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Analyzing and Modeling Toll Road Service Performance: TRSQ Model and Emerging Influencing Variables

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Abstract

The construction of toll roads supports economic and social mobility while driving regional development. However, toll road services face challenges such as deteriorating road quality, lack of facilities, and traffic disruptions due to accidents or repairs. This study aims to identify variables, examine their relationships, and develop a model for the factors influencing toll road services. The research uses both quantitative and qualitative approaches with explanatory research. The initial model of variables refers to the TRSQ model, which includes information, accessibility, reliability, mobility, safety and security, rest areas, and responsiveness. A questionnaire instrument is used and tested with SPSS for data validity and reliability. The data is then processed with SmartPLS to examine the relationships between variables. The results show a positive and significant impact on toll road service performance. However, 36.9% of toll road service performance is influenced by factors outside the model. To identify additional variables, bibliometric analysis using VOSviewer and expert opinions was used. The findings revealed that environmental factors, innovation, climate change, and public-private partnerships also affect toll road service performance. This led to the development of a model that serves as a framework for improving toll road service quality.

Keywords: TRSQ Model; Performance; Service; Toll Road; Transportation.

1. Introduction

Toll roads, as part of national infrastructure, play a vital role in accelerating the movement of people and goods while also serving as a catalyst for economic growth [1]. In Indonesia, toll road development is designed to create a more efficient transportation system, enhance regional integration, and strengthen local economies [2]. Toll roads are also expected to generate positive economic impacts by boosting economic activity in the areas they traverse [3]. In an era demanding sustainable transportation, toll roads function as an integrated ecosystem connecting physical infrastructure, digital data, and road users [4]. Therefore, consistent innovation in their construction and management is necessary to meet the highest quality standards [5]. Despite their significant benefits, toll roads in Indonesia still face several challenges. One major issue is the frequent long queues at toll gates, particularly during peak hours, along with declining road quality due to suboptimal maintenance and weather impacts [6]. Additionally, the lack of safety facilities such as traffic signs, guardrails, street lighting, and inadequate rest area conditions, including poor-quality toilets, remains a common complaint among users [7]. High toll fees and the lack of real-time traffic information also influence user satisfaction [8]. The minimum service standards (SPM), which should serve as a benchmark, are often not adequately implemented in several toll road segments [9].

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An important step in improving toll road services is identifying the key variables that influence optimal toll road services. This identification helps operators gain deeper insights into user needs and preferences, enabling them to design more relevant service improvement strategies [10]. A user survey-based approach is also necessary to ensure that implemented policies align with public expectations. For example, the application of intelligent technologies, such as digital traffic management systems, can enhance operational efficiency while reducing accident risks [11]. Looking ahead, the government continues to expand the toll road network and modernize existing infrastructure. One of the main focuses is the implementation of intelligent transportation technologies that support operational efficiency and environmental sustainability [12]. Through appropriate innovation adaptations, toll roads are expected to become a reliable transportation pillar that delivers quality services, fosters connectivity, and contributes to more inclusive national development [13].

Although research related to improving toll road services has been extensively conducted, existing studies have primarily used the Minimum Service Standard (SPM) as the main variable to assess toll road service quality. SPM focuses more on technical aspects, while the TRSQ model offers a more holistic view of service quality from the user's perspective. Existing studies have not fully explored the potential of TRSQ as a tool to evaluate and enhance toll road services. To address this gap, the approach proposed in this study is to use TRSQ as the main variable to assess toll road services. This study aims to provide a more comprehensive and data-driven guide in designing policies and innovations that can improve user satisfaction and operational efficiency of toll roads in Indonesia. This is important because the TRSQ-based approach has proven to be more effective in providing a clearer understanding of users' perceptions and satisfaction with toll road services. Therefore, this study aims to identify variables, test relationships between variables, and develop a model of toll road service quality variables. Therefore, this study aims to identify, test, and create a model of the variables of toll road services.

This study aims to identify the toll road service variables, examine the relationships between these variables, and develop a model for the toll road service variables. Therefore, this study poses the main question: How can a model be developed to evaluate and improve toll road services in Indonesia? This research is expected to make a significant contribution to designing more data-driven policies and innovations to improve user satisfaction and operational efficiency of toll roads. The article is structured into several sections: Section I presents the introduction, Section II describes the research methodology, and Section III presents the results and data analysis. Finally, Section IV will summarize the research findings and provide recommendations for future research.

2. Research Methodology

2.1. Case Study

This study was conducted on a toll road section with the aim of obtaining a deeper understanding of various aspects that influence toll road services. The selected study location is the Pemalang-Batang toll road, an essential part of the Trans Java toll road network, serving as one of the main connectors between strategic areas in Central Java and its surroundings (Figure 1). This toll road has a total length of 39.2 km, has been fully operational since 2018, and features two rest and service areas (TIP) in each direction toward Jakarta and Semarang [14].

Figure 1. Map of Pemalang Batang Toll Road

With the operation of the Pemalang-Batang toll road, travelers can reduce travel time from Pemalang to Batang to 39 minutes, compared to the previous duration of more than 2 hours [15]. This toll road serves as an alternative route that alleviates the traffic burden on the Pantura route [16]. Strategically located, the Pemalang-Batang toll road plays a significant role in supporting economic growth in Central Java, particularly in the industrial, goods, and services sectors

[15]. One notable impact of this toll road is the improved ease of goods delivery, shorter travel distances, and enhanced intercity transportation access [17]. However, in 2019, road damage affected 16.67% of accidents occurring on this section [18]. Traffic passing over the pavement reduces its structural and functional quality over time [19]. Damaged toll roads can pose safety risks to road users [13]. According to 2022 data, there were 214 traffic accidents reported on the Pemalang-Batang toll road [20]. This number increased by 7% to 230 incidents in 2023, based on reports from toll road operators. In 2023, the average daily traffic volume (LHR) on the Pemalang-Batang toll road reached 29,448 vehicles, reflecting a 4% increase from 28,402 vehicles in 2022 [14]. With the increasing traffic volume, it is essential to conduct evaluations to ensure that this toll road can consistently provide excellent services to its users.

2.2. Framework

Overall, the process of this research can be illustrated in the form of a research flowchart as shown in the Figure 2.

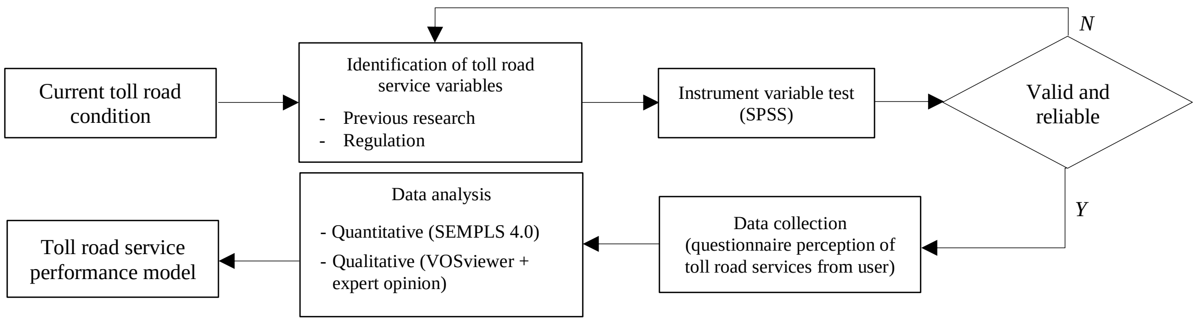

Figure 2. Research Flow Chart

2.3. Research Approaches

This study adopts an explanatory approach to analyze the causal relationships between research. Specifically, this study employs a mixed-methods research methodology, combining both quantitative and qualitative approaches. The research design used is a sequential explanatory model, where quantitative data is collected first, followed by qualitative data to provide further explanation [21]. The method applied in this study follows a sequential model, in which the first phase utilizes a quantitative approach with a higher weighting than the qualitative approach (QUAN → qual). This analysis aims to validate, deepen, and expand the quantitative data.

In the quantitative research phase, data was obtained from questionnaires completed by toll road service users. The questionnaire was designed using a Likert scale, a psychometric scale commonly applied in survey-based research [22]. Before distribution, instrument calibration was conducted using SPSS to ensure its validity and reliability. Once validated, the questionnaire was distributed offline at rest areas and online through social media platforms such as WhatsApp and Instagram. During the data collection process, the sampling method used is purposive sampling, a technique for selecting samples based on specific criteria [23]. Only toll road users who traveled within the last year were included as research data, while respondents who did not meet the criteria were excluded through judgment sampling. The sample size was determined based on the guidelines from Hair et al. (2017), which recommend a minimum of 10 times the total number of research indicators [24]. With 40 indicators in this study, the minimum required sample size is 400 samples.

