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Evaluating Road Serviceability Using SERVQUAL: A User-Centered Approach

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Abstract **Purpose:** This study aims to develop a cost-effective methodology for evaluating road serviceability by integrating the SERVQUAL model, traditionally used in service quality assessments, with a user-centered approach. **Design/Methodology/Approach:** The research involved evaluating roads in various cities in Ecuador, including Cuenca, Riobamba, Guano, Penipe, Salcedo, and Guaranda. These roads are considered secondary, main, and urban. The SERVQUAL model was adapted to gather user perceptions on road quality through surveys, focusing on dimensions: tangibles, reliability, responsiveness, assurance, and empathy. Statistical analyses, including Pearson correlation coefficients, were conducted to validate the reliability and consistency of the SERVQUAL model in this context. **Findings:** The findings indicate that user perception, as measured by the SERVQUAL model, is a reliable metric for assessing road serviceability. Significant consistency was observed across the SERVQUAL dimensions, demonstrating the model's effectiveness in capturing user satisfaction. The study showed that user feedback provides valuable insights into road conditions, complementing technical measurements and identifying specific areas of concern that may not be evident through traditional methods alone. **Conclusions:** This integrated approach offers a practical and economical alternative for road serviceability assessment. It enables road management authorities to incorporate user perceptions into their evaluations, providing a more holistic view of road quality. The methodology is particularly beneficial for regions with limited resources for extensive technical evaluations. **Originality/Value:** This study introduces an innovative application of the SERVQUAL model in road serviceability evaluation, demonstrating the feasibility and value of using user perceptions as a complementary metric to traditional technical measurements. The approach enhances traditional evaluation methods by incorporating user feedback and reducing costs, making it valuable for road maintenance planning and decision-making.

Keywords Road Serviceability, Roads, SERVQUAL, User-Centered Approach, User Perceptions

1. Introduction

The quality of life in a society is closely linked to the quality of public services, including road infrastructure, which plays a crucial role in socio-economic development [1]. Ensuring that managed roads achieve sufficient quality without adversely affecting the quality of life of the beneficiaries is essential for responsible agencies [2]. A key component of road management is the evaluation of pavement conditions. Traditional indicators like the Pavement Condition Index (PCI) [3] and the International Roughness Index (IRI) [4] are commonly used to determine the state of road surfaces [5]. The IRI reflects the level of comfort and safety for road users, as well as its impact on vehicle wear, fuel consumption, and carbon footprint [6].

Various devices are available to measure the IRI, categorized into four classes based on their precision [7]. The choice of device often depends on the available budget, the technical knowledge of personnel, and the number of personnel available [8]. However, the high cost and complexity of some devices can be limiting factors. Consequently, recent research has focused on developing low-cost methodologies to estimate the IRI. A common goal of these methodologies is to obtain an accurate IRI value without the need for extensive on-site data collection [9].

High-precision methods such as the rod and level or the use of MERLIN (Machine for Evaluating Roughness using Low-cost Instrumentation) fall into Class 1 [10]. Class 3 methods, like devices that use accelerometers, offer lower precision. This study considers SERVQUAL [11], a user perception-based assessment, which can be categorized as Class 3 or 4. Although it primarily focuses on user perceptions, it provides valuable insights that can complement technical measurements and facilitate the creation of comprehensive serviceability maps [12].

The integration of these methods provides a comprehensive evaluation of road serviceability, combining technical measurements with user feedback [13], [14].

The research was conducted across roads in several Ecuadorian cities. By correlating SERVQUAL scores with IRI values obtained from mobile-based measurements, this study aims to validate the methodology and highlight its potential for practical and economical road serviceability assessment. The findings suggest that this integrated approach can offer significant advantages, particularly for regions with limited resources for extensive technical evaluations.

Given these considerations, there arises the question: Is it feasible to obtain meaningful insights into road serviceability using only user perceptions? This study proposes a cost-effective approach that integrates the SERVQUAL model, traditionally used in service quality assessments, to evaluate secondary road serviceability. The integration of these methods provides a comprehensive evaluation of road serviceability, combining technical measurements with user feedback.

2. Methodology

Figure 1 shows the work breakdown structure of this study, and the deliverables are indicated below.

2.1. Data Collection Techniques

This study evaluates the serviceability of andean roads in various cities in Ecuador, including Cuenca, Riobamba, Guano, Penipe, Salcedo, and Guaranda. The evaluation involved the use of the SERVQUAL model for user perception assessments.

The evaluation of the roads is carried out by applying the MERLIN device, with which it is possible to calculate the International Regularity Index (IRI), which implies that the results obtained have a high approximation to reality, in such a way this information constitutes a basis that allows comparing the results that will be obtained from the application of the model SERVQUAL.

The IRI survey with the Merlin device is carried out in accordance with the guidelines established by the Transport Research and Road Laboratory [15]:

- in each sampling the calibration of the equipment is verified;
- the collection of information is carried out on the lane line where the vehicles circulate;
- the readings are taken every two meters in length and sections of 400 m;
- for each section the corresponding IRI is calculated by applying the corresponding equations [15], [16].

