

THE 2023 PKJI METHOD FOR ANALYZING ROAD SECTION PERFORMANCE WITH A WEBSITE-BASED APPLICATION

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Abstract

Manual calculation of road segment performance using the PKJI method has limitations, such as calculation complexity, susceptibility to human error, and a time-consuming process. The development of a web-based road segment performance analysis application using the 2023 PKJI method is aimed at overcoming these limitations. This is the first implementation of the 2023 PKJI website-based to analyze road section performance. The application development uses the waterfall model in four stages: analysis, design, implementation, and testing. The application is built using Visual Studio Code with the PHP programming language, providing features for automatic calculations of traffic volume, road capacity, free flow speed, degree of saturation, and level of service (LOS). Testing was conducted on three road segments in Tangerang, a city in Banten Province in Indonesia using black box testing and the System Usability Scale (SUS). The results show a calculation validity of 100% with a perfect accuracy level (difference = 0.0) compared to manual calculations, and the SUS score reached 87 with an A category. Performance analysis revealed that Pondok Jagung Timur Road and Rawa Kutuk Road achieved LOS A with low saturation levels (0.452 and 0.255), while Villa Melati Mas Raya Road reached LOS D with a critical saturation level (0.806). The application provides benefits in the form of digitalization of road performance analysis, increased calculation efficiency, minimization of human error, and high accessibility to support accurate decision-making in urban transportation infrastructure management.

Keywords: Road segment performance; 2023 PKJI; Web application; Traffic analysis; Degree of saturation

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Introduction

Road segments are a fundamental component of the transportation system that serves as a connector between regions to facilitate the movement of people, goods, and services (Batto *et al.*, 2022; Siswanto, Hendry, *et al.*, 2023). The classification of road segments is based on their function, status, and road class, referring to the applicable regulations (Woldu *et al.*, 2020; Zaranka *et al.*, 2023). The performance of a road segment becomes an important indicator in the road transportation system, reflecting the ability of that segment to serve traffic flow needs according to its function (Kundu *et al.*, 2023). If the volume of vehicles continues to increase without being matched with an increase in road capacity, the performance of the road segment will decline and is likely to cause congestion as well as reduce transportation efficiency (Dodi Frenky *et al.*, 2023; Kiende *et al.*, 2023). The performance of road segments is greatly influenced by various factors, such as the geometric conditions of the road, traffic volume, side friction, and land use patterns around the road (Feng *et al.*, 2023; Siswanto, Syaban, *et al.*, 2023). Measurements are conducted through various parameters such as road capacity, degree of saturation, average vehicle speed, travel time, delay, and queues occurring on the road segment (Cao *et al.*, 2023; Li *et al.*, 2023). These parameters are used to determine the Level of Service (LOS), which reflects the operational quality of the road and users' perception of driving comfort (Mufhidin *et al.*, 2022; Hasyim *et al.*, 2023). The assessment of road segment performance aims to analyze whether the road segment can accommodate the volume of vehicles passing through without causing congestion or a decline in traffic service quality (Cherkos & Jha, 2021; Shbeeb, 2022). The performance assessment of road segments is very important because it directly affects the smooth movement of people and goods, which impacts economic growth and community productivity (Isradi *et al.*, 2022; Rivera-Royero *et al.*, 2022; Siswanto *et al.*, 2025).

Calculations and analyses of road segment performance have been extensive with various methods and diverse conditions. Microscopic simulation and road network topology were used to analyze the performance of road segments in downtown Boise, with interventions on topologically critical and congested road segments successfully improving the Level of Service (LOS) from F to E and from D to C (Ahmed *et al.*, 2023). Exponential regression and K-means cluster analysis were used to analyze the performance of

three midblock road segments in the city of Srinagar, India. The result showed that the presence of pedestrians crossing illegally caused an increase in vehicle delay and a decrease in the LOS (Ameen *et al.*, 2023). The HCM and the 1997 MKJI methods were used to analyze the performance of the Perintis Kemerdekaan road segment in Makassar City, resulting in a road LOS in the D to E category, indicating congested traffic conditions, low speeds, and near maximum capacity due to side friction and vehicle density (Hafram & Asrib, 2022). The performance of Indonesian toll roads was analyzed using the 1997 MKJI method and HDM-4, resulting in overloading of heavy vehicles, causing a significant decrease in speed and an increase in operational costs (Setiawan, 2020). The 1997 MKJI method with a modified four-step model approach was used to analyze the performance of road sections in the Batang Integrated Industrial Area, predicting a significant decline in road performance by 2029 (Antoro *et al.*, 2024).

The manual performance calculation system for road segments faces various issues that affect the accuracy and efficiency of the analysis. The main constraint faced is the reliance on static assumptions used in the manual method, such as fixed parameters for road capacity adjustment factors that often do not reflect the dynamic conditions in the field (Rivera-Royero *et al.*, 2022). The manual calculation process tends to be complex and time-consuming because it must be carried out in stages, starting from determining free-flow speed, road capacity, to the degree of saturation (Kiende *et al.*, 2023). The system is also less sensitive to temporal variations, making it difficult to accurately project long-term traffic growth (Setiawan, 2020; Hafram & Asrib, 2022). Manual data collection is also prone to human errors that can lead to inaccuracies in measuring traffic volume and slow vehicle factors (Kundu *et al.*, 2023). The manual system has limitations in conducting multivariable analysis between the interactions of various factors such as road widening and the reduction of heavy vehicles, which must be calculated separately (Cao *et al.*, 2023). That requires more time and effort. The representation of small geometric changes in the road also requires a thorough recalculation, which adds to the workload (Cherkos & Jha, 2021; Shbeeb, 2022). Another factor that poses a challenge is the use of vehicle volume conversion to passenger car units with a fixed factor that does not consider the actual variation in vehicle load (Hafram & Asrib, 2022; Feng *et al.*, 2023). The classification of the LOS based on the degree of

saturation cannot accommodate qualitative aspects such as rider comfort, which can actually be analyzed better (Setiawan, 2020; Batto *et al.*, 2022; Li *et al.*, 2023). The issue indicates that the manual calculation of road segment performance has significant limitations in supporting effective transportation infrastructure planning and management.

