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Original Article

Design and Implementation of Road Performance Assessment: Android-Based Application

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Abstract - *The Ministry of Public Works and Housing continues to make efforts to maintain road performance by carrying out road maintenance on an ongoing basis so that it is hoped that the critical role of roads can still run optimally and the target of improving connectivity can be achieved. Problems that often occur in the assessment of the performance of road segments that present the condition of road pavements, road shoulders, and drainage that require convenience in monitoring the performance of practical national road segments so that design and implementation are needed in the form of android-based applications using the system design method/prototype which is continued by system design using UML (Unified Modelling Language) and Databases and technical data collection on each section. As for the results of the analysis of this application design, the formation of the e-RSeP (Road segment performance) application has been tested on the national road segment of Central Java-Yogyakarta Province, with the RPPV presented from the IRI value, RPPV of 58.1%, RShsPV of 20.2%, and RDP value of 21.7% of these values indicate that pavement performance has the most significant value in assessing section performance. In addition, this application helps users monitor the performance achievements of sections easily and practically*.

Keywords - *Road performance, Pavement, Shoulder, Drainage, Android.*

1. Introduction

The Directorate General of Highways or abbreviated as the Director General of Bina Marga (2020) [12] in 2024, has a target to improve connectivity by realizing the dominance of the national road network, which has a travel time of under 2.0 hours / 100 km has an average speed of around 50 km/hour. The government, in this case, the Ministry of Public Works and Public Housing, continues to strive to maintain road performance with road preservation activities, one of which is sustainable road maintenance under the critical role of roads that run optimally and achieve connectivity improvement targets. As for the road performance indicators, one of them is the road stability value produced from analysis calculations that use the level of the road surface or called the *International Roughness Index* value IRI. Moreover, to determine the percentage value of the damage limit of a road using asphalt cover or cement concrete. According to the provisions of the IRI value range is shown in the table 1.

Table 1. The evaluation of the condition of asphalt/cement concrete-coated roads. (*Ministrerial Regulation of PUPR No.13/PRT /M/2011, 2011*) [21]

No.	IRI Value (m/km)	Condition Criteria	Maintenance Program
1	< 6	Good (G)	Routine Maintenance
2	6-<11	Moderate (M)	Routine Maintenance
3	11-<15	Small Damage (SD)	Periodic Maintenance
4	15>	Heavy Damage (HD)	Reconstruction/Structures Improvement

Currently, the performance of road pavements can be seen based on the SDI (Surface Damage Index) value, IRI value, and pavement structure value. In assessing the performance of road pavements, it must be free from indicators of the type of pavement damage, including road subsidence, cracking of road segments, road potholes, uneven -resurfacing, ruts or *rutting*, as for the value of the road pavement performance, which consists of the IRI, SDI, and Structural values of the Road Pavement.

Long segment performance assessment is carried out on the fulfilment of indicator values consisting of road performance indicators, including road pavement, shoulders, road equipment, drainage, complementary buildings, and plant control. The research of Halomoan et al. (2018) [17] in their study how the influence of components on the

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performance/performance of segments using the data collection method by conducting interview surveys and filling out questionnaires analyzed using the *Structural Equation Modeling (SEM)* method and obtained the value of the road pavement component which contributed 32%, the shoulder component by 21%, and the drainage component contributed 20% to the performance assessment of the road segment, where the element plays a vital role in road performance, capacity and road safety.

Dimpal and Truph (2014) [11] describe the current possible road roughness conditions, namely by using smartphone sensors where the use of data is explored directly by smartphones for maintenance handling needs and road programming as information on road surface conditions using accelerometer, microphone, radio sensing components. GSM and GPS sensors aim to improve traffic safety. In addition, other studies also explain that to estimate and classify surface conditions based on the level of road roughness, you can use a scheduling algorithm for proactive maintenance activities using IRI values as data support in the use of this system efficiently and economically for estimating road conditions with excess processing time. Brief with high flexibility for implementation due to its small size Akindele P et al. (2017) [3]. Another thing is creativity in carrying out a detection approach and using road damage based on two-dimensional (2D) and three-dimensional (3D) image recognition using a monocular camera, but an expensive vision-based system that requires high processing, which is also limited by the level of available lighting and weather conditions [20]. Li et al. (2009) introduced a system to detect road damage, such as potholes, etc., using laser scanning equipment and digital cameras [22].

The previous research described earlier only presented how the influence of each component of road equipment and complementary buildings and plant control components turned out to affect road performance but not significantly [17]. This research has yet to provide an overview of how models and applications of road shoulder and road drainage performance assessment are expected to be useful for shoulder and road drainage performance evaluation. Moreover, other research explains how to estimate road damage conditions with breakthroughs in several systems, both smartphone and accelerometer sensor systems, as well as digital cameras. Still, it does not yet support how to assess road performance to facilitate the selection process for handling road damage. Assessment of the quality of a road is critical in infrastructure management that is useful for adequate road maintenance operational allocation activities and has now informed the road user about the actual condition of the road starting from road damage, potholes, bumps, and other significant damage so that the transportation system remains safe, efficient and comfortably under control [30][33].

Various methods of monitoring road conditions have been used. However, for performance appraisal, they are still not significant for components and assessment systems that facilitate the assessment process, so an alternative is needed to provide solutions to overcome problems in assessing road performance which represents the condition of road pavement, shoulders, and drainage to facilitate effective monitoring of the performance of national road sections as a support for the needs of road preservation and construction implementation programs. From this, this study will design an application system based on a mobile application to facilitate monitoring of the performance of national roads based on several indicators that have been tested using the SEM method analysis. Following the opinion of Vittorio Astaria et al. (2012) [5] in their research, it is necessary to realize that a simple application that is easy to install on smartphone devices and allows users to monitor the quality of performance from the road surface [4] by raising the problem based on the background previously described, namely how to design and implement an Android-based application that can be reached and used by smartphone users as a convenience for information regarding the performance of roads, shoulders, and road drainage. The development of section performance assessment with an Android-based application (mobile application) is significant for making it easier for all road section PPKs to carry out monitoring by calculating section performance easily and practically. Pavement condition and its preservation relation showed in Figure 1, while this research gap showed in Figure 2.