Data analysis was conducted using both quantitative and qualitative approaches. The numerical data collected was analyzed through statistical calculations to provide a comprehensive overview of the research object, with the results presented in tables or graphs [25]. Data processing utilized SmartPLS (Partial Least Squares) software to examine the relationships between research variables with the Structural Equation Modeling (SEM) method. PLS-SEM is evolving rapidly as a statistical modeling technique. PLS-SEM statistical provide very robust model estimations with data that have normal as well as extremely non normal distributional [26].

The qualitative data collection approach in this analysis refers to the use of methods to gather expert opinions on a particular phenomenon. This method is commonly employed when the available quantitative analysis requires further reinforcement or clarification, necessitating expert perspectives from various viewpoints. The selection of experts must meet at least four criteria: possessing knowledge and experience related to the issue under investigation, having the capacity and willingness to participate actively, having sufficient time to participate, and having strong communication skills. In this study, a total of 11 experts/respondents were interviewed. These respondents consist of academics, practitioners, regulators, operators, and users. The profiles of these respondents were carefully selected, ensuring that they have extensive experience in the toll road sector.

To identify variables and develop the Toll Road Service Performance Model, the initial data exploration phase was conducted through a journal review using the VOSviewer application. This process aimed to identify variables through bibliometric analysis, which can be used to map additional variables that may influence toll road services. The analysis was then reinforced with input from experts to gain a deeper understanding of toll road service variables. The results of this analysis served as the foundation for developing a variable model that affects toll road performance.

3. Results and Analysis

3.1. Variables Identification

Several previous studies have measured the performance of toll road services. Table 1 are the most relevant studies:

Table 1. Relevant Research

No.	Title	Researchers	Year	Objective	Variable
1.	Evaluation of Toll Road Service Performance on Surabaya-Gempol Toll Road Based on User Perception	Alfiansyah et al. [27]	2023	To identify the performance of toll road services based on user perceptions of the indicators set in the Minimum Service Standards (MSS) for toll roads.	SPM
2.	The Influence of MSS Toll Road Services on Toll Road User Satisfaction in the Greater Jakarta Area	Dina & Amin [9]	2023	To analyze toll road user satisfaction regarding compliance with the Minimum Service Standards (MSS) for toll roads.	SPM
3.	Improving the Quality of Toll Road Services to Increase the Satisfaction Level of Pekanbaru–Dumai Toll Road	Putra et al. [28]	2023	To analyze the quality of services and satisfaction levels of toll road users, propose reference recommendations to improve and enhance toll road service quality.	SPM
4.	Quality of Service on Road User Satisfaction: A Study on Surabaya-Malang Toll Road Customers	Fajar Subkhan et al. [29]	2023	To analyze service quality from the perspective of toll road user satisfaction.	SPM
5.	Analysis of ServQual and Importance Performance Analysis on the Cengkareng-Batuceper-Kunciran Toll Road	Pratala et al. [30]	2023	To analyze toll road services and evaluate ServQual attributes to improve services on the toll road section.	SPM
6.	Satisfaction Level of Pekanbaru-Dumai Toll Road Users	Putra et al. [23]	2023	To determine the satisfaction level of users based on toll road service quality as perceived by users.	SPM
7.	Analysis of Marketing Relationship Strategy Through Customer Satisfaction in the Jakarta-Tangerang Branch	Cahyono et al. [31]	2021	To evaluate toll road user satisfaction.	SPM
8.	Evaluation of Toll Road Users in Indonesia on Received Services	Makmur [32]	2021	To gather feedback and expectations from toll road users on the performance of toll road sections based on safety, security, and comfort aspects of the services provided.	SPM
9.	Study of Surabaya-Mojokerto Toll Road Service Level Using the Customer Satisfaction Index (CSI) Method	Alfiansyah & Wardhani [33]	2021	To improve the toll road service index value.	SPM
10.	Toll Road Maintenance Towards Minimum Service Standard	Suwarto et al. [19]	2021	To assess road maintenance programs to evaluate their effectiveness in meeting the MSS.	SPM
11.	Analysis of Toll Road Service Level in Palindra from the Perspective of Users	Kurnia et al. [34]	2020	To analyze toll road service levels from the perspective of users and identify which service attributes need improvement.	SPM
12.	The Influence Model of Reliability, Assurance, Tangibles, Empathy, and Responsiveness on Customer Satisfaction and Highway Users' Loyalty	Waluyo et al. [35]	2020	To examine the influence of reliability, assurance, tangibles, empathy, and responsiveness on customer satisfaction and toll road user loyalty.	SPM

This study aims to identify the variables that influence toll road services, which aligns with the primary objective of the research. In Indonesia, studies related to toll road services generally use the minimum service standards (SPM) set by the government as a benchmark to assess toll road performance. However, this study opts to use the Toll Road Service Quality (TRSQ) model in identifying the variables that impact toll road services. The TRSQ model was developed by Dr. Herry Trisaputra Zuna and is a modification of the Servqual (service quality) model, which includes five main service dimensions [36]. This model is adapted with toll road SPM indicators as measurement tools, so it not only considers the physical aspects found in the SPM but also incorporates the user perspective [7].

Research conducted on the development of the TRSQ model shows that it has a higher accuracy rate compared to the other two models, Servqual and SPM. In the testing process of these three models, the accuracy rate was 95%. This model was selected based on the results of research that specifically studied toll road services using several methods. Previous studies can be used as a basis for selecting variables because they are considered to have proven significant in the same context. Therefore, the TRSQ model was chosen as the basis for measuring toll road service performance. The TRSQ model consists of seven variables: information, accessibility, reliability, mobility, safety and security, rest areas, and responsiveness [37].

Based on several studies, as shown in Table 1, there are some differences compared to this research. This study uses the TRSQ variable, whereas previous studies employed the SPM variable. Additionally, the purpose of this research is to identify variables that will later be used to develop a model of toll road service performance variables. Thus, it goes beyond merely measuring toll road service performance based on existing variables (SPM).

3.2. Variables Testing

This study carried out validity and reliability assessments through a pilot test with 36 participants. Based on a significance level of 5% (r table = 0.329; n = 36), the results of the questionnaire's validity test are presented in Table 2.

Table 2. Validity Test

Variable	Code	R Stat	R Stat
Information	IN1	0.577	Valid
	IN2	0.557	Valid
Accessibility	AK1	0.364	Valid
	AK2	0.617	Valid
	AK3	0.400	Valid
	AK4	0.557	Valid
	AK5	0.686	Valid
Reliability	KE1	0.630	Valid
	KE2	0.477	Valid
	KE3	0.697	Valid
	KE4	0.545	Valid
	KE5	0.668	Valid
Mobility	MO1	0.470	Valid
	MO2	0.628	Valid
Safety and Security	KK1	0.673	Valid
	KK2	0.587	Valid
	KK3	0.676	Valid
	KK4	0.710	Valid
	KK5	0.670	Valid
	KK6	0.702	Valid
Rest Area	TI1	0.608	Valid
	TI2	0.740	Valid
	TI3	0.617	Valid
	TI4	0.789	Valid
	TI5	0.726	Valid
Responsiveness	KET1	0.755	Valid
	KET2	0.817	Valid
	KET3	0.775	Valid
	KET4	0.766	Valid
Excelent Service	PP1	0.808	Valid
	PP2	0.837	Valid
	PP3	0.756	Valid
	PP4	0.763	Valid
	PP5	0.773	Valid
	PP6	0.765	Valid

Note: If r-statistic > r-table, it is considered valid.

From Table 2, it can be observed that each indicator's value surpasses the calculated r value, confirming its validity. An instrument is deemed reliable when its Cronbach's Alpha value is above 0.60 [38]. The test results reveal a Cronbach's Alpha value of 0.96, which is well above 0.60, signifying its reliability.

3.3. Test Variable Relationships

After the relevant variables have been identified and preliminary validation has been conducted through instrument calibration, the next step is to analyze the relationships between the predefined variables. For this analysis, the Structural Equation Modeling Partial Least Square (SEMPLS) method is used. This process begins with testing the measurement model, known as the outer model, which includes evaluations of convergent validity, discriminant validity, and reliability. Once these criteria are satisfied, the analysis proceeds to the structural model, or inner model, which assesses collinearity, the coefficient of determination, predictive relevance, and the significance of relationships using t-tests and p-values [26].

3.3.1. Outer Model

The initial step in the SEMPLS method involves testing the outer model or measurement model. This model aims to ensure that the relationship between latent constructs and their indicators is reliable and aligns with the observed data. The evaluation focuses on convergent validity, discriminant validity, and reliability. The measurement model explains how constructs are measured and verifies that the instruments used meet validity and reliability standards. In applications such as SmartPLS, this evaluation is visualized through an outer model diagram (Figure 3).