Software for road performance analysis is widely available, including the 1997 MKJI manual calculation, the KAJI application (1997 MKJI method) and the International Highway Capacity Manual (HCM) application. The 1997 MKJI manual calculations are inherently static, time-consuming, and prone to human error. They are also less capable of handling dynamic field conditions or performing efficient multivariable analysis. The KAJI application is built on an old DOS platform with poor usability, impractical reporting features, lack of periodic data storage, and it is limited to Android. International HCM applications are often not specifically designed for the unique geometric conditions, vehicle composition, and traffic behavior regulations in Indonesia. A web-based road performance application using the 2023 PKJI method is proposed to address these issues. This application is the first to implement the 2023 PKJI method, which is a new standard in Indonesia, and is built using Visual Studio Code software with the PHP programming language. The proposed web-based application is capable of running on various platforms, such as website and mobile, is easily accessible, and user-friendly, providing automated calculations, integrated data management, real-time analysis, and cross-platform accessibility. This represents a significant contribution by providing Indonesian transportation engineers and planners with a dedicated, accurate, and efficient tool aligned with the latest national standards, enabling more precise and data-driven infrastructure management decisions. The web-based road performance application using the 2023 PKJI method can be utilized by stakeholders to formulate policies for increasing and improving transportation infrastructure more accurately and based on actual data, thereby indirectly improving the quality of road services for the public.

Methods

The development of the road performance analysis is carried out in four stages: identification, road performance analysis, development, and application of road performance analysis. Identification is aimed at recognizing problems and the performance needs of the road. Road performance analysis is carried out using a combination of the 2023 PKJI and transportation regulations applicable in Indonesia. The application development adopts the waterfall model, comprising analysis, design, implementation, and testing. The road performance analysis application produced from the development is used to analyze the performance of road segments (Figure 1).

Identification is carried out by identifying and analyzing limitations and needs through a literature study. The results of the identification include a list of problems and specifications for functional (automatic calculations and analysis) and non-functional (accessibility) needs. Road performance analysis involves calculation using the 2023 PKJI method and transportation regulations. The 2023 PKJI method is used to calculate traffic volume, road capacity, free flow speed, and degree of saturation. Traffic volume is the number of vehicles passing a point on the road within a certain time period, calculated from the number of vehicles and their equivalents using Equation (1). Equivalent values are divided into divided roads (Appendix 1) and undivided roads (Appendix 2). Road capacity is the maximum volume of vehicles that can pass a road segment within a certain time period, obtained from the calculation of the basic capacity value with its correction factors using Equation (2). The value of the correction factor consists of the basic capacity correction factor (Appendix 3), lane width (Appendix 4), direction separator (Appendix 5), lateral resistance with shouldered road (Appendix 6), lateral resistance with curb road (Appendix 7), and city size (Appendix 8). Free flow speed is the speed of vehicles when traffic volume is very low, obtained from the calculation of the basic free flow speed with its correction factors using Equation (3). The free flow speed correction

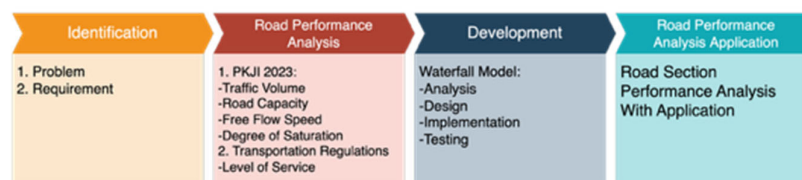


Figure 1. Road Performance Analysis Development

factor consists of basic free flow speed (Appendix 9), lane width (Appendix 10), side friction with shoulder (Appendix 11), side friction with curb (Appendix 12), and city size (Appendix 13). The degree of saturation is the ratio between traffic volume and road capacity, indicating the level of road usage, and is calculated using Equation (4). Transportation regulations are used to determine the LOS based on the degree of saturation and to analyze the performance of road segments. The LOS consists of six categories that can describe road conditions (Table 1).

$$Q = TC_{KS} \times EMP_{KS} + TC_{SM} + EMP_{SM} + TC_{MP} \times 1 \quad (1)$$

where Q is the traffic volume, TC_{KS} is the count of medium vehicles, EMP_{KS} is the passenger car equivalent of medium vehicles, TC_{SM} is the count of motorcycles, EMP_{SM} is the passenger car equivalent of motorcycles, and TC_{MP} is the count of passenger cars.

$$C = C_0 \times FC_{LJ} \times FC_{PA} \times FC_{HS} \times FC_{UK} \quad (2)$$

where C is the capacity of the road segment, C_0 is the basic capacity of the road segment (SMP/hour), FC_{LJ} is the lane width correction factor, FC_{PA} is the traffic direction separation correction factor, FC_{HS} is the roadside interruption correction factor, dan FC_{UK} is the city size correction factor.