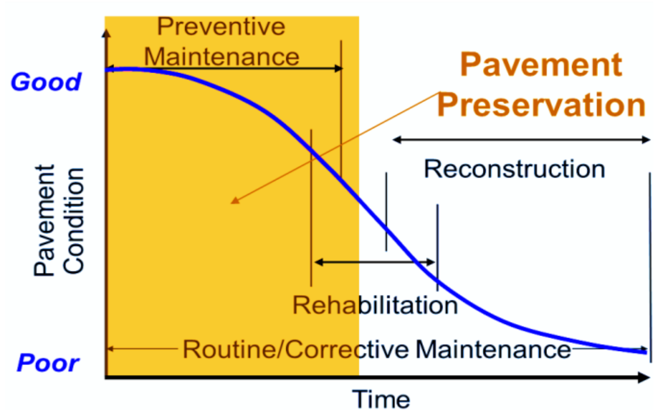


Fig. 1 Pavement Condition vs Pavement Preservation Relation [17]

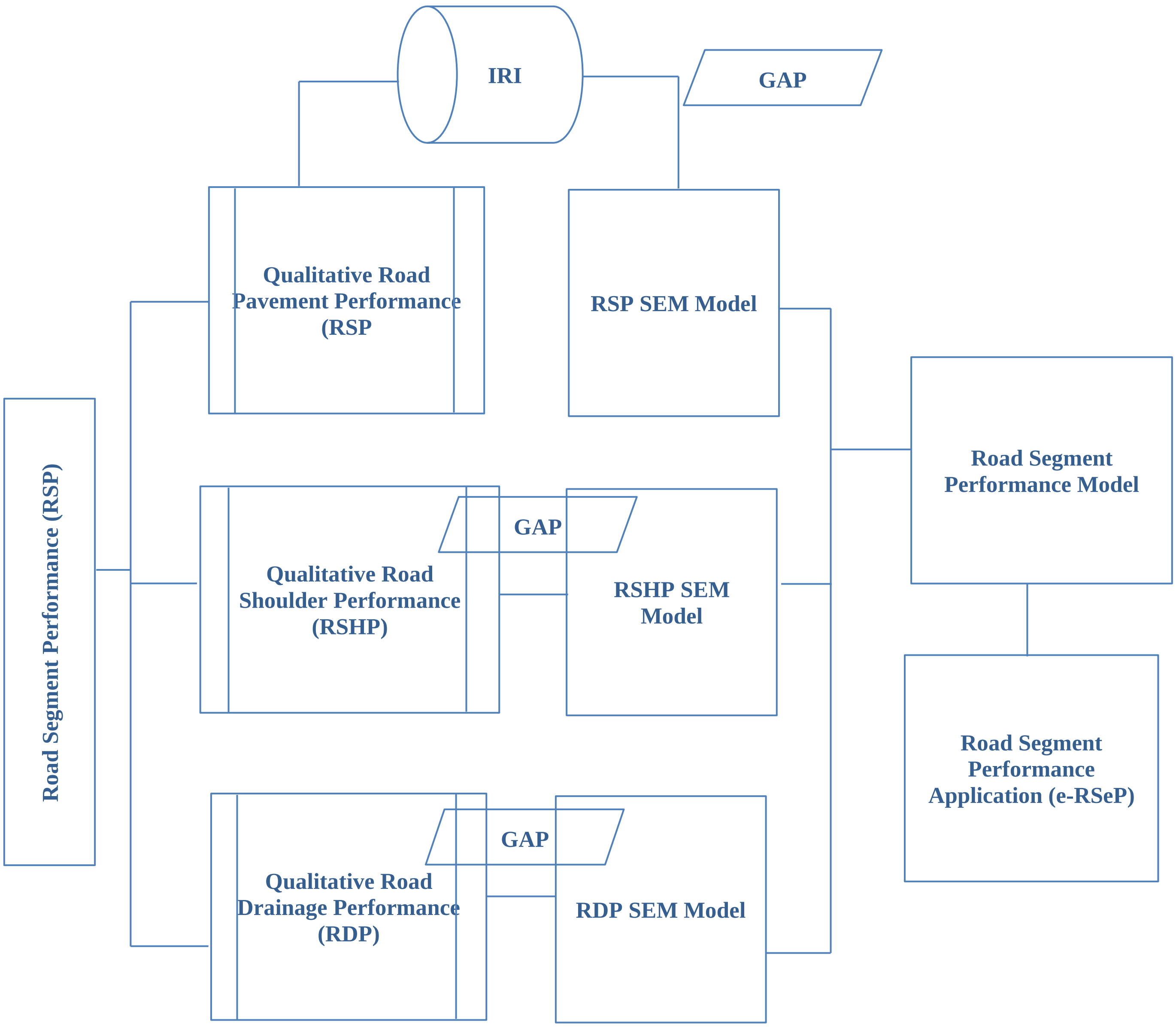


Fig. 2 Research Gap

2. Literature Review

2.1. Road Pavement Performance

Road pavement is one of the many critical indicators in assessing road segment performance. In Roza and Sriono's research (2020) [26] on how road components affect the performance of road segments. They used the data collection method by conducting interview surveys and filling out questionnaires which were analyzed using the *Structural Equation Modeling (SEM)* strategy, resulting in the road pavement components that contributed the most to the achievements of a percentage of 32% of the performance value of sections compared to drainage components, shoulders, road fittings and complementary buildings and plant control. The components referred to in the performance assessment of road segments include: a) road pavement components have an essential influence on the performance of road segments; b) road shoulder components and drainage components are also components of the type damage to the performance of road segments.