The surveys are then applied to the people who live in the towns that are connected by the roads studied, selecting those most recurrent users of the road.

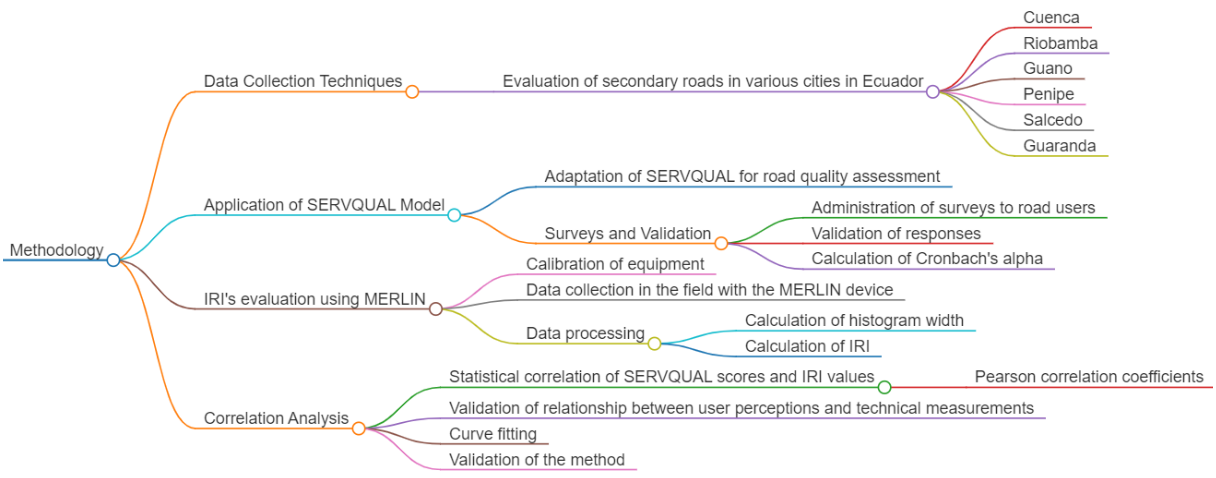


Figure 1. Methodological Framework

2.2. Application of SERVQUAL Model

The SERVQUAL model, traditionally used for assessing service quality in various industries, was adapted to measure user perceptions of road quality. Surveys were distributed to road users to gather data on three dimensions of service quality: reliability, responsiveness and empathy. The surveys were designed to capture the users' expectations and perceptions regarding the roads they frequently use [17].

The SERVQUAL survey model consists of 22 questions [18], distributed in 5 dimensions. In this research, the following 7 questions are adjusted to the reality of the object of study:

- Reliability Dimension

1. The Road Administrator complies with road maintenance on the established date.
2. The Road Administrator shows interest in resolving road failures.

- Sensitivity Dimension

3. The Road Administrator socializes road maintenance planning.
4. In the rainy season, ditch cleaning is timely and fast.
5. There is a willingness to carry out maintenance.

- Empathy Dimension

6. For you, which state presents the road?
7. Feel comfortable when traveling on the road.

Respondents respond according to the Likert scale 1 (lowest) and 5 (highest).

2.3. Servqual Evaluation

To evaluate the Servqual value of each path, the process is followed:

1. Cleaning of the data obtained, determining the acceptable range of response validation as shown in equation 1. This range is delimited by excluding the values that represent the 25% lowest or highest rating of all the responses obtained (Figure 2).

$$R:\ [\bar{x} - z\ \ \sigma; \bar{x} + z\ \ \sigma] \quad (1)$$

$\bar{x}$, median; z, standard normal distribution; σ, standard deviation

2. With the valid answers, the average value (Pi) is calculated.
3. Steps 1 and 2 are repeated for the seven questions asked.
4. SERVQUAL qualification is equal to the average of the Pi values obtained

$$S = \frac{\sum_1^7 P_i}{7} P_i \quad (2)$$

As a test of the reliability of the survey, the results obtained are admitted only if the internal consistency of the surveys carried out is good and Cronbach's alpha is between 0.8 and 0.9 [19].

2.4. Correlation Analysis

To validate the methodology, the SERVQUAL scores obtained from user surveys were statistically analyzed to determine their reliability and consistency. Pearson correlation coefficients were calculated to assess the relationship between user perceptions and other potential technical measurements that might be considered in future studies.

The results are graphed in a Cartesian coordinate system, with the abscissa being the ServQual value and the ordinate being the IRI values. In this way, the correlation analysis is carried out according to the Pearson coefficient.

2.5. Correlation Equations

It is important to consider that road deterioration is not constant (Figure 3), which is why the IRI values obtained in each analyzed segment will vary. This leads to a diversity of user criteria when defining the condition of the road.