Table 1. Level of Services (LOS)

No.	D _j (km/hour)	LOS	Road Conditions
1.	< 0.60	A	- Free flow with low volume and high speed - The traffic density is very low. - The driver can choose the desired speed.
2.	0.6 – 0.70	B	- Stable flow with moderate traffic volume and speed slightly limited by traffic - Low traffic density and internal traffic obstacles do not affect speed. - Drivers still have the freedom to choose their speed.
3.	0.71 – 0.80	C	- The flow is stable, but vehicle movement is controlled by higher traffic volume, and speed can be regulated by traffic. - Traffic congestion due to internal traffic obstacles is increasing. - Drivers have limitations in choosing speed, changing lanes, or overtaking.
4.	0.81 – 0.90	D	- The flow is approaching instability with high traffic volume and low speed. Traffic is still tolerated, but it is greatly affected by changes in flow conditions. - Moderate traffic density, but fluctuations in traffic volume and temporary obstacles can cause significant speed reductions. - The driver has very limited freedom in operating the vehicle, low comfort, but it is still tolerable for a short period.
5.	0.91 – 1	E	- The flow approaches instability with traffic volume nearing road capacity and low, variable speeds. - High traffic density due to high internal traffic obstacles. - Drivers are starting to experience short-duration traffic jams.
6.	> 1	F	- The flow is obstructed, resulting in a long queue of vehicles with a volume above capacity and low speed. - The traffic density is very high, and there are traffic jams for a considerable duration. - Drivers experience frustration, high stress, physical and mental fatigue, difficulty maneuvering, fuel wastage, and time loss.

Table 2. Questions in the Application Testing

No	Question	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1.	I think I will often use this app again.					
2.	I found this application complicated to use.					
3.	I feel that this application is easy to use.					
4.	I think that I will need help from a technical person to be able to use this application.					
5.	I found the functions in this application well integrated.					
6.	I feel there are many inconsistencies in this application.					
7.	I feel that others will quickly understand how to use this application.					
8.	I feel that this application is very complicated to use.					
9.	I feel there are no obstacles in using this application.					
10.	I need to learn a lot of things before using this application.					

Note: Answers are made by marking an X in the answer column.

$$V_B = (V_{BD} + V_{BL}) \times FV_{BHS} \times FV_{BUK} \quad (3)$$

where V_B is the free flow speed of passenger cars (MP) (km/h), V_{BD} is the basic free flow speed of MP, V_{BL} is the lane width correction value (km/h), FV_{BHS} is the side friction correction factor, and FV_{BUK} is the city size correction factor.

$$D_j = \frac{q}{c} \quad (4)$$

where D_j is the degree of saturation, C is the capacity of the road segment (SMP/hour), and q is the traffic volume (SMP/hour).

The development of road segment performance analysis uses the waterfall model to produce an application that can be used to perform computerized road segment performance analysis. The stages of the process in the waterfall model are system requirements, system design, implementation, and system testing. System requirements encompass analyzing and gathering needs to produce specifications, constraints, and assumptions of functional and non-functional requirements. System design is carried out to detail the architecture, database, algorithms, and process logic or data processing to produce system design, architecture diagrams, technical specifications, and interface design. Implementation refers to the creation of program code using programming languages, technologies, tools, and modules that have been developed and determined to produce source code that is ready to be deployed or used, code documentation for development guidance, and build or executable files according to the platform. System testing allows the testing of each component or module, interactions, the overall system, and user validation. This is to ensure that there are no bugs or errors and to generate performance tests for further development or improvements until the system is ready for release. Testing is conducted using the System Usability Scale (SUS), a questionnaire with 10 questions which prospective users answer on a 5-point scale after trying the application (Table 2). The score is obtained by calculating the score for each question (5). The resulting score serves as the basis for determining the category of the application testing that has been conducted (Table 3). Each stage must be fully completed before moving to the subsequent stage. Changes in requirements in the early stages require costly and time-consuming re-iterations (Figure 2).

$$\bar{X} = \sum_{i=1}^n \frac{x_i}{n} \quad (5)$$

where $\bar{X}$ is the average value, x_i is the respondent's score, and n is the number of respondents.

Table 3. Acceptance Categories

No	Score	Category	Ranking	Acceptance
1.	80-100	A	Very Good	Accepted
2.	70-79	B	Good	Accepted
3.	60-69	C	Fair	Repair Required
4.	50-59	D	Bad	Repair Required
5.	0-50	F	Very Bad	Declined

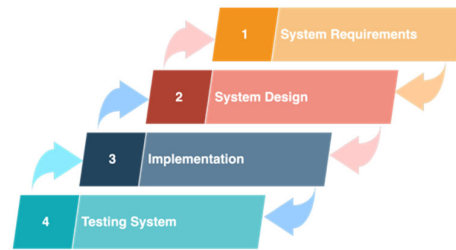


Figure 2. Waterfall Model

The development of an acceptable road segment performance analysis application enables computerized calculations. The results of the application calculations are then compared with the results of manual calculations. The difference in the calculation results serves as an indicator of errors that need to be corrected. The performance analysis of the road segments involves three road segments in Tangerang, a city in Banten Province, Indonesia, namely Pondok Jagung Timur Road, Rawa Kutuk Road, and Villa Melati Mas Raya Road. The selection of these three road segments is due to their role as connectors between urban areas, economic activity centers, residential areas, recreation centers, and business centers, characterized by high traffic volumes and complex traffic patterns in the buffer zone of DKI Jakarta Province. The absence of calculation discrepancies suggests that the developed application is used to analyze the performance of the three road segments.

Results and Discussion

Using the 2023 PKJI method, the identification produces manual performance analysis of road segments, but it has several limitations. The method requires complex calculations involving various parameters such as traffic volume, vehicle composition, and road geometry. This manual process is often time-consuming and prone to errors. Conventional systems are unable to provide real-time analysis or adequate data visualization. The accessibility of the available tools is also

limited for lay users. The 2023 PKJI-based application is proposed to address these issues. The application is designed to perform automatic calculations according to PKJI standards, including calculating saturation degree, free flow speed, and road service level. The system is equipped with comparative analysis features and interactive data visualization. The application is also designed with user-friendly principles and accessible through various platforms. Process speed and data security are other important aspects in the development of this application. The implementation of the application is expected to improve the efficiency of road performance analysis. Road performance analysis includes the calculation of traffic volume, road capacity, free flow speed, degree of saturation, and road service level. Manual calculations were conducted on three road segments in Tangerang. The three roads show differences in technical specifications despite all being classified as city roads. All three sections of the road have a shoulder width of 0.5 meters and are not equipped with a median. The data indicates a variation in road capacity, with Villa Melati Mas Raya Road having a greater capacity compared to the other two road segments (Table 4).