According to Vhendi, Andri, and Isradi (2022) in their research on how to analyze road performance in the city of Batam, Indonesia, which uses quantitative analysis by collecting and evaluating statistical numerical data results that segment performance which is a measure that describes the condition of the road segment, in general, can be seen from the capacity and saturation of the road indirectly the higher the number it will affect the performance of the pavement. [23].

Road pavement is part of a road network that requires maintenance, and management requires limited data sources. The road has the hope that the performance of the road infrastructure is always at the top level during its service life. In addition, the authorities themselves have hopes that the performance of this road can be achieved with resources. However, it is known to have unavoidable contradictions that make it attractive enough to be a problem and feel challenging. In this study, the IRI method was used with a roughness evaluation machine using low-cost instrumentation, in this case, using an indicator of cost.

However, in determining its maintenance, it still uses the priority scale used in the IRI condition roughness index for each span, for example, in the 1 Gudlavalleru-Chitram span with a rating value of 40% along 7.2 m/km, which suggests an overlay design and the 2nd Gudlavaller-Penjandra span with rating value of 90% along 6.9 m/km with recommendations for maintenance. This proves that this method can be used as supporting data in evaluating pavement performance. [27].

2.2. Road Shoulder Performance

The research by Sutradhar and Pal (2020) stated that the main factors affecting the performance of road shoulder pavements include shoulder width, compaction, the slope of the road shoulder, differences in the height of the edge of the road shoulder that does not comply with the provisions, areas covered by vegetation, and surface depression. This shows that the components of the road shoulder are not only influenced by internal factors, such as the quality of the materials used and the installation technique but are also influenced by external factors, such as the width of the road shoulder, compaction, the slope of the road shoulder, the difference in the height of the edge of the shoulder. [25].,

Sutradhar and Pal's research (2020) stated that the main factors that affect the performance of road shoulder pavements, including road shoulder width, compaction, road shoulder slope, differences in road shoulder height that are not in accordance with the provisions, areas covered by plants, and *surface depression* This shows that road shoulder components are not only influenced by internal factors, such as the quality of the materials used and installation techniques, but it is also influenced by external factors, such as road shoulder width, compaction, road shoulder slope, road shoulder height difference, an area covered by vegetation, and *surface depression* [29].

In addition, according to Al-Suleiman and Gharaybeh (1997), carrying out road shoulder maintenance using subjective and objective methods that are influenced by several factors that have been analyzed can provide benefits with the highest level for shoulders that use asphalt rather than those that do not use asphalt. Based on the primary survey, it was found that the condition of the road shoulder at any time was much better compared to the secondary road [1]. According to Dachlan (2019), the damage on the edges of the pavement of a road and the shoulder area is due to the height difference. Its condition, shape and dimensions influence this road shoulder's performance, requiring treatment recommendations [8].

2.3. Drainage Performance

Drainage is a system that drains water flowing over the road surface so there is no cladding or flooding on the road. The performance value of the percentage of road drainage stability is a measure that shows how well the road drainage system can perform its function, which is to drain water flowing over the road surface so that there is no cladding or flooding on the road. The higher the performance value of the percentage of road drainage stability means that the drainage system is better at performing its functions. The performance value of the percentage of road drainage stability could be higher, meaning that the drainage system is less effective in draining water and can cause damage to road pavements.

In the research of Zain et al. (2012), problems in poor drainage systems must be identified on roads where routine repairs and maintenance are carried out. It is necessary to evaluate the condition of the drainage itself in a city; in this study, data were collected from three locations around the city of Amman by inspecting visually with documentation that was assessed based on the rating system for drainage roadways that produce more than 60% on roads in locations determined to have problems in poor drainage conditions that have a significant impact on the environment. This makes the evaluation serve as a reference for regional decision-makers in assisting in planning drainage system maintenance activities with recommendations on managing the problem [2].

Several studies have investigated the condition of the drainage systems of different parts of the country [7,21,25]. A poor drainage system is also a concern for the environment, for example, in the condition of the roadside drainage network in the Ahmadu Bello University, Zaria area, most of which 75% of the drainage system network in this region has poor ratings due to erosion on the shoulder of the road, there are holes, clogged drains sewers, puddles in the streets. It is necessary to carry out recommendations for handling in full with appropriate maintenance policies (Nkeleme I. E et al., 2020) [15]. Walker et al. (2000) said that the most crucial part of carrying out routine evaluations of drainage systems is maintaining and managing highways [7].

