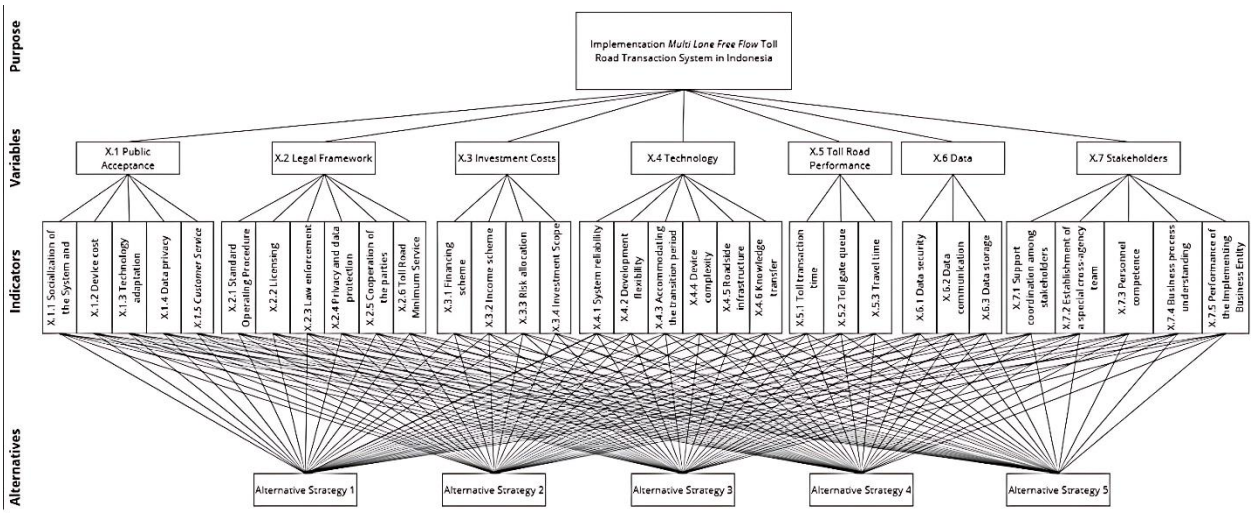

Figure1 .
Hierarchical Structure of Toll Road MLFF System Implementation Policy in Indonesia.

3. Research Results

Interviews and questionnaires were conducted from September to November 2024 with 7 (seven) expert resource persons and 18 AHP respondents. Although quantitatively the amount of data is small, the AHP method emphasizes the understanding of the topic knowledge possessed by the resource persons, so that even though it is not large in number, it can still produce reliable results. As in the topic of this research which discusses the implementation policy of *the Multi Lane Free Flow* Toll Road electronic toll transaction system in Indonesia, there are still very few parties who understand the topic, so that expert sources and respondents in this research are parties who are directly involved in the implementation of the Toll Road MLFF System Project in Indonesia and meet the predetermined criteria.

The results of the *Analytical Hierarchy Process* that have been carried out still need to be tested for reliability against several parameters that will be explained to facilitate reader understanding. The main parameter that needs to be considered is the Consistency Ratio (CR) obtained from the comparison of the Consistency Index (CI) with the Random Consistency Index (CIn). The amount of CI is calculated based on the λmax value in each data group, while the RIn value is obtained based on the reference table according to the amount of data (n) in each data group. A summary of the CR test results is presented in Table 3 below.

Table 2.
Summary of AHP Consistency Ratio Test Results

Variables	n	RIn	λmax	CI	CR
Key Variables	7	1,32	7,159	0,026	0,020
Public Acceptance	5	1,12	5,240	0,060	0,054
Legal Framework	6	1,24	6,224	0,045	0,036
Investment Costs	4	0,9	4,200	0,067	0,074
Technology	6	1,24	6,338	0,068	0,055
Toll Road Performance	3	0,58	3,038	0,019	0,033
Data	3	0,58	3,038	0,019	0,033
Stakeholders	5	1,12	5,154	0,038	0,034

Based on the AHP consistent ratio test results, it is found that all analysis results have a *Consistency Ratio* (CR) value lower than the 10% consistency threshold, so it can be concluded that the analysis

results are consistent and acceptable. Therefore, it can be stated that there are 7 (seven) variables with 32 (thirty-two) indicators as key factors influencing the implementation of the *Multi Lane Free Flow* electronic toll transaction system on toll roads in Indonesia to improve toll transaction speed services.