There is a fluctuation in traffic volume that varies depending on the observation time in the three roads. The total traffic volume experienced

a significant increase during peak hours (4:00 PM - 6:00 PM) with R3 reaching a peak of 1,303.4 vehicles/hour, while R1 and R2 recorded 581.5 and 356.3 vehicles/hour, respectively. Passenger cars (PC) dominated the traffic composition on all road segments with a contribution of more than 50% to the total volume. Heavy vehicles (KB) experienced a proportional increase over time on R3, reaching 62.4 vehicles/hour in the afternoon. The difference in traffic load between road segments indicates an uneven distribution of vehicle flow (Table 5).

The analysis of the performance of the three road segments in Tangerang uses four main parameters: road capacity, free flow speed, degree of saturation, and level of service. The road capacity (C) shows significant variation after adjusting the correction factor, with R3 reaching 1,615 pc/h even though it has the lowest basic capacity. The highest free flow speed (VB) was recorded on R3 at 57.85 km/h, far exceeding R1 (28.29 km/h) and R2 (31.00 km/h). The degree of saturation (D_j) revealed different operational conditions, with R3 at a level of 0.806, categorized as LOS D, while R1 (0.452) and R2 (0.255) were categorized as LOS A. This finding confirms that R3 experiences the highest traffic pressure despite having optimal capacity and speed, while R1 and R2 operate under relatively smooth conditions (Table 6).

Table 4. Road Geometric Data

No	Data	Pondok Jagung Timur Road	Rawa Kutuk Road	Villa Melati Mas Raya Road
1.	City	Tangerang	Tangerang	Tangerang
2.	Population	1.913 Million	1.913 Million	1.913 Million
3.	Status	City Road	City Road	City Road
4.	Type	2/2 TT	2/2 TT	4/2 T
5.	Road Width	5.0 meters	5.0 meters	10.0 meters
6.	Lane Width	2.5 meters	2.5 meters	5.0 meters
7.	Road Shoulder Width	0.5 meters	0.5 meters	0.5 meters
8.	Median	None	None	None
9.	Code	R1	R2	R3

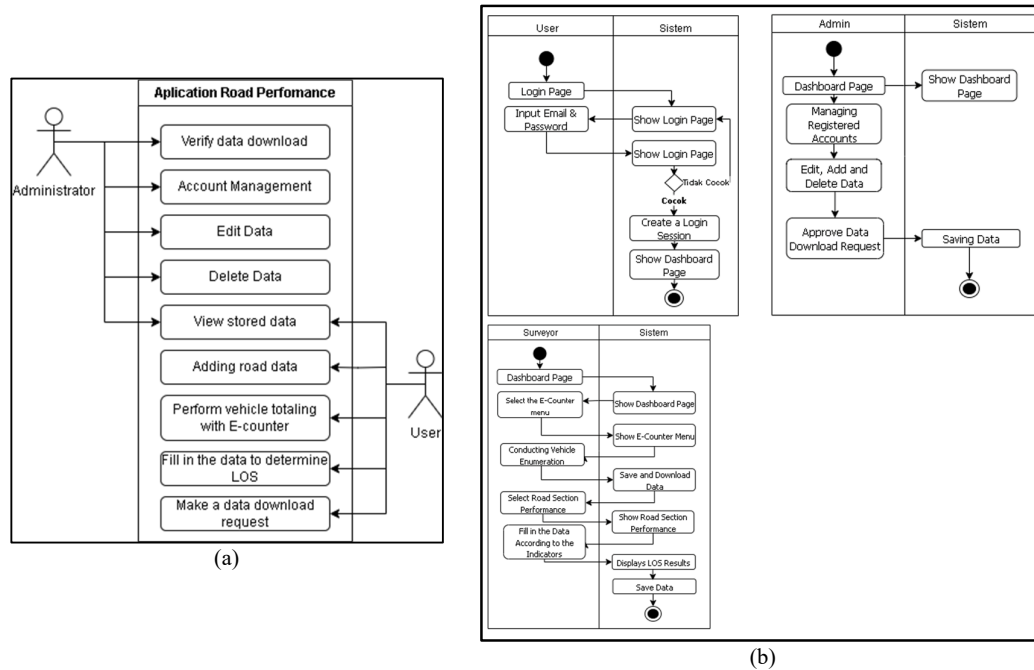
Table 5. Traffic Volume (Q)

No	Time	SM			MP			KB			Total		
		R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
1.	06.00-07.00	123.0	57.0	96.5	125.0	48.0	173.0	15.6	13.0	15.6	263.6	118.0	285.1
2.	07.00-08.00	125.5	62.5	121.7	128.0	53.0	221.0	15.6	14.3	20.4	269.1	129.8	363.1
3.	12.00-13.00	206.5	99.0	260.5	210.0	84.0	471.0	24.7	23.4	40.8	441.2	206.4	772.3
4.	13.00-14.00	187.5	87.5	283.7	191.0	74.0	513.0	23.4	20.8	44.4	401.9	182.3	841.1
5.	16.00-17.00	239.5	149.5	366.7	243.0	127.0	665.0	28.6	35.1	58.8	511.1	311.6	1090.5
6.	17.00-18.00	272.0	171.0	388.0	277.0	145.0	853.0	32.5	40.3	62.4	581.5	356.3	1303.4