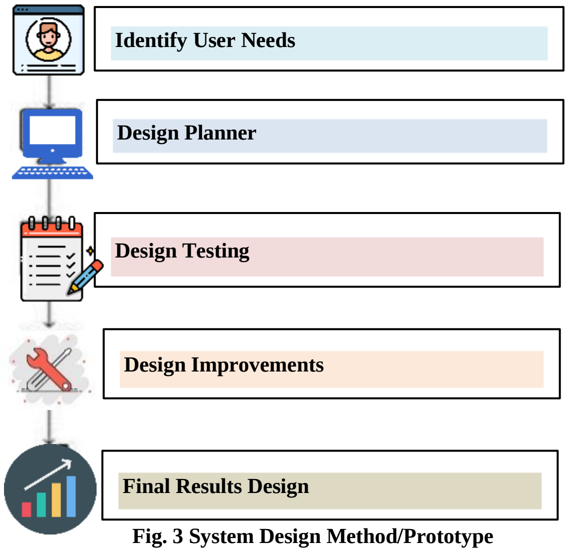


Fig. 3 System Design Method/Prototype

2.4. Android-Based Mobile Application

According to Turban, a mobile application is a term often used in describing applications on the internet that are widely used on smartphones. The preparation of this application is based on a program consisting of rows of commands or instructions made that are easily understood by the computer language, which is then run in a row of numerical calculations lined up in commands, infinity, ends and produces output. To run these commands requires a commonly used programming language, namely Android, an open-source Operating System (OS) system that everyone can use. Android is also most often used on smartphones with increased applications in operating systems with two programming languages: Java and Hyper Test Markup Language / HTML.

In the research of Zain et al. (2012), problems in poor drainage systems must be identified on roads where routine repairs and maintenance are carried out. It is necessary to evaluate the condition of the drainage itself in a city; in this study, data were collected from three locations around the city of Amman by inspecting visually with documentation that was assessed based on the rating system for drainage roadways that produce more than 60% on roads in locations determined to have problems in poor drainage conditions that have a significant impact on the environment. HTML From the research of Mohammad J, Hua G Z, and Beijing Z (2016) evaluation of the navigation performance of GPS devices near intersections, this is a navigation application that can be used on smartphones to identify existing and potential problems regarding the movement of road users, especially on turning roads. [4]. Based on a comprehensive and existing literature review (Engelhardt, M., Bain, L.J., and Blumenthal, S., 1992) (Hernán de Solminihac et al., 2009), (Hidayat, R., Setiyadi, S., and Hutabarat, L.E., 2021), it can be noted that the use of analytical methods used in determining pavement,

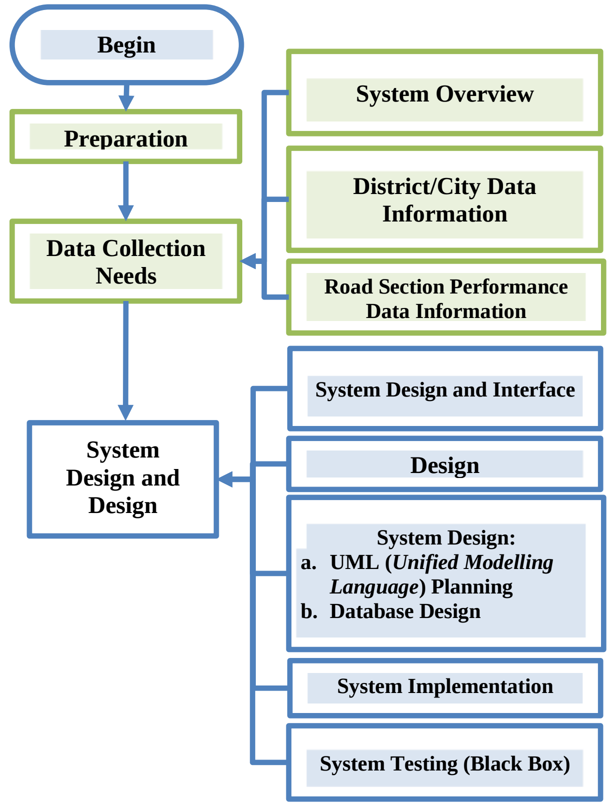


Fig. 4 E-RSEP Application Design Flowchart

- drainage and road shoulder conditions has not yet focused or ended with application in the form of a mobile application that makes it easier for users, in this case, the actors involved in assessing segment performance [17,18,31].

3. Research Methods

3.1. Road Segment Performance Value (RSePV) Model Design

Road Segment Performance Value (hereafter called an RSePV) is an analysis model designed for the form of a mobile application. This model calculates the performance of road segments according to the modeling formula designed through the programming language, originally referred to using the Structural Equation Modeling (SEM) concept. This modeling application uses the prototyping development method, which is software development focusing on aspects of design, function and interface. The Evolutionary prototype used as a model in this performance application project was broadly designed with reference to the Evolutionary Prototype model (RM Roth, BH Wixom and A Dennis, 2019) [10]. This research was motivated by differences in the performance indicators of road conditions. These indicators were the basis for planning the road maintenance programs, which were in line with those set by the Director General of Highways in the 2018 General Specifications, Revision 2 (2020), Divi-sion-10, as standard road maintenance. In Division-10 General Specifications for Highways, 6 (six) road components must be fulfilled based on the indicators, namely pavement components, shoulders, drainage and road equipment, and plant control from both the left and right sides of the road [12].

Figure 5 following is the Full Model SEM of RSePV.