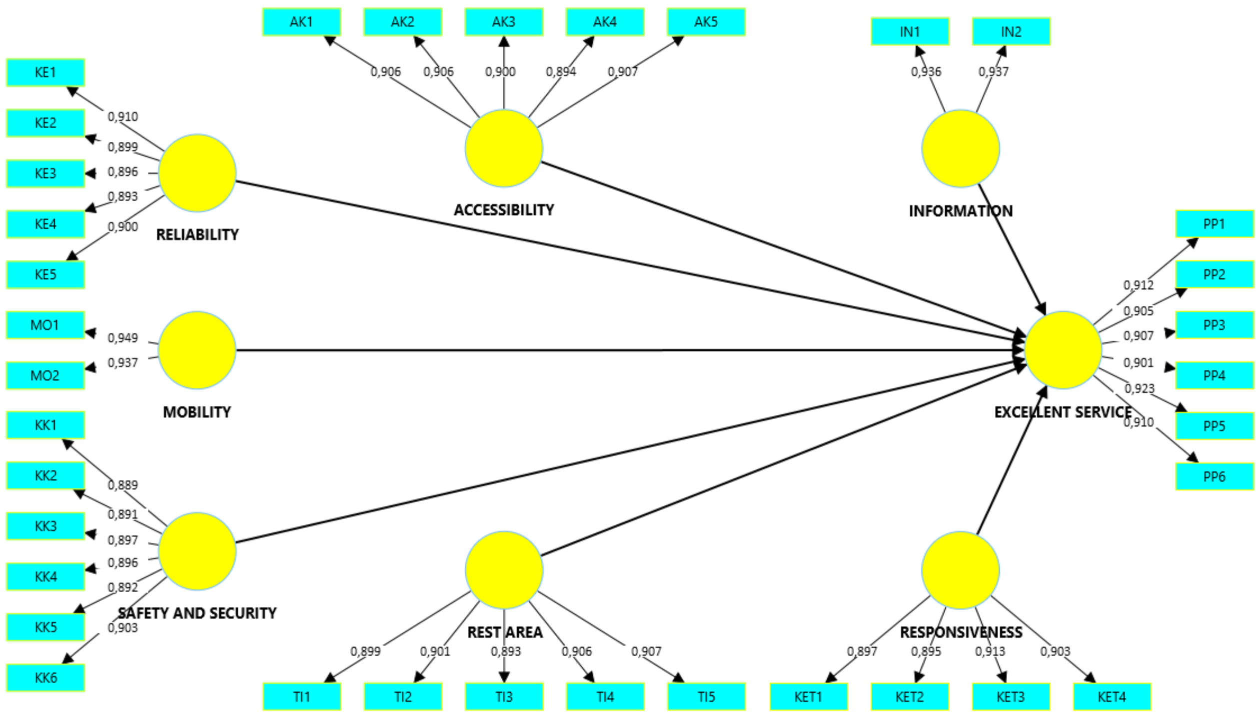

Figure 3. Measurement Model (Outer Model)

The first step in evaluating the outer model is to examine the outer loading values of the indicators. High outer loading values indicate that the indicators within a construct have significant similarity, reflecting a consistent interpretation of the construct. To meet the criteria for convergent validity, the minimum acceptable outer loading value is 0.7. The results of the outer loading analysis can be seen in Table 3.

In general, indicators with very low outer loading values (below 0.40) should be removed from the construct. Based on the results of the convergent validity test, it can be observed that all indicators have outer loading values ≥ 0.70. Therefore, all indicators in this study can be considered to meet the criteria, and there is no need to eliminate indicators or re-estimate the model. This finding confirms that the measurement model has strong convergent validity, ensuring that the indicators appropriately represent the latent constructs.

Next, to consider in discriminant validity testing is the Fornell-Larcker criterion (Table 4). For this criterion to be met, the square root of the Average Variance Extracted (AVE) should be greater than the highest correlation with other constructs in the model.

Table 3. Outer Loading

	Accessibility	Information	Reliability	Safety and Security	Responsiveness	Mobility	Excellent Service	Rest Area
AK1	0.906							
AK2	0.906							
AK3	0.900							
AK4	0.894							
AK5	0.907							
IN1		0.936						
IN2		0.937						
KE1			0.910					
KE2			0.899					
KE3			0.896					
KE4			0.893					
KE5			0.900					
KET1					0.897			
KET2					0.895			
KET3					0.913			
KET4					0.903			
KK1				0.889				
KK2				0.891				
KK3				0.897				
KK4				0.896				
KK5				0.892				
KK6				0.903				
MO1						0.949		
MO2						0.937		
PP1							0.912	
PP2							0.905	
PP3							0.907	
PP4							0.901	
PP5							0.923	
PP6							0.910	
TI3								0.893
TI1								0.899
TI2								0.901
TI4								0.906
TI5								0,907

Table 4. Fornell Larcker Criterion

	Accessibility	Information	Reliability	Safety and Security	Responsiveness	Mobility	Excellent Service	Rest Area
Accessibility	0.902							
Information	0.655	0.937						
Reliability	0.670	0.642	0.900					
Safety and Security	0.661	0.634	0.669	0.895				
Responsiveness	0.377	0.364	0.369	0.380	0.902			
Mobility	0.647	0.612	0.644	0.630	0.379	0.943		
Excellent Service	0.586	0.580	0.585	0.590	0.594	0.590	0.910	
Rest Area	0.379	0.362	0.366	0.375	0.654	0.365	0.572	0.901

Based on Table 4, the square root values of the AVE for each construct are greater than the correlations with other constructs, indicating that these values meet the Fornell-Larcker criterion. This result confirms that the constructs in the model have adequate discriminant validity, meaning that each construct is distinct and does not significantly overlap with others.

The next criterion to consider is the cross loading value. According to this criterion, the outer loading of an indicator on its respective construct should be greater than the cross loading on other constructs. This indicates that the latent variable better predicts the indicators in its own construct block than in the blocks of other constructs. The outer loading values can be seen in Table 5.

Table 5. Cross Loading

	Accessibility	Information	Reliability	Safety and Security	Responsiveness	Mobility	Excellent Service	Rest Area
AK1	0.906	0.572	0.594	0.574	0.324	0.598	0.539	0.333
AK2	0.906	0.602	0.598	0.596	0.331	0.586	0.546	0.370
AK3	0.900	0.610	0.611	0.595	0.327	0.582	0.521	0.366
AK4	0.894	0.574	0.600	0.617	0.355	0.584	0.511	0.327
AK5	0.907	0.597	0.621	0.603	0.366	0.570	0.524	0.312
IN1	0.618	0.936	0.615	0.603	0.352	0.573	0.540	0.321
IN2	0.609	0.937	0.588	0.585	0.330	0.574	0.547	0.357
KE1	0.611	0.556	0.910	0.623	0.310	0.574	0.537	0.344
KE2	0.602	0.581	0.899	0.619	0.331	0.588	0.531	0.335
KE3	0.619	0.603	0.896	0.582	0.322	0.557	0.519	0.307
KE4	0.578	0.579	0.893	0.584	0.334	0.569	0.520	0.329
KE5	0.605	0.572	0.900	0.601	0.362	0.610	0.526	0.333
KET1	0.342	0.337	0.321	0.323	0.897	0.308	0.550	0.592
KET2	0.335	0.306	0.333	0.321	0.895	0.352	0.521	0.582
KET3	0.351	0.353	0.354	0.365	0.913	0.362	0.544	0.592
KET4	0.332	0.316	0.322	0.362	0.903	0.346	0.527	0.593
KK1	0.585	0.569	0.591	0.889	0.358	0.556	0.545	0.356
KK2	0.574	0.549	0.587	0.891	0.340	0.577	0.514	0.337
KK3	0.613	0.555	0.602	0.897	0.323	0.550	0.513	0.318
KK4	0.604	0.590	0.595	0.896	0.346	0.551	0.532	0.356
KK5	0.582	0.571	0.604	0.892	0.358	0.580	0.515	0.323
KK6	0.591	0.567	0.611	0.903	0.318	0.567	0.545	0.320
MO1	0.626	0.595	0.613	0.606	0.376	0.949	0.579	0.369
MO2	0.593	0.558	0.601	0.581	0.338	0.937	0.530	0.317
PP1	0.518	0.529	0.502	0.524	0.537	0.509	0.912	0.553
PP2	0.517	0.506	0.526	0.532	0.538	0.527	0.905	0.504
PP3	0.545	0.562	0.558	0.547	0.529	0.543	0.907	0.499
PP4	0.522	0.482	0.501	0.522	0.546	0.513	0.901	0.511
PP5	0.527	0.536	0.546	0.522	0.556	0.558	0.923	0.547
PP6	0.567	0.550	0.561	0.572	0.537	0.568	0.910	0.506
TI3	0.344	0.363	0.330	0.348	0.579	0.323	0.534	0.899
TI1	0.336	0.313	0.321	0.328	0.589	0.323	0.514	0.901
TI2	0.353	0.309	0.323	0.355	0.592	0.330	0.498	0.893
TI4	0.336	0.332	0.346	0.346	0.601	0.337	0.518	0.906
TI5	0.340	0.312	0.332	0.311	0.585	0.333	0.510	0.907

Based on Table 5, it can be concluded that the cross loading values for each indicator of every variable are higher (outer loading is greater) than the cross loading values of other variables. This indicates that these indicators have met the discriminant validity criteria as measured by the cross loading values. This finding reinforces that each indicator is more strongly associated with its respective construct than with other constructs, confirming that the measurement model effectively differentiates between constructs.