Note: SM= Motorcycle, MP= Passenger Car, KB= Heavy Vehicles

Table 6. Road Capacity (C), Free Flow Speed (V_B), Degree of Saturation (D_J) and Level of Service (LOS)

No	Road	Correction Factor C					C	Correction Factor V_B				V_B	Q	D_J	LOS
		C_O	FC_{LJ}	FC_{PA}	FC_{HS}	FC_{UK}		V_{BD}	V_{BL}	V_{BHS}	V_{BUK}				
1.	R1	2800	0.56	1	0.82	1	1285	44	-9.50	0.82	1	28.29	581.5	0.452	A
2.	R2	2800	0.56	1	0.89	1	1395	44	-9.50	0.90	1	31.00	356.3	0.255	A
3.	R3	1700	1.08	1	0.88	1	1615	61	4.00	0.89	1	57.85	1303.4	0.806	D

**Figure 3. (a) Use Case Diagram (b) Activity Diagram**

Two main types of users in the road performance analysis application using the 2023 PKJI method are administrators and users, who have different roles in the system. The administrators have full authority to verify downloaded data, manage user accounts, edit and delete data, and view all stored data, while the users have limited access to view stored data, add new road segment data, perform vehicle calculations using the e-counter, fill in data to determine the LOS, and make data download requests. The features provided include integrated data management, automated road performance analysis, and a verified data download system (Figure 3(a)). The integrated process flow consists of the user process (login, validation, dashboard access), the admin process (login, verification, data management, download request approval, and data storage), and the surveyor process (login, e-counter, vehicle counting, data input according to the 2023

PKJI, LOS display, and data storage). The application has a strict authentication system, a structured workflow for each user, e-counter data integration for automatic calculations, implementation of the 2023 PKJI method for LOS determination, and a centralized data storage system (Figure 3 (b)). The application architecture consists of four main integrated classes: the user class for managing user authentication, the road data class for storing geometric road information, the e-counter class as an automatic vehicle counting system, and the road segment performance class as the core analysis that stores performance calculation results to determine LOS and capacity based on the 2023 PKJI. The integration of these four classes creates a comprehensive system that automates road segment performance analysis, from traffic counting data collection, geometric road data processing, to accurate LOS calculations according to the 2023 PKJI standards (Figure 4).

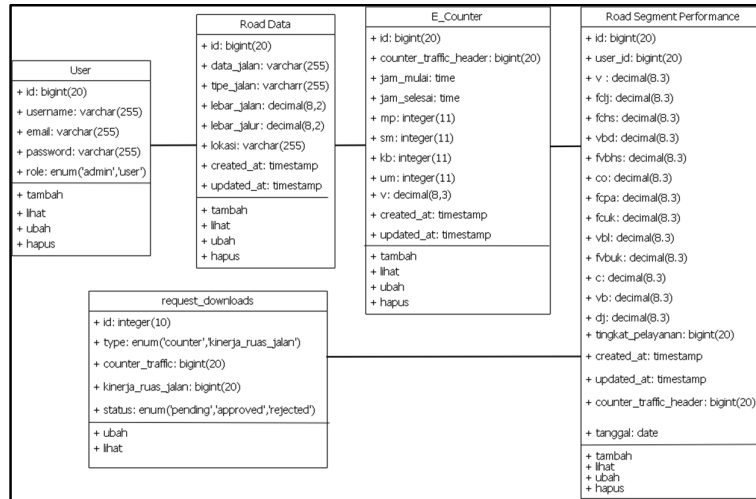
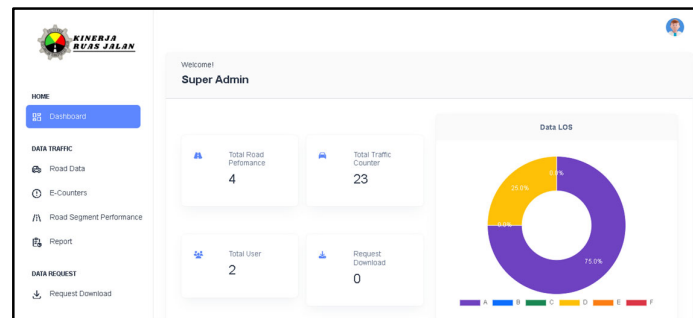


Figure 4. Class Diagram



(a)

(b)

(c)

Figure 5. Interface (a) Dashboard (b) E-counter (c) Road Section Performance Survey

The road segment performance analysis application using the 2023 PKJI method is built on a web-based platform. The application provides a comprehensive super admin dashboard with a responsive and user-friendly web interface equipped with a navigation menu that includes dashboard, traffic data (road code, e-counter, road segment performance), and report. The application also displays real-time statistics in the form of total

road data, total e-counter, total users, and pending e-counter in the form of informative cards and pie charts for LOS data visualization that can be accessed through a browser. The system features calculate e-counter traffic data, allowing users to collect traffic data online with start and end time settings for data collection, as well as an interactive manual counter for various types of vehicles that can be operated directly from the browser without

the need for special software installation. The road capacity feature provides a detailed and interactive input form for road capacity analysis based on the 2023 PKJI parameters and various correction factors, allowing users to calculate road capacity and LOS in real time (Figure 5). The advantages of the web-based application lie in its high accessibility, as it can be accessed from various devices through a web browser, ease of maintenance and centralized system updates, multi-user access capability with a secure login system, and real-time data integration among various users. This creates an efficient platform for analyzing road segment performance that can be collaboratively used by various stakeholders in transportation infrastructure management