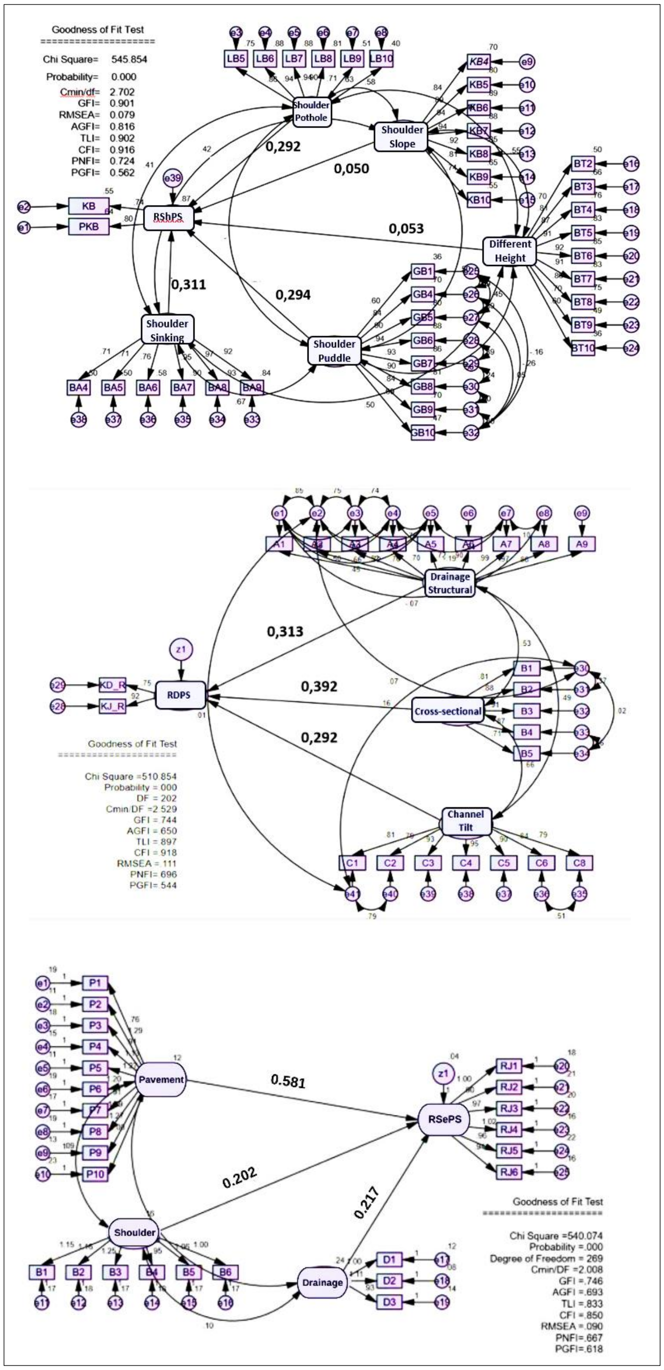


Fig. 5 Full Model SEM of RSePV

The following is an analysis of calculations on the e-RSeP model using the formula derived from the research:

The model of the Road Segment Performance assessment is:

$$RSePV = \{(0,581.\ RPPV) + (0,202.\ RShPV) + (0,217.\ RDPV)\} \quad (1)$$

Where:
RSePV = Road Segment Performance Value
RPPV = Road Pavement Performance Value from IRI
RShPV = Road Shoulder Performance Value
RDPV = Road Drainage Performance Value

$$RSePV = \{(0,581.RPPV) + (0,202.\ (100 - \{0,311.BA + 0,294.GB + 0,292.LB + 0,053.BT + 0,050.KB\})) + (0,217.(100 - \{0,392.PS + 0,313.SD + 0,292.KS\}))\} \quad (2)$$

Where:
BA = Area of collapsed shoulder/total segment area (m2)
GB = Area of standing water on the shoulder of the road/total area of the segment (m2)
LB = Area of hole on road shoulder with a diameter of > 20 cm/total area of segment (m2)
BT = Length of road shoulder elevation difference and pavement edge, which is more than 5 cm/total length of the segment (m)
KB = Length of the slope of the road shoulder outside the range of 4-6%/total segment area (m).
PS = Cross-sectional area of blocked drainage channels/total segment area (m2)
SD = Length of damaged drainage structure/total length of drainage segment (m)
KS = Length of channel slope outside the tolerance range/length of drainage segment (m).

3.2. e-RSeP Application Design

Electronic Performance of Road Segments, abbreviated as e-RSeP, is an application to calculate the performance of road segments by the modeling formula designed in the programming language. Measurement of the needs of problems in building this information system through descriptive analysis that was first carried out to describe or show the data that has been collected, which is then carried out with the prototyping development method, which is software development that is focused on aspects of design, function and interface. The Evolutionary prototype used as a model in this performance application project is designed in outline from the Evolutionary Prototype model (RM Roth, BH Wixom and A Dennis, 2019) [9] where the User and the Developer are on interface together in defining the specifications and functions of the design used in the software designed in this study (see figure 6)