Another criterion to consider in discriminant validity is the Heterotrait Monotrait Ratio (HTMT). HTMT is the average of all relationships between indicators across different constructs. The maximum correlation value for HTMT is 0.9. If the HTMT correlation value exceeds 0.9, it may indicate a lack of discriminant validity. HTMT is considered more sensitive and accurate in detecting discriminant validity issues. Table 6 is the HTMT data result:

Table 6. Heterotrait Monotrait Ratio (HTMT)

	Accessibility	Information	Reliability	Safety and Security	Responsiveness	Mobility	Excellent Service	Rest Area
Accessibility								
Information	0.727							
Reliability	0.711	0.714						
Safety and Security	0.699	0.701	0.707					
Responsiveness	0.404	0.408	0.395	0.406				
Mobility	0.711	0.704	0.709	0.690	0.421			
Excellent Service	0.615	0.638	0.616	0.618	0.631	0.642		
Rest Area	0.402	0.401	0.389	0.396	0.701	0.401	0.601	

Based on Table 6, no HTMT correlation values exceed 0.9. These values meet the HTMT criteria and pass the discriminant validity test, indicating that the constructs are well discriminated in measuring the intended variables. This result confirms that there is no significant multicollinearity between constructs, ensuring that each construct distinctly represents a different concept in the model.

Another method to assess discriminant validity is by examining the AVE value. A variable is considered to have good discriminant validity if its AVE value is greater than 0.5.

Based on the AVE values presented in Table 7, it is evident that all constructs have AVE values greater than 0.5. Therefore, no issues related to discriminant validity are found in the tested model. This result confirms that each construct explains more than half of the variance of its indicators, ensuring that the constructs are well-defined and not significantly overlapping with others in the model.

Table 7. Average Variance Extracted (AVE)

	Average variance extracted (AVE)
Accessibility	0.814
Information	0.878
Reliability	0.810
Safety and Security	0.800
Responsiveness	0.814
Mobility	0.889
Excellent Service	0.828
Rest Area	0.812

At this stage, each construct has met all the necessary criteria for discriminant validity testing, thus it can be concluded that each construct is empirically distinct from the others and captures phenomena not represented by other constructs within the model. Consequently, each indicator is considered to meet the criteria for discriminant validity testing.

The next step in testing the outer model is the internal consistency reliability test. This is conducted using Cronbach's alpha and composite reliability values. Cronbach's alpha indicates the correlation among indicators within a construct, while composite reliability assesses the variation in outer loading across the indicator variables. Accepted Cronbach's alpha and composite reliability values must be greater than 0.7.

The test results in Table 8 show that all latent variables meet the reliability test criteria. This is based on the fact that the Cronbach's alpha and composite reliability values for all latent variables are greater than 0.7. Therefore, all latent variables are considered reliable after meeting all the measurement criteria. This finding confirms that the measurement model has strong internal consistency, ensuring that the indicators consistently represent their respective constructs.

Table 8. Reliability

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)
Accessibility	0.943	0.944	0.956
Information	0.861	0.861	0.935
Reliability	0.941	0.942	0.955
Safety and Security	0.950	0.950	0.960
Responsiveness	0.924	0.924	0.946
Mobility	0.876	0.881	0.941
Excellent Service	0.958	0.959	0.967
Rest Area	0.942	0.942	0.956

3.3.2. Inner Model

After the measurement model is validated and reliable, the next step is to perform a structural model assessment, also known as the inner model evaluation. When the measurement model (outer model) shows good results, the next evaluation step in SEMPLS analysis is to assess the structural model (inner model). The structural model is analyzed to find evidence supporting the theoretical model (theoretical relationships between exogenous and endogenous constructs). The inner model evaluation is conducted through several tests, such as collinearity, explanatory power, predictive power, and significance of model relationships, which will be discussed further. Figure 4 is the inner model diagram in SmartPLS based on the testing results.

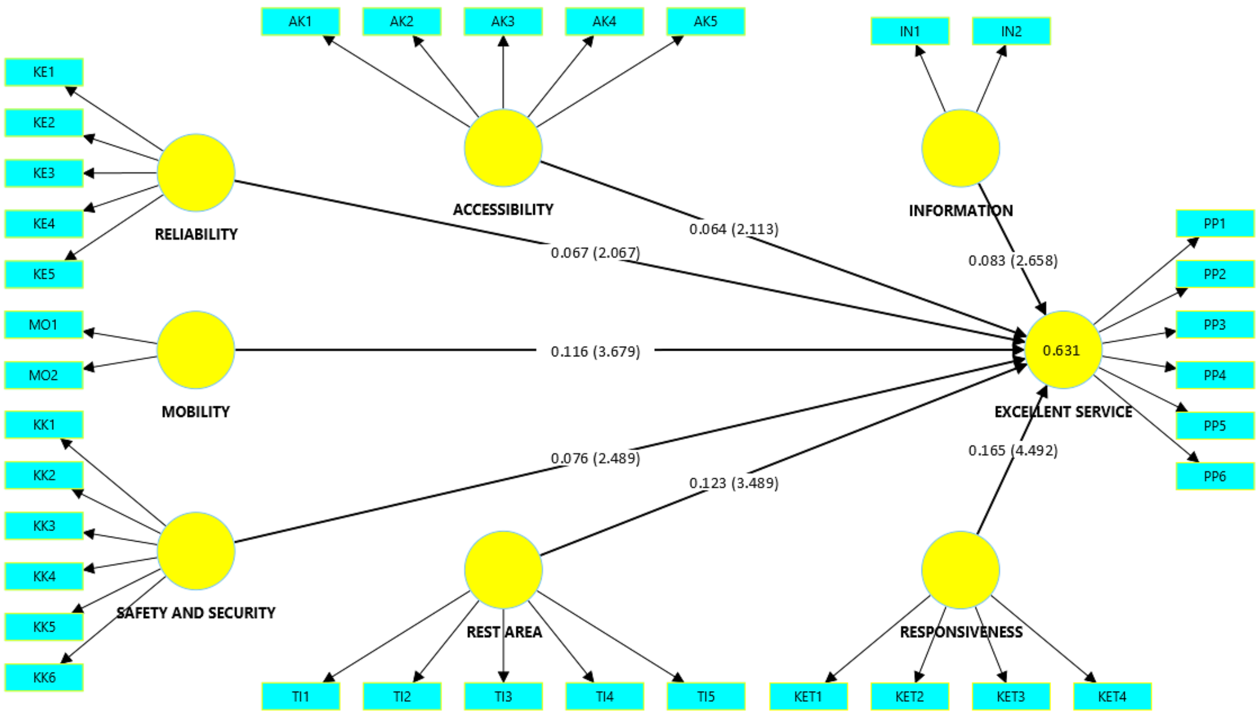

Figure 4. Structural Model (Inner Model)

The first step in assessing the inner model is to evaluate its collinearity by examining the Variance Inflation Factor (VIF) values. Collinearity refers to a condition where two or more predictor (independent) variables in the model have a high linear relationship, meaning they are strongly correlated with each other. The collinearity test can be conducted by checking the VIF value. If the VIF value is less than 5, the model is considered fit and can proceed to the next analysis. The results of the VIF test can be seen in Table 9.

Table 9. Variance Inflation Factor (VIF)

	VIF		VIF
AK1	3.598	**KK3**	3.645
AK2	3.561	**KK4**	3.531
AK3	3.446	**KK5**	3.482
AK4	3.334	**KK6**	3.753
AK5	3.667	**MO1**	2.543
IN1	2.329	**MO2**	2.543
IN2	2.329	**PP1**	4.159
KE1	3.742	**PP2**	3.941
KE2	3.405	**PP3**	3.970
KE3	3.335	**PP4**	3.880
KE4	3.298	**PP5**	4.716
KE5	3.451	**PP6**	4.087
KET1	3.003	**TI1**	3.336
KET2	3.000	**TI2**	3.472
KET3	3.395	**TI3**	3.264
KET4	3.147	**TI4**	3.619
KK1	3.358	**TI5**	3.644
KK2	3.457		

As shown in Table 9, the VIF values between the research variables meet the test criteria, i.e., < 5. Based on the structural model testing results, it can be concluded that the model is generally good. This indicates that there are no serious multicollinearity issues among the predictor variables, ensuring that the regression estimates are stable and reliable.