Table 4 summarizes the results of the AHP analysis on all variables and indicators of the implementation of the MLFF Toll Road System in Indonesia. The results of the analysis found that the 2 (two) variables with the highest weights are the Legal Framework with 25.70% and Toll Road Performance with 18.18%. Furthermore, in terms of indicators, it is found that the 5 (five) indicators with the highest weight are Toll Transaction Time with 12.38%, Privacy and Data Protection with 8.34%, Revenue Scheme with 6.87%, Data Privacy with 6.81%, and Law Enforcement with 6.58%.

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Table 3.
Results of AHP Analysis and Weighting on variables and Indicators.

Variables	EVN Global Weight	Indicator	EVN Local Weight	EVN Global Weight	Local Rank	Global Rank
Public Acceptance	14.28%	Socialization of the System and Benefits	17.77%	2.54%	2	12
		Device cost	8.58%	1.23%	5	28
		Technology adaptation	16.51%	2.36%	3	14
		Data privacy	47.71%	6.81%	1	4
		Customer service	9.43%	1.35%	4	25
Legal Framework	25.70%	Standard Operating Procedure	7.47%	1.92%	5	19
		Licensing	18.57%	4.77%	3	8
		Law enforcement	25.62%	6.58%	2	5
		Privacy and data protection	32.44%	8.34%	1	2
		Cooperation of the parties	11.08%	2.85%	4	11
		Toll Road Minimum Service Standards	4.81%	1.24%	6	27
Investment Costs	13.68%	Financing scheme	10.52%	1.44%	4	23
		Income scheme	50.23%	6.87%	1	3
		Risk allocation	24.52%	3.35%	2	10
		Investment Scope	14.74%	2.02%	3	18
Technology	13.18%	System reliability	40.43%	5.33%	1	7
		Development flexibility	18.97%	2.50%	2	13
		Accommodating the transition period	16.17%	2.13%	3	16
		Device complexity	4.76%	0.63%	6	31
		Roadside infrastructure	6.74%	0.89%	5	30
		Knowledge transfer	12.94%	1.71%	4	21
Toll Road Performance	18.18%	Toll transaction time	68.06%	12.38%	1	1
		Toll gate queue	11.79%	2.14%	3	15
		Travel time	20.14%	3.66%	2	9
Data	7.97%	Data security	68.06%	5.42%	1	6
		Data communication	11.79%	0.94%	3	29
		Data storage	20.14%	1.60%	2	22
Stakeholders	7.02%	Support coordination among stakeholders	18.27%	1.28%	4	26
		Establishment of a special cross-agency team	7.22%	0.51%	5	32
		Personnel competence	19.45%	1.36%	3	24
		Business process understanding	25.65%	1.80%	2	20
		Performance of the Implementing Business Entity	29.40%	2.06%	1	17

Furthermore, to facilitate the representation of the results of the AHP analysis above, representative results will be presented in the form of a summary of the order of weighting on the variables as well as the order of weighting of the top 10 (ten) on the research indicators presented in Table 5 and Table 6 below.

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Table 4.
Recapitulation of Main Variable Weighting.

Variables	EVN Global Weight	Global Rank
Public Acceptance	14.28%	3
Legal Framework	25.70%	1
Investment Costs	13.68%	4
Technology	13.18%	5
Toll Road Performance	18.18%	2
Data	7.97%	6
Stakeholders	7.02%	7

Table 5.
Recapitulation of Indicators with the Highest Weight.