The black box testing and usability testing are used to test the performance application for the three roads assessed. The black box testing was carried out by actors (administrators and surveyors) with each person carrying out one experiment. The results from the black box testing for the administrators and surveyors were 100% valid for both the test class and test items, which yielded 16 results (Table 7). Testing using the System Usability Scale (SUS) involves the director and employees of the ANDALALIN Division at PT Dewari Citraloka Indonesia. The test involved 12 respondents, and the questionnaire was distributed via Google Forms. The responses from the 12 respondents were analyzed and calculated, resulting

in a score of 87. The number falls within the A predicate range, which can be interpreted as the application being usable well, as shown in Equation (6). SUS respondents consisted of transportation sector professionals who could provide credible and relevant feedback. The sample size was adequate for initial validation and usability testing, which may limit the generalizability of the findings to broader contexts. Coverage of more diverse road segments and user groups could have increased the reliability of the method.

$$\text{Nilai } \bar{x} = \frac{1055}{12} = 87 \quad (6)$$

The comparison of calculations between the manual method and the application for analyzing road segment performance using the 2023 PKJI method shows a perfect accuracy level with a difference value of 0.0 for all calculation parameters on the three tested road segments (R1, R2, R3) (Table 8). The results confirm that the web-based application has successfully implemented the 2023 PKJI calculation algorithm accurately and reliably. The application can be used as a tool for accurately, efficiently, and consistently analyzing road segment performance compared to manual calculations, which take longer duration of time and are prone to human error. The application can be used with high confidence for road segment performance analysis in transportation engineering practices.

Table 7. Black Box Testing

No	Actor	Test Class	Test Items	Results
1.	All Actors	Display the website's main page	Website main page display	Valid
2.	All Actors	Login	Verification	Valid
3.	All Actors	Display the actor's dashboard page	Dashboard	Valid
4.	All Actors	Display the e-counter page	e-counter page display	Valid
5.	All Actors	Display the road section performance page	Road section performance page display	Valid
6.	Administrators	Display the download request page	Request download page display	Valid
7.	Administrators	Display the user page	User page display	Valid
8.	All Actors	Display the website information	Website information page display	Valid
9.	All Actors	Display the usage procedures	Procedures page display	Valid
10.	Administrators	Delete data	Successful data deletion	Valid
11.	Administrators	Edit data	Successful data editing	Valid
12.	All Actors	View data	Data viewing display	Valid
13.	All Actors	Download data	Successful data download	Valid
14.	Surveyors	Add and subtract numbers in the e-counter feature	Number increases and decreases	Valid
15.	Administrators	Verify download requests	Download request is successfully verified	Valid
16.	Surveyors	Calculate road section performance results	Calculation results are successfully displayed	Valid

Table 8. Traffic Volume (Q)

No	Road	Q			C			VB			D _i			LOS		
		Man	App	Dif	Man	App	Dif	Man	App	Dif	Man	App	Dif	Man	App	Dif
1.	R1	581.5	581.5	0.0	1285	1285	0.0	28.29	28.29	0.0	0.452	0.452	0.0	A	A	Equal
2.	R2	356.3	356.3	0.0	1395	1395	0.0	31.00	31.00	0.0	0.255	0.255	0.0	A	A	Equal
3.	R3	1303.4	1303.4	0.0	1615	1615	0.0	57.85	57.85	0.0	0.806	0.806	0.0	D	D	Equal

Note: Man=Manual, App=Application, Dif=Difference

For the Pondok Jagung Timur road section, the application successfully made a comprehensive calculation by systematically displaying all road performance parameters in detail. The road capacity calculation shows a basic capacity (C_0) of 2800.000, with applicable correction factors applied, such as traffic lane width ($FC_{LV} = 0.560$), capacity due to PA on undivided road type ($FC_{PA} = 1.000$), side resistance ($FC_{HS} = 0.820$), and capacity for city size ($FC_{UK} = 1.000$), resulting in a final capacity (C) of 1285.760. The calculation of free flow speed starts from the basic free flow speed (V_{BD}) of 44.000 km/h, with applicable correction factors, including basic free flow due to effective traffic lane or lane width ($V_{BL} = -9.500$), free flow resistance due to side obstacles ($FV_{BHS} = 0.820$), and city free flow speed due to city size for passenger cars (MP) ($FV_{BUK} = 1.000$), resulting in a free flow speed (V_B) of 28.290 km/h. The application calculates the degree of saturation (D_j) at 0.452, which falls into the LOS A category with the description 'Free flow with low volume and high speed. Very low traffic density, drivers can choose the desired speed.' (Figure 6).

The results of the performance analysis of Rawa Kutuk Road from the developed application

indicate a basic capacity of 2,800 vehicles per hour, adjusted to various correction factors including lane width ($FC_{LV} = 0.560$), directional separation condition on undivided roads ($FC_{PA} = 1.000$), side friction ($FC_{HS} = 0.890$), and city size ($FC_{UK} = 1.000$), resulting in an effective capacity of 1,395.52 vehicles per hour. The actual recorded traffic volume was 356.30 vehicles per hour, with a degree of saturation reaching 0.255 or 25.5%, indicating very low road utilization. The free flow speed was calculated at 31.05 km/h after considering the base speed of 44 km/h with corrections for effective lane width (-9.5 km/h), side friction ($FV_{BHS}=0.900$), and city factor ($FV_{BUK}=1.000$). These operational conditions classify the road in the LOS A category, which represents free-flowing traffic conditions with low volume and high speed. Very minimal traffic density and full flexibility for drivers to choose their desired travel speed without experiencing obstacles or disruptions from other vehicles. This reflects the ideal conditions for vehicle mobility on that road segment according to the analysis standards set forth in the 2023 PKJI (Figure 7).