The next step in evaluating the structural model is to assess the explanatory power of the model using the R-Square value. The R-Square value indicates the extent to which exogenous constructs explain endogenous constructs. The explanatory power of a model is closely related to its ability to fit the existing data, measured by the strength of the association shown by the PLS path model. The most commonly used measure to evaluate the explanatory power of the structural model is the coefficient of determination, or R-Square value. The higher the R-Square value, the better the model's ability to predict the research variables. The results of the R-Square testing analysis can be seen in Table 10.

Table 10. R Square

	R-square	R-square adjusted
Excellent Service	0.631	0.624

The table above shows that the R-Square value for excellent service is 0.631, indicating that the influence of independent variables on excellent service is 63.1%, with the remaining 36.9% influenced by other variables outside the model. Based on these R-Square values, it can be concluded that the influence of exogenous constructs on endogenous constructs is moderate, as it falls within the range of 0.5-0.74.

For the path model in this study to be useful for managerial decision-making, the model must produce findings that can be generalized. Generalizing research findings requires an assessment to ensure that the results not only apply to the data used during the calculation process but can also be applied to other datasets. The assessment of predictive power can be done by looking at the predictive relevance value. The higher the Q-Square value obtained, the better the research findings and the better it can predict outcomes with different sample data. The results of the Q-Square test can be seen in Table 11.

Table 11. Q Square

	Q-square
Excellent Service	0.518

Based on the Q-Square calculation results, it can be concluded that the Q-Square values for the variables of prime service are >0, indicating that the model has good predictive relevance. Table 11 shows that the variables of accessibility, information, reliability, safety and security, responsiveness, mobility, and rest areas have a impact on prime service is 0.518.

The path coefficient is used to measure the extent of the relationship between variables in this study by evaluating the estimated values in terms of direction (sign) and magnitude. The original sample values, ranging from -1 to +1, indicate a negative to positive relationship between the variables. The criteria used to determine the significance of each variable in influencing toll road service performance are assessed by measuring the direct effect between latent variables using the bootstrapping method in SmartPLS. To be considered significant, the t-statistic value must be above 1.96 or the p-value must be below 0.05. Below is the path coefficient value in Table 12.

Table 12. Significant Test

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
Accessibility → Excellent Service	0.064	0.063	0.030	2.113	0.035
Information → Excellent Service	0.083	0.082	0.031	2.658	0.008
Reliability → Excellent Service	0.067	0.066	0.032	2.067	0.039
Safety and Security → Excellent Service	0.076	0.076	0.031	2.489	0.013
Responsiveness → Excellent Service	0.165	0.164	0.037	4.492	0.000
Mobility → Excellent Service	0.116	0.116	0.031	3.679	0.000
Rest Area → Excellent Service	0.123	0.121	0.035	3.489	0.000

In influencing excellent toll road service, the analysis results show that the responsiveness variable contributes the most, with a value of 0.165, followed by the rest area variable at 0.123, the mobility variable at 0.116, the information variable at 0.083, the safety and security variable at 0.076, the reliability variable at 0.067, and the accessibility variable at 0.064. Additionally, the analysis results above show that all the tested variables have a positive and significant relationship. This is indicated by the positive coefficient values, a t-test value > 1.96, and a p-value < 0.05. Thus, it can be concluded that these variables have a positive and significant relationship with excellent toll road service (Figure 5).

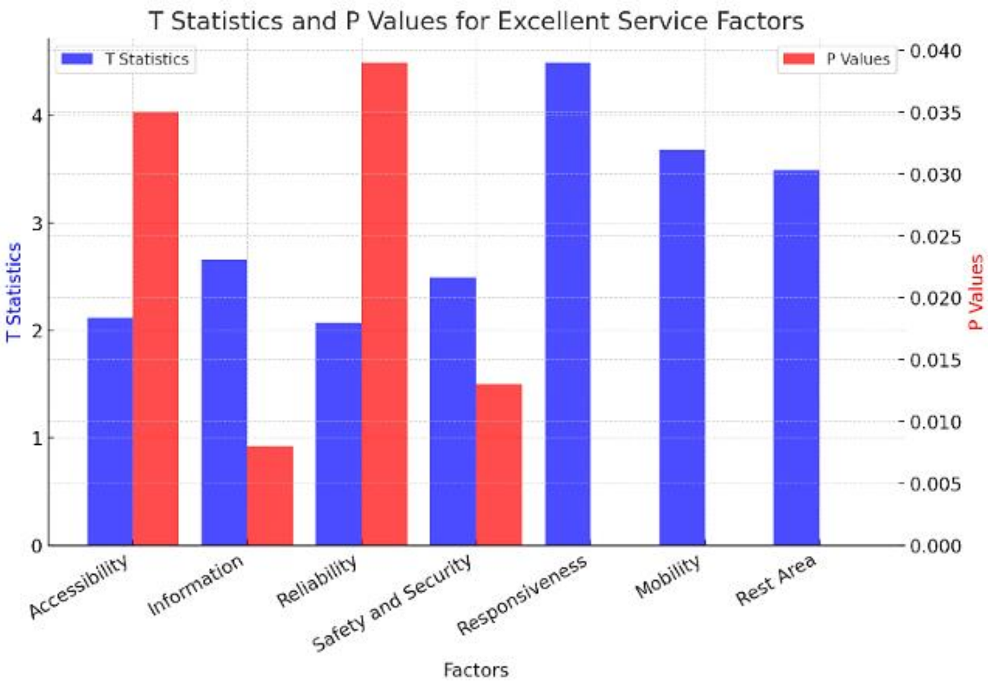

Figure 5. Significant Diagram

3.4. Toll Road Service Performance Model

The variables tested in this study are based on the TRSQ model, which is a service quality development model encompassing accessibility, information, reliability, safety and security, responsiveness, mobility, and rest areas. The testing revealed that these service quality variables positively influence excellent toll road services. This indicates that good toll road service quality can create excellent service for users, fostering satisfaction with the services they receive. However, it is necessary to identify other variables outside this model that may affect toll road services by incorporating expert opinions, as the variable relationship test shows that 36.9% of toll road services are influenced by factors beyond the tested variables.

In developing this model, the research began with bibliometric analysis using the VOSviewer software. VOSviewer is a software tool for constructing and visualizing bibliometric networks, which may include journals, researchers, or individual publications. These networks are built based on citations, bibliographic coupling, co-citations, or co-authorship relationships (VOSviewer, 2024). Before using VOSviewer, the researchers accessed scientific publication references related to toll road service performance using the Publish or Perish (PoP) application. Searches were conducted via Google Scholar using keywords such as toll road service performance, sustainable toll road, and toll road innovation for publications dated between 2020 and 2024. These searches yielded 350 metadata entries.

The mapping and clustering in the bibliometric analysis conducted through VOSviewer are complementary, providing detailed insights into the structure of a bibliometric network. This mapping facilitates the identification of relationships between topics/variables based on research trends.

The toll road service performance concept derived from the VOSviewer results refers to a collection of scientific publications using keywords aligned with the research theme. To produce high-quality, interactive mappings, these findings can be implemented in network forms like the diagram above. The mapping results highlight several variables relevant to toll road service performance, including sustainability performance, innovative technology, environmental performance, public private partnership, and climate change (see Figure 6).