Indicator	EVN global weight	Global Rank
Toll transaction time	12.38%	1
Privacy and data protection	8.34%	2
Income scheme	6.87%	3
Data privacy	6.81%	4
Law enforcement	6.58%	5
Data security	5.42%	6
System reliability	5.33%	7
Licensing	4.77%	8
Travel time	3.66%	9
Risk allocation	3.35%	10
More	36.48%	-

The final stage of the research conducted an analysis to assess the best alternative strategies that can affect the successful implementation of the *Multi Lane Free Flow* Toll Road electronic toll transaction system in Indonesia to improve toll transaction speed services. The analysis was conducted on the five alternative strategies previously identified using the results of the AHP analysis for weighting the key factors. The summary of the analysis results is presented in Table 7 which finds that the best alternative strategy with the highest value of 22.23% is the selection of the best electronic toll transaction system technology. Followed by the second rank is the prioritization of stakeholder collaboration, public acceptance, funding, and framework with 21.17% and in the third rank with 20.78% is the prioritization of stakeholder collaboration, public acceptance, funding, and framework.

Table 6.
Summary of Best Strategy Alternative Analysis Results.

Code	Variables							∑ AHP Score	Rank
	X.1	X.2	X.3	X.4	X.5	X.6	X.7		
S.1	**3.10%**	5.30%	2.95%	**3.13%**	**4.48%**	**1.79%**	1.48%	**22.23%**	**1**
S.2	3.03%	**5.94%**	2.81%	2.62%	3.14%	1.75%	1.49%	**20.78%**	**3**
S.3	2.43%	4.27%	2.46%	2.19%	2.89%	1.28%	1.18%	**16.70%**	**5**
S.4	2.87%	4.50%	2.45%	2.63%	3.86%	1.54%	1.27%	**19.12%**	**4**
S.5	2.85%	5.69%	**3.01%**	2.61%	3.82%	1.61%	1.59%	**21.17%**	**2**

4. Discussion

Research on electronic toll transaction systems on toll roads is actually not new and some developed countries have also implemented the MLFF System policy on the toll roads they manage. Based on a literature study conducted by Shahrier, et al. [23] studying and summarizing 316 research articles related to electronic toll transaction systems, found the distribution of countries that have implemented the electronic toll transaction system and variations in the selection of technology used. In addition, as summarized in Table 1, previous research on electronic toll transaction systems on toll roads is dominated by topics related to technology and its influence on toll road performance. However, this

research focuses more on policy formulation to encourage the successful implementation of the Toll Road MLFF System itself, so that the stakeholder involvement factor is also considered as one of the factors that has the potential to affect the success of implementation.

The implementation of this research is driven by the phenomenon of barriers to the implementation of a contactless cashless electronic toll transaction system with *Multi Lane Free Flow* on Indonesian Toll Roads, so this research aims to analyze key factors and alternative strategies that are considered to affect the success of the implementation using the AHP method. The results of the analysis show that the top three ranked key factors that must be considered in the formulation of this policy are the legal framework, toll road performance, and public acceptance. This is in line with several previous studies that discuss these factors, Kamiliah and Wijaya [8] stated in their research that the legal framework is important to be carefully prepared. It is also reinforced by research Lixia, et al. [15] regarding the readiness of data privacy protection through the certainty of the legal framework. The implementation of the Toll Road MLFF System is also proven to improve the performance of the toll road itself, Rizal [4] and Hidayatul [19] found similar results in separate studies, namely toll gates with a *free flow* transaction system have higher capacity and can eliminate queues at toll gates when compared to Automatic Toll Boards (GTO) and Semi-Automatic Boards (GSO) currently in operation. In addition, other benefits can also be felt by implementing the Toll Road MLFF System, as the results of a study in Serbia, Milenković, et al. [3] found that the application of the MLFF system compared to the manual system can reduce CO2 levels by 25-45% and Nox 32-98% depending on the type of vehicle and scenario, and calculated the projected ecological benefits obtained by 1.35-1.49 million euros. Other research related to public acceptance factors also shows that the implementation of the Toll Road MLFF System policy needs to be supported by planning regarding the technology adaptation process and device costs [14] as well as the socialization of the system and the benefits that will be felt by the community [9, 10, 13].