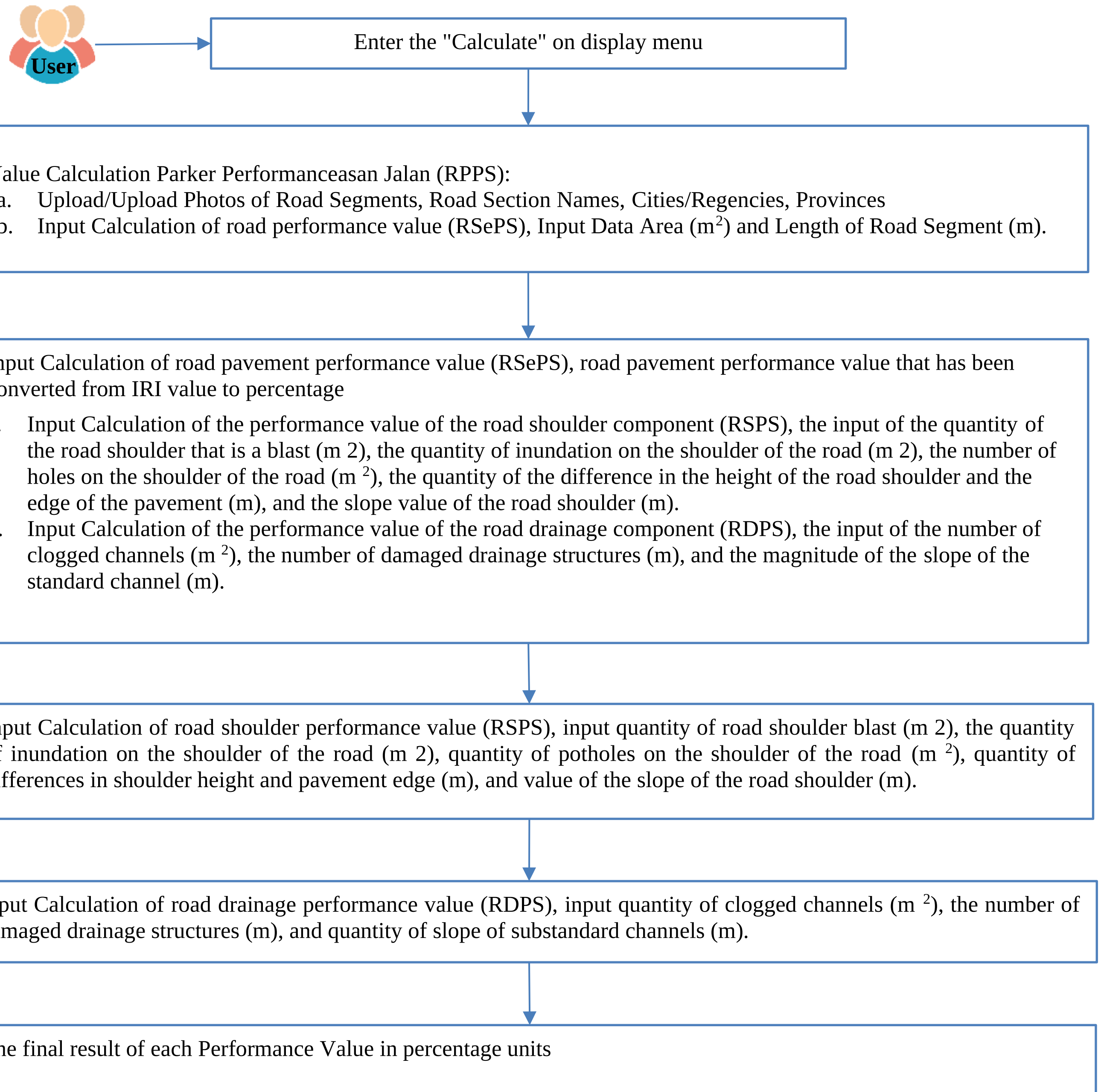


Fig. 6 Class Diagram

This research is motivated by the differences in road condition performance indicators which are the basis for road maintenance/preservation programming planning with the demands of road performance indicators in the field that the Director General of BM has set in the 2018 General Specification Revision 2 (2020) [1] Division-10 as a road implementation standard. Division-10 of the General Specifications of Bina Marga, 6 (six) road components must be met with indicators, namely pavement components, shoulders, drainage and road equipment, and plant control from the left and right sides of the road [13]. The design flow goes through several stages to achieve the goals presented in the diagram in figure 3.

In calculating the performance of road segments using this android-based application to support the needs of road preservation and construction implementation programs. Among others, namely:

1) At the starting stage, first, do the equipment that will be used, including the software system and hardware system.

2) A preparatory stage includes a data collection plan.

3) Data collection stage; The survey data is in the form of pictures of conditions, data on road segments, cities and districts, segment area, length of segments reviewed, technical data on road shoulders, damage to road shoulders, puddles of road shoulders, clogged drainage, damaged and slopes that can be input directly on the mobile application to facilitate the calculation of road segment performance.

4) The Design and System Design Phase consists of the following:
   a. The system design process in the application and interface design.

   b. Designing the application display design Planning system with Planning UML (*Unified Modelling Language*), the function deeply describes procedure and process work from the designed application. That Was a deep Use Case Diagram with process Search data on this application.

5) System Implementation is to implement the interface of each interaction page of each toll calculation of RSePS, RPPS, RShPS, and RDPS.

6) System Testing (Black Box), the tests are performed only by observing the execution results by examining the functional application being designed for development; this test aims to determine the function of each element of the tool's interface on the form that works properly

4. Results and Discussion

4.1. User Interface Application Design

The design of this application is conceptualized as lightweight and portable for easy use while in the field. This application is designed without special storage, will not use the *phone's memory system* and does not require a *cloud server*. In addition, users can do *a screen capture layer* if they have done data calculations. The interface design system in this application is carried out by designing the menu arrangement on display for users. The display has been designed, and designed the application system on *smartphones* will be shown in the table below:

Of the three components used in the performance assessment described in the table above, namely pavement, shoulders and drainage from the calculation results, the performance value of the road segment appears in the blue column in the unit's percentage of each calculation indicator. By designing a full model SEM of RsePV, it is found that:

1. Road pavement performance is measured with IRI.

2. From the achievement of the pavement performance value, an enormous performance value from the road segment was 58.1%, followed in the next order by 20.2% for the shoulder performance value and 21.7% for the drainage performance.

3. The contribution of each indicator of damage or disturbance to the shoulder of the road contributes to (a) the blast on the shoulder of the road contributes 31.1% to the performance of the shoulder of the road, (b) the puddle on the shoulder of the road contributes to the performance of the shoulder of the road by 29.4%, (c) the hole in the shoulder contributes 29.2%, (d) the difference in the height of the pavement edge and the shoulder of the road contributes to the performance of the shoulder of the road by 5.3%, and (e) the slope of the road shoulder contributes to the performance of the road shoulder by 5.0%.