Road Capacity		Free Flow Speed	
Basic Capacity (C_0)	2800.000	Basic Free Flow Speed (V_{BD})	44.000
Traffic Lane Width Correction Factor (FC_{LV})	0.560	Basic Free Flow Speed Correction Due to Effective Traffic Lane or Lane Width (V_{BL})	-9.500
Capacity Correction Factor Due to PA on Undivided Road Type (FC_{PA})	1.000	Free Flow Resistance Correction Factor Due to Side Obstacles (FV_{BHS})	0.820
Side Resistance Correction Factor (FC_{HS})	0.820	City Correction Factor Free Flow Speed Due to City Size For Vehicle Type MP (FV_{BUK})	1.000
Capacity Correction Factor for City Size (FC_{UK})	1.000		
$C = (C_0) \times (FC_{LV}) \times (FC_{PA}) \times (FC_{HS}) \times (FC_{UK})$		$V_B = (V_{BD} + V_{BL}) \times FV_{BHS} \times FV_{BUK}$	
C = 1285.760		$V_B = 28.290$	
Degree of Saturation		Conclusion	
Volume (V)	581.500	Category	A
Road Capacity (C)	1285.760	Description	Free flow with low volume and high speed, Very low traffic density, drivers can choose the desired speed.
$D_j = q / C$			
$D_j = 0.452$			

Figure 6. Interface of Analysis Results for Pondok Jagung Timur Road

Road Capacity		Free Flow Speed	
Basic Capacity (C_0)	2800.000	Basic Free Flow Speed (V_{BD})	44.000
Traffic Lane Width Correction Factor (FC_{LV})	0.560	Basic Free Flow Speed Correction Due to Effective Traffic Lane or Lane Width (V_{BL})	-9.500
Capacity Correction Factor Due to PA on Undivided Road Type (FC_{PA})	1.000	Free Flow Resistance Correction Factor Due to Side Obstacles (FV_{BHS})	0.900
Side Resistance Correction Factor (FC_{HS})	0.890	City Correction Factor Free Flow Speed Due to City Size For Vehicle Type MP (FV_{BUK})	1.000
Capacity Correction Factor for City Size (FC_{UK})	1.000		
$C = (C_0) \times (FC_{LV}) \times (FC_{PA}) \times (FC_{HS}) \times (FC_{UK})$		$V_B = (V_{BD} + V_{BL}) \times FV_{BHS} \times FV_{BUK}$	
C = 1395.520		$V_B = 31.050$	
Degree of Saturation		Conclusion	
Volume (V)	356.300	Category	A
Road Capacity (C)	1395.520	Description	Free flow with low volume and high speed, Very low traffic density, drivers can choose the desired speed.
$D_j = q / C$			
$D_j = 0.255$			

Figure 7. Interface of Analysis Results for Rawa Kutuk Road

Road Capacity		Free Flow Speed	
Basic Capacity (C_0)	1700.000	Basic Free Flow Speed (V_{80})	61.000
Traffic Lane Width Correction Factor (FC_{LW})	1.080	Basic Free Flow Speed Correction Due to Effective Traffic Lane or Lane Width (V_{80L})	4.000
Capacity Correction Factor Due to PA on Undivided Road Type (FC_{PA})	1.000	Free Flow Resistance Correction Factor Due to Side Obstacles (FV_{BHS})	0.890
Side Resistance Correction Factor (FC_{HS})	0.880	City Correction Factor Free Flow Speed Due to City Size For Vehicle Type MP (FV_{BUK})	1.000
Capacity Correction Factor for City Size (FC_{UK})	1.000		
$C = (C_0) \times (FC_{LW}) \times (FC_{PA}) \times (FC_{HS}) \times (FC_{UK})$		$V_0 = (V_{80L} + V_{80L}) \times FV_{BHS} \times FV_{BUK}$	
$C = 1615.000$		$V_0 = 57.850$	
Degree of Saturation		Conclusion	
Volume (V)	1303.400	Category	D
Road Capacity (C)	1615.000	Description	The flow is approaching unstable with high traffic volume and low speed. Traffic is still tolerable but is greatly affected by changes in flow conditions. Traffic density is moderate but fluctuations in traffic volume and temporary obstacles can cause lar
$D_s = q / C$			
$D_s = 0.806$			

Figure 8. Interface of Analysis Results for Villa Melati Mas Raya Road

The results of the performance analysis of Villa Melati Mas Raya Road from the application indicate a basic capacity of 1,700 vehicles per hour, adjusted with various correction factors including lane width ($FC_{LW} = 1.080$), directional separation conditions on undivided roads ($FC_{PA} = 1.000$), side friction ($FC_{HS} = 0.880$), and city size ($FC_{UK} = 1.000$), resulting in an effective capacity of 1,615 vehicles per hour. The actual recorded traffic volume is 1,303.40 vehicles per hour, with a degree of saturation of 0.806 or 80.6%, indicating very high road utilization and approaching the maximum capacity limit. The free flow speed is calculated at 57.85 km/h, considering a base speed of 61 km/h with positive corrections due to effective lane width (+4 km/h), side friction ($FV_{BHS} = 0.890$), and city factor ($FV_{BUK} = 1.000$). These operational conditions classify the road in the LOS D category, indicating that the traffic flow is approaching an unstable condition with high traffic volume and low speed. Traffic is still tolerable, but it is highly affected by changes in flow conditions, moderate traffic density, and fluctuations in traffic volume and temporary obstacles, which can cause congestion. This indicates road conditions that require special attention in traffic management according to the analysis standards set forth in the 2023 PKJI (Figure 8).