More specifically at the indicator level, the analysis results also show a concentration similar to the variable level, namely the toll transaction time ranked first in line with the main objectives of the Toll Road MLFF System policy. The next ranked indicators have a similar focus framework, which is related to legal aspects related to data privacy protection and security as well as law enforcement in the implementation of the Toll Road MLFF System policy. The factors mentioned above ultimately lead to the selection of the best recommended strategy alternative. The analysis found that the Alternative Strategy with the first highest score is S.1, namely "Selection of the best electronic toll transaction system technology" which shows that in the formulation of the Toll Road MLFF System implementation policy in Indonesia it is recommended to prioritize the selection of the best type of MLFF technology by considering various aspects. Although the selection of *Global Navigation Satellite System* (GNSS) Technology to be used in the Toll Road MLFF System in Indonesia has been assessed with a multi-criteria assessment approach reported in the Toll Road MLFF Feasibility Study document in Indonesia. However, the technology recommendation is considered less tested because it is different from the implementation experience of the party that compiled the feasibility study. Although the alternative strategy related to the selection of the best technology excels in this study, this does not indicate that the successful implementation of the *Multi Lane Free Flow* Toll Road electronic toll transaction system in Indonesia can run through a single policy. Alternative strategies with the second and third rankings related to stakeholder collaboration and preparation of the legal framework are also important aspects that need to be prepared jointly by involving other stakeholders. This is because in preparing the policy there are various aspects that are managed simultaneously such as toll road infrastructure, toll payment transactions, traffic regulation, law enforcement, and digital technology implementation.

Through the results of the analysis in this study, factors that can affect the successful implementation of the *Multi Lane Free Flow* Toll Road electronic toll transaction system in Indonesia are identified. In addition, key factors that can be prioritized in the preparation of the best alternative strategy can also be compiled. Broadly speaking, the results of this study recommend the preparation of

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policies for the implementation of the Toll Road MLFF System to consider the preparation of legal aspects through stakeholder collaboration in selecting the best technology to improve toll road performance so that it can be well received by the public.

5. Limitations and Recommendations

The implementation of this research focuses on the preparation period for the implementation of the Toll Road MLFF System policy in Indonesia by involving expert sources who are directly involved in the formulation and implementation of the policy. The results of this study can be recommended to be considered in the formulation of policies related to the implementation of electronic toll transaction systems on toll roads, but adjustments and re-analysis can be made by considering the conditions and factors needed. Furthermore, for future research development, re-analysis can be carried out when the Toll Road MLFF System policy in Indonesia has been implemented to further understand the differences in factors that need to be considered between the planning and operational phases.

6. Conclusion

This research found that there are 7 (seven) main factors that have the potential to influence the successful implementation of the *Multi Lane Free Flow* Toll Road electronic toll transaction system in Indonesia to increase the speed of toll transaction services, namely public acceptance, legal framework, investment costs, technology, toll road performance, data, and stakeholders. The seven main factors are also detailed into 32 indicators to get sharper analysis results. The 3 (three) factors that are considered the most influential based on AHP analysis are the legal framework with 25.7%, toll road performance with 18.18%, and public acceptance with 14.28%. At the indicator level, the top 2 (two) rankings are the toll transaction time indicator with 12.38% and privacy and data protection with 8.34%. Furthermore, the weighting of the AHP analysis results is used to assess the best alternative strategies that recommend the selection of the best electronic toll transaction system technology. However, this does not indicate that the successful implementation of the *Multi Lane Free Flow* Toll Road electronic toll transaction system in Indonesia can run through a single policy. Alternative strategies with the second and third rankings relating to stakeholder collaboration and preparation of the legal framework are also important aspects that need to be prepared jointly by involving other stakeholders. So, in general, the results of this study recommend that the preparation of policies for implementing the Toll Road MLFF System should consider preparing legal aspects through stakeholder collaboration in selecting the best technology to improve toll road performance so that it can be well received by the public.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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