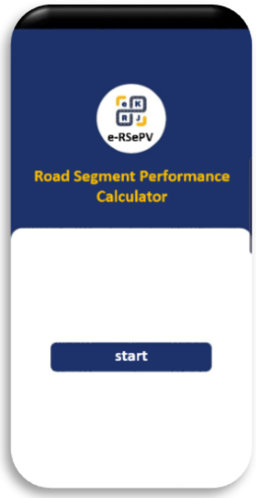
4. The contribution of each indicator of damage or disturbance to road drainage respectively contributes: (a) the condition of the cross-section of the road drainage channel contributes the most dominant to the performance of road drainage by 34.6%, (b) structural drainage contributes to road drainage performance by 31.1%, and (c) the slope of the drainage channel contributes by 29.2%.

The following is an example of the calculation results of the Performance Calculation Trial Results carried out by calculating the performance of the road shoulder carried out on national road segments that are adjusted to the limitations in this study. The number of road segments tested was 5 (five) road segments for the trial representing the working areas of BBPJN Central Java and DI Yogyakarta, especially Central Java Province. The list of road segments that were tested included:

a. Kartasuro-Bts Road segment. Klaten City
b. Klaten-Prambanan Bts Road (Bts. D.I Yogyakarta)
c. Bts. D.I Yogyakarta-Muntilan Road segment
d. North Arterial Road segment (Semarang City)
e. Jalan Bts. Kota Kendal - Bts. Semarang City

See Figure 7 for the road segment performance analysis results using RSP modelling in the e-RSeP application. The figure shows a graph of the stability of the 5 (five) roads with damage categories referring to Table. 2 (the Ministry of State Apparatus Empowerment and Bureaucratic Reform categories). The parameters are the performance of road pavement, shoulders, drainage and road segments where one another has an influence on the performance of segments.

Table 2. Use and Application Testing of e-RSeP ***Source: Analysis and Design Results, 2022.***

<table>
<tr><th>Function</th><th colspan="2">Screen Display</th></tr>
<tr><td>The main display menu, "Tools -Calculate," is used to input the Performance Calculation page.</td><td colspan="2">
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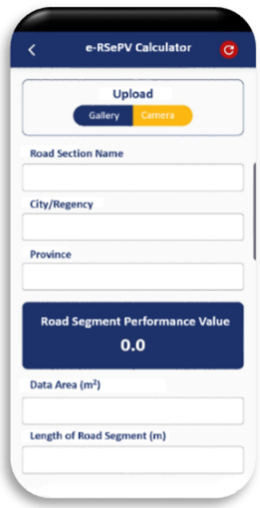
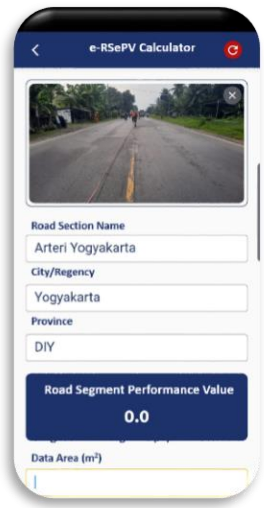
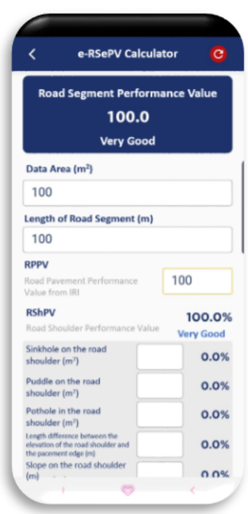
- The Calculation Calculator tool displays a command to record photos of road segments monitored from gallery storage or a live camera. Other fields, such as the name of the section, the name of the area and the name of a province, are also inputted by the User part of the data of the road segment being monitored.
- The user inputs the value of the area and length of the path being monitored.

</td><td>

(a)</td><td>

(b)</td></tr>
<tr><td>The system requests to input:

- Input the value of the pavement performance that has been changed from the road flatness value to the percentage.
- The input of calculation of the performance value of the road shoulder is carried out on the monitored segment, with inputs of the number of road shoulders that appear to be ablaze, the quantity of visible inundation, the number of potholes, and the number of differences in shoulder height and pavement edges, as well as quantity of slope on the shoulders.
- Input the calculation of drainage performance by inputting the value of the area of the channel that has a plug, the length of structural damage to the drainage and the length of the slope of the substandard yang channel.

</td><td>

(a)</td><td>

(b)</td></tr>
</table>

Table 3. Results of the Road Segment Performance Analysis with the e-RSeP model

No	Name of Segments	RSeP Values (in Km)			
		Very good	Good	Below average	Poor
		88,31-100	76,61-88,30	65-76,6	25-64,99
		27,00	22	0	0
1	Segments of the border of Kendal City to the border of Semarang City in 2022 (Length of 8 Km)	3,00	5,00	-	-
2	Segments of Jln. Arteri Utara (Martadinata, Fly Over Sudarso, Semarang City (Length of 10 Km)	6,00	4,00	-	-
3	Segments of Muntilan to Salam (The border of DI Yogyakarta Province (Length of 8 Km)	3,00	5,00	-	-
4	Segments of Kartosuro to the border of Klaten City (Length of 16 Km)	8,00	8,00	-	-
5	Segments of the border of Klaten city to Prambanan (The border of DI Yogyakarta Province (Length of 7 Km)	7,00	-	-	-