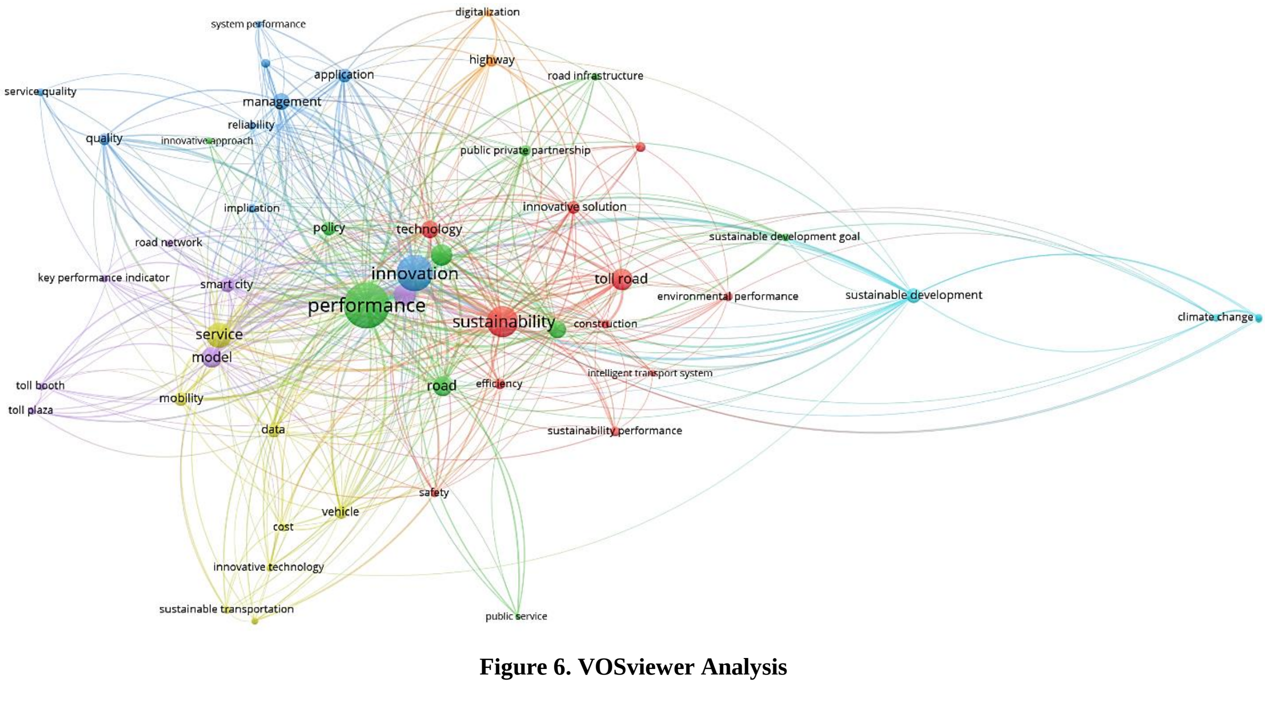

Figure 6. VOSviewer Analysis

The next step is to integrate the research findings with expert opinions in the field of toll roads, including input from toll road users. This process aims to ensure that the additional variables identified are truly relevant and contribute to improving toll road service quality. As a follow-up, an expert panel assessment is conducted as a validation method. This panel consists of academics, industry practitioners, and stakeholders with experience and insights into toll road management and development. The assessment is carried out to review, evaluate, and reach a consensus on the variables that should be incorporated into the final model. Once the validation process is completed, the conclusions from each expert are presented as part of the final analysis to strengthen the justification of the developed model. The following section provides a summary of the experts conclusions (see Table 13).

Table 13. Expert Opinion

No.	Expert	Innovation	Environmental	Public private partnership	Climate Change
1	Transportation Engineering Expert, Bandung Institute of Technology (ITB) as an academician	The integration of smart transportation systems and electric vehicles can modernize toll roads, ensuring a more efficient and seamless driving experience. Implementing AI-driven traffic management can reduce congestion and enhance road capacity.	The use of renewable energy sources for toll infrastructure, such as solar panels in toll plazas, can improve sustainability. Encouraging green rest areas with eco-friendly facilities is also essential.	Collaborations between public and private entities can accelerate the development of digital tolling systems, such as Multi-Lane Free Flow (MLFF), enhancing efficiency.	The implementation of low-emission vehicles and electric vehicle charging stations along toll roads is crucial in reducing the carbon footprint of transportation.
2	Civil Engineering Lecturer, Krida Wacana Christian University as an academician	The use of IoT-based monitoring systems can enhance toll road safety by providing real-time updates on road conditions and potential hazards. Smart road lighting can improve visibility and efficiency.	Renewable energy-based road lighting should be prioritized to improve energy efficiency while ensuring road safety. Greening of toll roads can also enhance environmental quality.	Establishing partnerships to develop intelligent transportation systems can improve traffic management and reduce operational costs.	The application of smart lighting and solar-powered LED systems can help mitigate the effects of extreme weather by ensuring continuous road safety.
3	Transportation Analyst, Soegijapranata University as an academician/ practitioner	Advanced tolling technologies, such as contactless and electronic payment methods, can enhance user convenience. Implementing AI-driven predictive maintenance can help prevent road deterioration.	Ensuring minimum environmental standards for road construction and maintenance is crucial. Adopting sustainable materials in road construction can improve longevity and reduce environmental impact.	Private companies should be incentivized to develop eco-friendly toll infrastructure, integrating data analytics for better management.	Transitioning towards green transportation by reducing fuel consumption through congestion management and smart tolling solutions is necessary.
4	Director of Training & Campaign, Indonesia Road Safety Partnership as a practitioner	AI-based accident monitoring systems can enhance safety by detecting accidents in real time and enabling quick response actions. Implementing emergency response technology, such as automated distress calls, can save lives.	Sustainable infrastructure should include eco-friendly barriers and road separators that minimize accident impacts while supporting environmental conservation.	Encouraging private sector investment in road safety technology, such as automated incident detection and AI-based monitoring, can improve overall service quality.	Emergency response systems must be improved to handle extreme weather conditions, ensuring the safety of toll road users.
5	Expert Staff for Environment, Ministry of Public Works (PU) as a regulator	Smart toll booths with automated systems can enhance efficiency and reduce human error. Implementing real-time traffic monitoring can improve traffic flow and minimize delays.	Sustainable toll roads must incorporate eco-friendly materials, efficient drainage systems, and green spaces for carbon absorption. Developing climate-resilient infrastructure is essential.	Public-private collaborations should focus on enhancing toll road facilities with eco-friendly designs, integrating renewable energy sources in toll road infrastructure.	Climate adaptation strategies, such as flood risk management and temperature-resistant road materials, should be prioritized.
6	Head of Operations and Maintenance, Toll Road Regulatory Agency (BPJT) as a regulator	Toll operators must integrate modern payment systems, such as digital wallets and blockchain-based tolling, to enhance service efficiency.	Waste management strategies, including recycling programs in rest areas, should be encouraged. Rest areas should adopt environmentally friendly designs to minimize ecological impact.	Encouraging the private sector to invest in renewable energy-powered toll booths and rest areas can drive sustainable road management.	Regulations should promote modern vehicles powered by renewable energy, such as hydrogen and electric vehicles, to mitigate climate change impacts.
7	Policy Analyst, Ministry of Transportation as a regulator	Policy frameworks should support the integration of AI and big data for traffic management and congestion reduction. Smart tolling policies can enhance efficiency and reduce bottlenecks.	The government should promote policies that mandate green infrastructure in toll road projects, encouraging eco-friendly designs and sustainable operations.	Private companies should be incentivized to contribute to toll road sustainability by offering green solutions and energy-efficient infrastructure.	Government policies should support climate mitigation efforts by encouraging the use of smart, low-emission transportation systems.
8	President Director, PT Pemalang Batang Toll Road as an operator	Developing family-friendly rest areas with modern facilities, such as interactive digital services, can improve user satisfaction. Smart rest areas with automated service points can enhance convenience.	Implementing eco-rest area concepts with solar energy, circular waste management, and green spaces can improve sustainability.	Private operators should collaborate with environmental agencies to develop carbon-neutral toll operations.	Using renewable energy sources in toll road operations and promoting electric vehicle adoption can contribute to climate change mitigation.
9	Toll Road Safety Officer, PT Jasa Marga as an operator	Implementing AI-powered early warning systems and drone-based monitoring can enhance road safety. Automated emergency response systems can improve accident management.	Expanding emergency services, such as fire trucks and ambulances at strategic locations, can reduce the environmental impact of accidents.	Private sector investment in emergency response infrastructure, such as AI-based distress call systems, can enhance service reliability.	Developing climate-adaptive emergency response strategies is essential to ensure road safety during extreme weather events.
10	Toll Road User, Jakarta as an society	AI-powered applications providing real-time traffic and weather predictions can improve the driving experience.	Road cleanliness and proper waste disposal at rest areas should be enhanced to maintain environmental quality.	Users expect seamless cooperation between toll operators and digital service providers to improve payment systems and information access.	Implementing solar-powered LED lighting and weather-resistant road materials can improve safety and efficiency.
11	Toll Road User, Pekalongan as an society	More warning signs and digital information boards in accident-prone areas can improve user awareness and safety.	The use of solar-powered road lighting can enhance energy efficiency and reduce carbon emissions.	The development of digital payment systems and toll road navigation apps through private sector collaboration can improve user experience.	The integration of climate-responsive designs, such as better road drainage to prevent flooding, is necessary.

Based on the opinions of experts from various backgrounds academics, practitioners, regulators, operators, and the public, it can be concluded that the four key variables, namely innovation, environmental sustainability, public-private partnership, and climate change, have significant relevance in improving toll road services. Innovation in toll road services is a crucial factor in enhancing efficiency, safety, and user convenience. The adoption of advanced technologies such as the Multi-Lane Free Flow (MLFF) system, artificial intelligence (AI) for accident monitoring, and AI-based applications providing real-time traffic and weather information is considered essential in improving the overall user experience.