A comprehensive analysis of the three road segments revealed a spectrum of operational characteristics that reflect the complexity of Indonesia's urban road infrastructure challenges with varying degrees of severity. Pondok Jagung Timur Road exhibits the most problematic condition, with significant side barriers due to weak access controls, illegal parking, street vendors, and disorderly pedestrian crossings. Inadequate lane widths prevent optimal vehicle operation and reduce operational speeds (Kiede *et al.*, 2023), and high traffic conflicts from the mixing of fast and

slow-moving vehicles (Rivera-Royero *et al.*, 2022). Rawa Kutuk Road has the best operational characteristics, with minimal side barriers, although reduced capacity indicates a mismatch between lane width standards and operational needs (Batto *et al.*, 2022; Cao *et al.*, 2023). Very low saturation levels indicate substantial spare capacity (Isradi *et al.*, 2022; Mufhidin *et al.*, 2022). Villa Melati Mas Raya Road is in critical condition, with high saturation levels creating vulnerability to traffic disruptions (Hafram & Asrib, 2022). High traffic volumes create unstable flow conditions (Rivera-Royero *et al.*, 2022), and significant side barriers require improved road environmental management (Kiede *et al.*, 2023). These conditions indicate systemic problems in Indonesia's urban road infrastructure, with transportation functions degraded by uncontrolled multi-use (Feng *et al.*, 2023). A holistic approach through improved design, traffic regulation, and enforcement is consistent with evaluating network development priorities and reallocating resources to high-capacity segments (Li *et al.*, 2023).

The operational conditions of urban roads exhibit diverse and interconnected characteristics within the regional transportation system (Hafram & Asrib, 2022). Geometric factors, particularly lane width and side barriers, are key determinants of effective capacity and operational performance. Reduced capacity indicates a mismatch between design standards and vehicle operational needs (Rivera-Royero *et al.*, 2022). Variations in saturation levels reflect the uneven distribution of traffic loads within the urban road network (Feng *et al.*, 2023). This requires strategies tailored to the characteristics of each segment (Batto *et al.*, 2022; Isradi *et al.*, 2022) through geometric design optimization, side barrier control, and the implementation of traffic demand management to

achieve a balance between infrastructure and sustainable mobility.

The proposed web-based road performance analysis application using the 2023 PKJI method has significant functional advantages over existing road performance analysis applications. The application provides cross-platform access via a browser with a responsive super admin dashboard equipped with an integrated navigation menu and real-time data visualization in the form of informative cards and pie charts for LOS analysis, distinguishing it from the KAJI application which is limited to the Android platform with a non-user-friendly DOS interface (Ahmed *et al.*, 2023). International HCM applications use foreign standards that are not suitable for Indonesian conditions, while the proposed application implements the latest national standards with the calculate e-counter traffic data feature that allows real-time online traffic data collection, automatic start-end time settings, and interactive manual counters for various vehicle types without additional software installation.

The developed 2023 PKJI application can provide a layered authentication system with differentiated user management between administrators and surveyors, enabling more granular access control compared to the 1997 MKJI manual system that lacks multi-user features (Hafram & Asrib, 2022). The road capacity analysis feature with interactive input forms for the 2023 PKJI parameters and correction factors produces perfect calculation accuracy (0.0 difference) on all parameters, which is different from conventional systems that are prone to manual calculation errors. The integrated four-class architecture (user, road data, e-counter, road segment performance) creates a comprehensive automated system that other applications do not have, with efficient multivariable analysis capabilities and centralized data management that supports transportation stakeholder collaboration (Cao *et al.*, 2023; Li *et al.*, 2023).

The integration of the Internet of Things (IoT) and machine learning (ML) enables automated, real-time data flow on traffic volume, vehicle classification, and average speed into application databases. Standardized datasets from IoT networks create unprecedented resources for predictive analytics. ML models can predict short-term congestion, estimate changes in LOS due to urban development, and simulate the impact of interventions before implementation. The platform evolves from manual surveys to real-time monitoring dashboards that enable transportation authorities to detect congestion and proactively manage traffic, transforming descriptive analytics

tools into prescriptive decision support systems for sustainable urban transportation planning.

Conclusions

The web-based road performance analysis application using the 2023 PKJI method has been successfully developed using the waterfall development model with perfect accuracy (difference = 0.0) for all calculation parameters. This was proven through the black box testing with 100% validity and a System Usability Scale (SUS) score of 87 in category A. The implementation of the application on three road segments in Tangerang City revealed diverse operational characteristics, namely Pondok Jagung Timur and Rawa Kutuk roads with service level A (degree of saturation of 0.452 and 0.255), while Villa Melati Mas Raya road achieved service level D with a critical saturation degree of 0.806, requiring immediate traffic management intervention. The application successfully overcomes the limitations of manual methods that require an extended duration and are prone to human error by providing a comprehensive, user-friendly solution that can be accessed through various devices. As a result, it can make a significant contribution to the digitalization and standardization of road performance analysis, which can be widely implemented in transportation engineering practices to achieve a sustainable balance between infrastructure supply and mobility demand in urban transportation systems. The development of integration with the Internet of Things (IoT) systems and machine learning technology to enable more comprehensive predictive analysis and real-time monitoring in managing urban road network performance is a potential area for further research.

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Author Contributions

Conceptualization: R.A., J.S.; Methodology: R.A., R.P.; Investigation: J.S., R.P.; Data Curation: R.A.; Writing - Original Draft: R.A.; Writing - Review & Editing: R.A., J.S., R.P.; Supervision: J.S. All authors have read and agreed to the published version of the manuscript.

Ethics Statement

Ethical approval was not required for this study because it did not involve human participants, animals, identifiable personal data, or materials requiring institutional ethical review.

Declaration of Generative AI Use

The authors used ChatGPT (OpenAI) for language editing and coding assistance. All outputs were manually verified and revised by the authors.

Conflict of Interest

The authors declare that they have no conflicts of interest related to this work.

Data Availability Statement

All data are available from the authors.

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