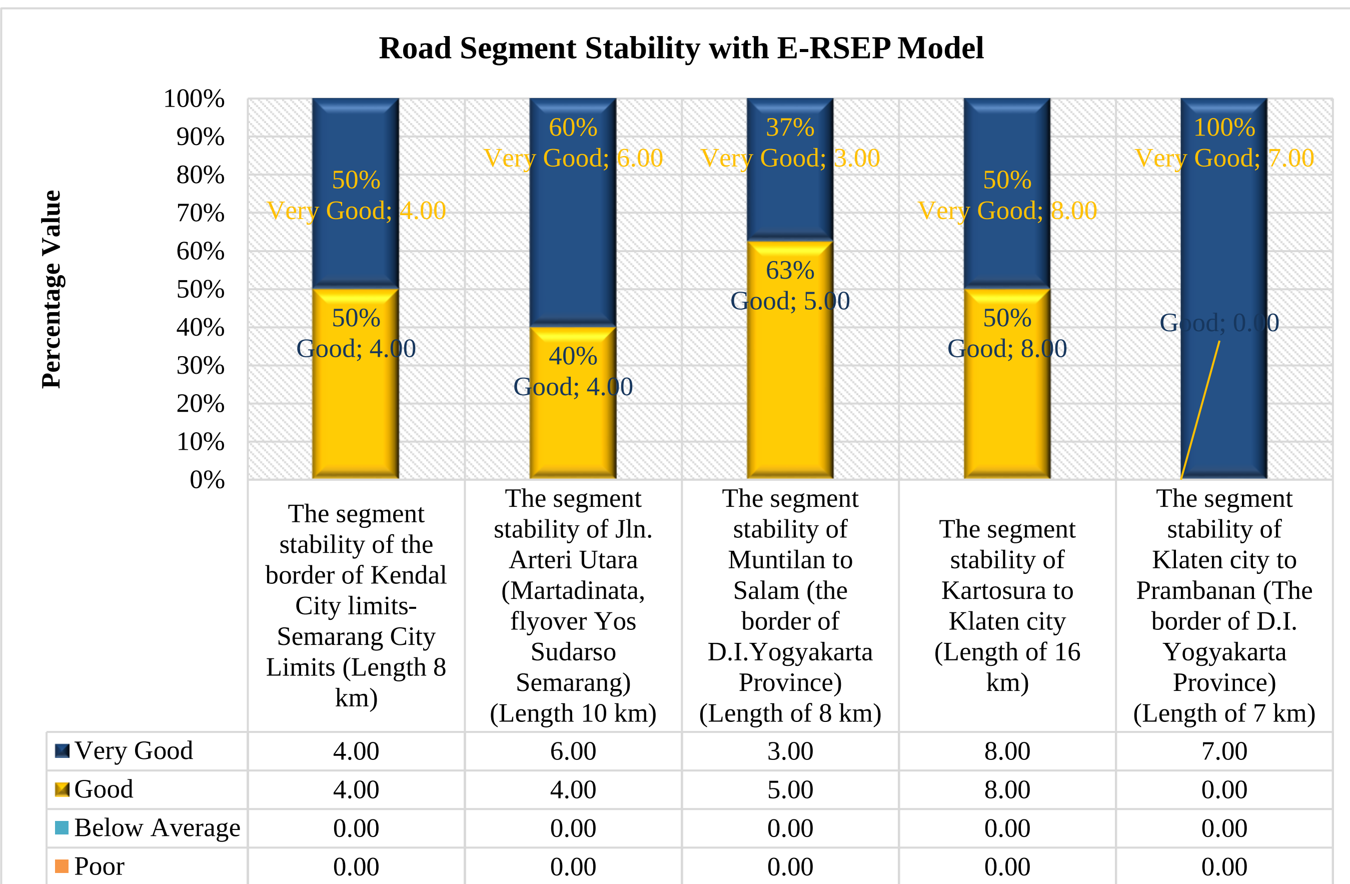


Fig. 7 Graph of Road Stability Based on the Analysis of the e-RSeP Model

4.2. se and Application Testing of e-RSeP

Here is the use and testing of the e-RSeP application

1. On the segment of the border of Kendal city to the border of Semarang city about 8 Km long, the average performance stability values of the segments are (1) "Very Good "for 3 Km or 37% and (2) "Good" for 5 Km or 67%.

2. On Jln. Arteri Utara (Martadinata, Yos Sudarso Fly Over) along 10 Km, the average performance stability values of the segments are (1) "Very Good" for 6 Km or 60% and (2) "Good" for 4 Km or 40%.

3. On the segments of Muntilan to Salam (the border of DI Yogyakarta Province) along 8 Km, the average performance stability values of the segments are (1) "Very Good" for 3 Km or 37% and (2) "Good" for 5 km or 67%.

4. On the segments of Kartosuro to the border of Klaten, about 16 km long, the average performance stability values of the segments are (1) "Very Good" for 8 km long or 50%, and (2) "Good" for 5 km or 50%.

5. On the segments of the border of Klaten city to Prambanan (the border of DI Yogyakarta Province, which is along 7 Km, the average performance stability value of the segments is "Very Good" for 7 Km or 100%.

6. From the performance values of the five road segments above, the average road stability in the area is in the very good category along each road section.

5. Conclusion

From the results of the analysis above, the following conclusions are drawn:

1. In the research on the development of a mobile application that is used to determine the percentage of section performance achievements from android-based road stability indicators for road segment performance assessment, the function of this application is to make it easier for all road segment KDP to monitor with section performance calculations easily and practically.

2. This application also helps users or implementers on-road segments, including service providers, who have done physical work to monitor the achievement of work results that have met the required achievements.

3. From the results of the analysis of section performance calculations according to the sampling described above, the achievement value of the pavement performance value obtained the most considerable value of the performance of the road segment of 58.1%, which was followed in the next order of 20.2% for the value of the road segment shoulder performance, and 21.7% for drainage performance value.

In addition, the benefits of this application are to facilitate monitoring the performance of national road segments specifically for the Province of Central Java-Yogyakarta is a case study object to support the needs of road preservation and construction implementation programs.

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