Additionally, environmental aspects are a primary concern in the sustainable development and management of toll roads. Experts agree that the implementation of green infrastructure concepts, renewable energy-based lighting, improved waste management, and carbon emission reduction through eco-friendly transportation can support the long-term sustainability of toll roads. Meanwhile, public-private partnerships are seen as an effective strategy for developing more modern and efficient toll road services. Experts emphasize the importance of collaboration between the government and the private sector in investing in green technology, enhancing digital-based services, and implementing blockchain-based toll systems to improve transparency and operational efficiency.

On the other hand, climate change poses a significant challenge in toll road management. Experts highlight the need for mitigation strategies, such as implementing technologies that reduce the impact of extreme weather, strengthening infrastructure resilience against flood and extreme temperature risks, and integrating electric vehicles and smart transportation systems to lower carbon emissions. Overall, all experts agree that these four variables are interconnected and contribute significantly to improving the quality of toll road services. The implementation of strategies based on innovation, environmental sustainability, public-private partnerships, and climate change mitigation will drive the development of safer, more convenient, efficient, and sustainable toll roads in the future (see Figure 7).

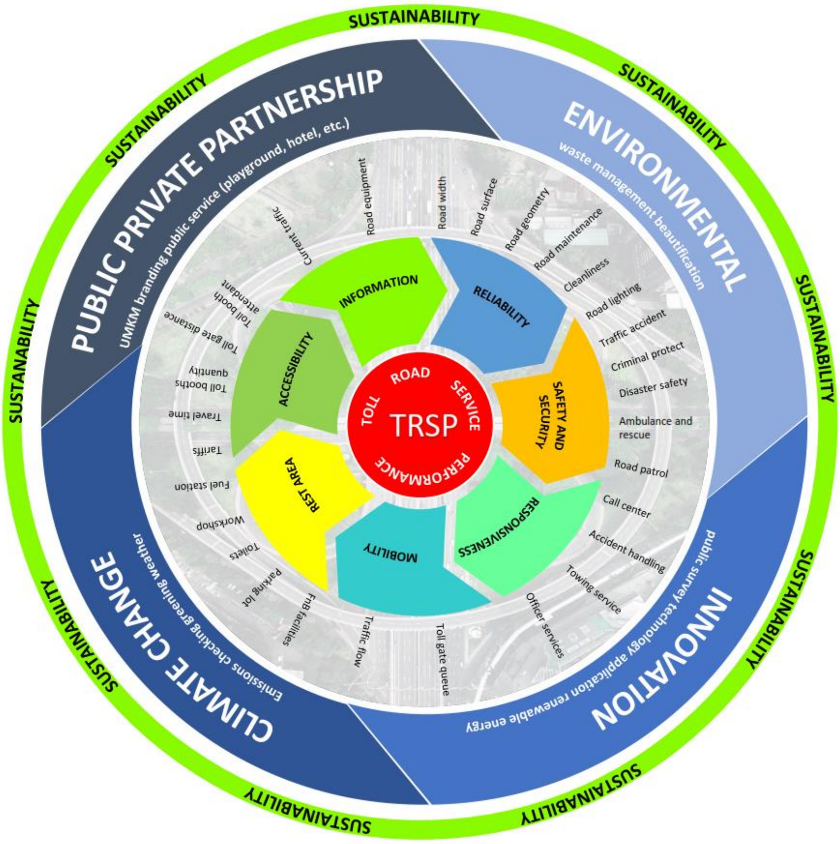

Figure 7. Toll Road Service Performance Model

4. Conclusion

This study successfully developed a comprehensive toll road service performance model designed to evaluate and improve service quality. The model considers seven key variables that significantly impact the toll road user experience: information, accessibility, reliability, mobility, safety and security, rest areas, and responsiveness. Each variable plays a critical role in creating a toll road system that not only meets the basic needs of users but also provides an optimal experience.

Information, as the first variable, includes the provision of accurate real-time data on traffic conditions, weather, and safety alerts. This enables users to make better travel decisions. Accessibility refers to the ease of entry and exit from the toll road, as well as the efficient design of toll gates to minimize congestion. Reliability reflects consistency in the quality of toll road services, ensuring predictable travel times and minimal operational disruptions. Other variables, such as mobility, emphasize the importance of smooth traffic flow with the support of advanced traffic management technology. Safety and security are fundamental pillars, providing emergency facilities such as ambulances and rescue services, as well as adopting monitoring systems to reduce accident risks. Rest areas are designed not only to meet basic needs but also to serve as integrated service centers with facilities supporting sustainability, such as waste management and green initiatives. Responsiveness reflects the toll operator's ability to quickly address user needs, including incident management.

This research shows that these variables have a positive and significant impact on toll road service performance, contributing 63.1%. This indicates that most key aspects are covered in the model. However, there remains a 36.9% influence from variables outside the model, highlighting room for further improvement. The study also successfully identified several additional variables that could contribute more to enhancing toll road service performance in the future. Environmental aspects, for example, focus on beautification, waste management, and reducing the environmental impact of toll road infrastructure development. Innovation includes the use of advanced technologies, such as blockchain-based toll systems to improve transparency and efficiency, and the use of renewable energy. Climate change is an important consideration in designing infrastructure that is resilient to extreme conditions, such as flooding or adverse weather. Additionally, emission management and greening initiatives can be applied across toll road corridors. Finally, public-private partnerships play a strategic role in creating synergy between the government and the private sector to support financing and management of toll road services.

The integration of these additional variables in the future is expected to expand the model's scope, creating a holistic approach that includes aspects of sustainability, efficiency, and adaptation to global challenges. With focused development, this model has the potential to become a standard framework for improving toll road service quality. However, to refine this study, it is necessary to conduct a trial implementation of the model based on the final identified variables to evaluate its effectiveness in improving toll road services.

5. Declarations

5.1. Author Contributions

Conceptualization, E.P.R. and I.B.P.; methodology, E.P.R.; software, I.B.P.; validation, E.P.R. and A.M.C.; formal analysis, E.P.R.; investigation, E.P.R., I.B.P., and A.M.C.; resources, E.P.R.; data curation, A.M.C. and I.B.P.; writing—original draft preparation, I.B.P.; writing—review and editing, I.B.P. and A.M.C.; visualization, I.B.P.; supervision, E.P.R. and A.M.C.; project administration, A.M.C.; funding acquisition, E.P.R. All authors have read and agreed to the published version of the manuscript.

5.2. Data Availability Statement

The data presented in this study are available in the article.

5.3. Funding

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5.5. Conflicts of Interest

The authors declare no conflict of interest.

6. References

[1] Smollett, T. (1993). No. 38. The Works of Tobias Smollett: Poems, Plays, and The Briton, 428–536, Oxford Scholary Edition, Oxford, United States. doi:10.1093/oseo/instance.00217004.

[2] Dewi, N. P. Y. T., Usadha, D. N., & Kamala, D. (2022). Service Quality and Employee Performance on Consumer Satisfaction of PT. Jasa Marga Bali Tol. Jurnal Manajemen Dan Bisnis Equilibrium, 8(1), 25–36. doi:10.47329/jurnal_mbe.v8i1.773.

[3] Ahmad, F. S. (2022). Impact of Trans Java Toll Road Development on Economic Growth in Central Java. Jurnal Ekonomi Dan Kebijakan Pembangunan, 11(1), 1–18. doi:10.29244/jekp.11.1.2022.1-18.

[4] Sholeh, D. R. (2024). Creating a Future Toll Road: The Implementation of Advanced Technology in Getaci Toll RoadSumber. Available Online: https://garut.pikiran-rakyat.com/nasional/pr-528061167/menggagas-jalan-tol-masa-depan-penerapan-teknologi-canggih-di-tol-getaci?page=all (accessed on May 2025). (In Indonesian).

[5] BPJT. (2021). Commencement of Cooperation in the Application of Artificial Intelligence Technology to Monitor Road Conditions on Toll Roads. Badan Pengatur Jalan Tol, Jakarta, Indonesia. Available online: https://bpjt.pu.go.id/berita/dimulainya-kerja-sama-penerapan-teknologi-artificial-intelligence-untuk-memantau-kondisi-jalan-di-jalan-tol (accessed on May 2025). (In Indonesian).

[6] Dwi Oktavianus, D., Urip Pandiangan, B., Daffa Rian Fahlefi, M., & Rosyani, P. (2024). Analysis of Vehicle Detection and Counting on Toll Roads with OpenCV-Python Using Image Thresholding and Contours Methods. Jurnal Artificial Inteligent Dan Sistem Penunjang Keputusan, 2(2), 112–118. (In Indonesian).

[7] Hendarto, S., Simorangkir, C. O., Ayuningtyas, K. N. S., & Prakoso, A. D. (2021). Evaluation of Service Performance Provided on the Trans-Java Toll Road Based on the Perception of Logistics Truck Drivers. Jurnal Teknik Sipil, 28(2), 207–220. doi:10.5614/jts.2021.28.2.10. (In Indonesian).

[8] Rangkuty, M. H. F., & Tarigan, A. A. (2022). Analysis Of People's Satisfaction Levels On High Cliff Toll Rates Policy. Jurnal Manajemen Akuntansi (JUMSI), 2(2), 191–202. (In Indonesian).

[9] Dina, D. M. D. D. M., & Amin, M. (2023). The Effect of Toll Road SPM Service Substance on Toll Road User Satisfaction in the Jabodetabek Area. Jurnal Infrastruktur, 9(1), 7-14. (In Indonesian).

[10] Setyawan, A., Hermani, W. T., Yulianto, B., & Gravitiani, E. (2024). Influence of maintenance funds on improve road steadiness with the Curva expert program. Civil Engineering Journal, 10(2), 546-554. doi:10.28991/CEJ-2024-010-02-014.

[11] Parikesit, D., Wardhana, Y. M., Makmur, A., & Kurniawan, D. A. (2023). Policy perspectives on toll road development in Indonesia. PT Penjaminan Infrastruktur Indonesia (Persero) dan Pusat Studi Transportasi Logistik UGM, Jakarta, Indonesia.

[12] Parikesit, D., Amalia, P., & Diyen, V. (2024). Regulatory challenges in modernizing toll road transaction systems in Indonesia. Journal of Infrastructure, Policy and Development, 8(8), 1-12.

[13] Wulandary, D. D., Rivai, A. K., & Rahmi, R. (2022). Investigating Customer Satisfaction of the Bakauheni-Palembang Toll Road. Jambura Science of Management, 4(1), 29–45. doi:10.37479/jsm.v4i1.11445.

[14] Bank Syariah Indonesia. (2023). Annual Report 2023. Bank Syariah Indonesia, Jakarta, Indonesia. (In Indonesian).

[15] Wire, P. (2023). The Potential of Pemalang -- Batang Toll Road is Very High, Waskita is Ready to Conduct Strategic Cooperation at the Asean Indo Pacific Forum (AIPF). Antara, Jakarta, Indonesia. Available online: https://www.antaranews.com/berita/3706611/potensi-tol-pemalang-batang-sangat-tinggi-waskita-siap-lakukan-kerjasama-strategis-pada-asean-indo-pacific-forum-aipf (accessed on May 2025). (In Indonesian).

[16] Komite Percepatan Penyediaan Infrastruktur Prioritas. (2014). Pemalang – Batang Toll Road (39KM). Committee For Acceleration of Priority Infrastructure Provision, Jakarta, Indonesia. Available online: https://kppip.go.id/proyek-strategis-nasional/jalan-dan-jembatan/jalan-tol-pemalang-batang-39km/ (accessed on May 2025). (In Indonesian).

[17] Hidayat, T., & Anggorowati, V. D. A. (2020). Analysis of the Impact of the Existence of the Trans Java Toll Road in the Pemalang-Batang Area. Equilib, 1(1), 111-119. (In Indonesian).

[18] Budiharjo, A., Haryoko, D. W., & Jepriadi, K. (2021). Analysis of Toll Road Damage Level. Teras Jurnal: Jurnal Teknik Sipil, 11(1), 157. doi:10.29103/tj.v11i1.417. (In Indonesian).

[19] Suwarto, F., Kurnianto, Y. F., Setiabudi, B., & Sholeh, M. N. (2021). Toll road maintenance towards minimum service standard. IOP Conference Series: Earth and Environmental Science, 700(1). doi:10.1088/1755-1315/700/1/012058.

[20] Sadya, S. (2023). 8 Toll Roads in Indonesia with the Most Accidents in 2022. Indonesian Data, Jakarta, Indonesia. Available online: https://dataindonesia.id/sektor-riil/detail/8-ruas-tol-di-indonesia-dengan-kecelakaan-terbanyak-pada-2022 (accessed on May 2025). (In Indonesian).

[21] Creswell, J. W., & Clark, V. L. P. (2017). Designing and conducting mixed methods research. Sage Publications, New York, United States.

[22] Tahrir, M. (2023). Study of User Satisfaction Level of Balikpapan-Samarinda Toll Road After Tariff Increase. Jurnal Sipil Sains, 13(2), 1–10. doi:10.33387/sipilsains.v13i2.6518.

[23] Putra, S. G., Wicaksono, A. D., & Prayitno, G. (2023). Level of Satisfaction of Pekanbaru-Dumai Toll Road Users. Planning for Urban Region and Environment Journal (PURE), 11(4), 241-248. (In Indonesian).

[24] Hair Jr, J. F., Matthews, L. M., Matthews, R. L., & Sarstedt, M. (2017). PLS-SEM or CB-SEM: updated guidelines on which method to use. International Journal of Multivariate Data Analysis, 1(2), 107-123. doi:10.1504/IJMDA.2017.087624.

[25] Sutisna, I. (2020). Research Statistics Data Analysis Techniques Quantitative Research. Universitas Negeri Gorontalo, 1–15. (In Indonesian).

[26] Sarstedt, M., Ringle, C. M., & Hair, J. F. (2022). Partial Least Squares Structural Equation Modeling. Handbook of Market Research. Springer, Cham, Switzerland. doi:10.1007/978-3-319-57413-4_15.

[27] Alfiansyah, A. D., Fatikasari, A. D., Wardhani, P. C., & Bowoputro, H. (2023). Evaluation of Surabaya-Gempol Toll Road Service Performance Based on User Perception. Agregat, 8(1), 800–806,. doi:10.30651/ag.v8i1.17772.

[28] Putra, S. G., Wicaksono, A. D., Prayitno, G., & Hiep, N. T. (2023). Improving the Quality of Toll Road Services to Increase Satisfaction Level of Pekanbaru – Dumai Toll Road. Civil and Environmental Science, 006(01), 24–32. doi:10.21776/ub.civense.2023.00601.4.

[29] Fajar Subkhan, M., Anom Maruta, I., & Mahendra, I. A. (2023). Quality of Service on Road User Satisfaction: Study on Surabaya-Malang Toll Road Customers. International Journal of Social and Management Studies (IJOMAS), 02(02), 186–195.

[30] Pratala, E., Supriyadi, Y. N., & Saragih, G. S. (2023). Analisis Servqual Dan Importance Performance Analysis Pada Jalan Tol Ruas Cengkareng-Batuceper-Kunciran. Bureaucracy Journal: Indonesia Journal of Law and Social-Political Governance, 3(3), 2637–2649.

[31] Cahyono, Y., Suheri, S., Wanto, W., Wardana, W., & Gatot, G. (2021). Analisis Marketing Relationship Strategy Melalui Customer Satisfaction Survei Pada Pengguna Jalan Tol PT. Jasa Marga (Persero)TBk Cabang Jakarta-Tangerang. Lensa, 15(2), 53–66. doi:10.58872/lensa.v15i2.15. (In Indonesian).

[32] Makmur, A. (2021). Evaluation Of Toll Road Users in Indonesia Towards the Receivable Services. Jurnal Jalan Jembatan, 38(1), 47-58. (In Indonesian).

[33] Alfiansyah, A. D., & Wardhani, P. C. (2021). Study of Surabaya-Mojokerto Toll Road Service Level Using the Customer Satisfaction Index (CSI) Method. Journal of Civil Engineering Science dan Technology, 2(2), 12-18.

[34] Kurnia, A. Y., Pataras, M., & Permata, D. Y. (2020). Analysis Of Service Level of Palindra Toll Road from User Perspective. Applicable Innovation of Engineering and Science Research (AVoER), 213-217. (In Indonesian).

[35] Waluyo, M., Sumiati, & Waluyo, M. R. (2020). The Influence Model of Reliability, Assurance, Tangibles, Empathy, Responsive-ness on Customer Satisfaction and Highway Users Loyalty. Conf. Eco-Innovation Sci. Eng. Technol, 243–247. doi:10.11594/nstp.2020.0539.

[36] Humas FT UI. (2016). FTUI Doctor Develops Toll Road Service Model. University of Indonesia, Jakarta, Indonesia. Available online: https://eng.ui.ac.id/doktor-ftui-kembangkan-model-pelayanan-jalan-tol/ (accessed on May 2025).

[37] Zuna, H. T., Hadiwardoyo, S. P., & Rahadian, H. (2016). Developing a model of toll road service quality using an artificial neural network approach. International Journal of Technology, 7(4), 562–570. doi:10.14716/ijtech.v7i4.2612.

[38] Slamet, R., & Wahyuningsih, S. (2022). Validity and Reliability of the Alliance Work Satisfaction Instrument. Jurnal Manajemen Dan Bisnis, 17(2), 51–58. doi:10.46975/aliansi.v17i2.428.