Various correlations between SERVQUAL and IRI are carried out, where the IRI values obtained along a road were grouped into ranges labeled Maximum, Q3, Median, Q1, and Minimum. For each range, a curve fitting is performed based on the SERVQUAL score obtained.

2.6. Method Validation

With the adjusted curves, several validations were performed on roads not considered in the previous steps, where field data for IRI and SERVQUAL surveys had already been collected.

The purpose of the validation is to verify the similarity between the results obtained by applying the proposed model and the actual values obtained in the field.

Using the SERVQUAL score, the adjusted equations are applied to estimate the corresponding IRI value, which is then classified into ranges labeled Maximum, Q3, Median, Q1, and Minimum. In this case, it is important to note that the equation will not provide the exact IRI value; rather, it offers an alternative way to understand the range in which the road condition falls.

In accordance with technical standards, the condition of a road can be characterized as very good, good, fair, poor, or very poor.

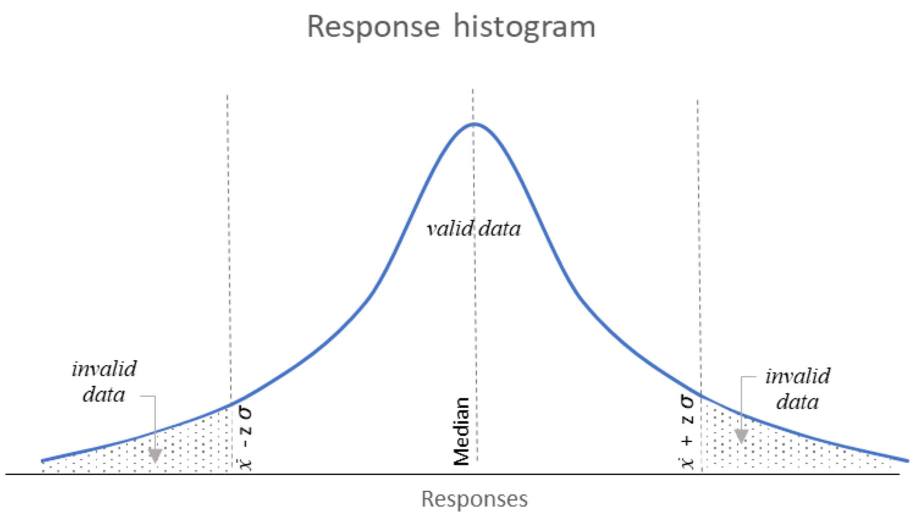


Figure 2. Response validation scheme

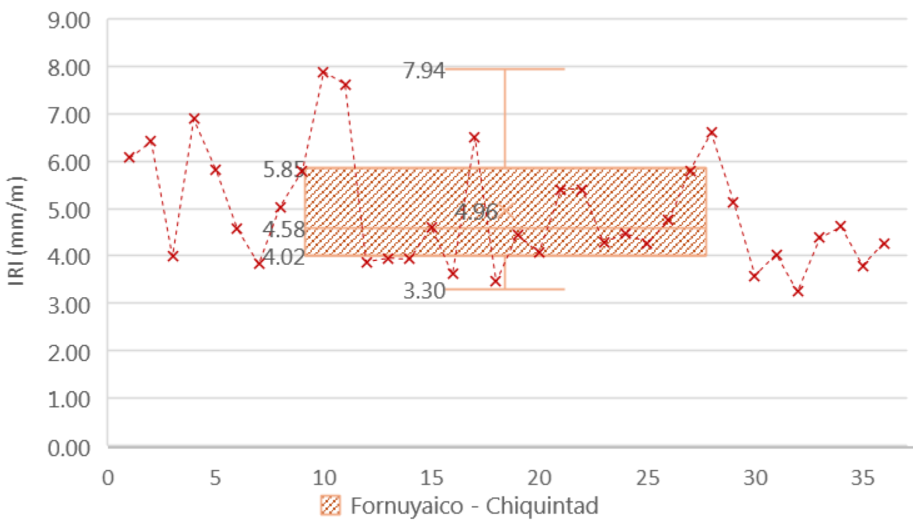


Figure 3. IRI Distribution Example

3. Results

3.1. Findings from SERVQUAL Survey

The SERVQUAL model was adapted to assess user perceptions of road serviceability across dimensions: tangibles, reliability, responsiveness, assurance, and empathy. Surveys were distributed to road users in the selected cities, and the responses were analyzed to obtain SERVQUAL scores.

A total of 1667 surveys were conducted with users (population between 20 and 70 years old) of 35 secondary roads, covering a total of 170 km of surveyed roads. The distribution of the surveys is indicated in Table 1.

After the response validation process, Cronbach's alpha coefficients were obtained greater than 0.8. Figure 4 shows all results of Cronbach's alpha for each road.

3.2. Correlation of SERVQUAL Scores and IRI Values

Statistical analysis was conducted to determine the correlation between SERVQUAL scores and IRI values.

In all cases, the correlations ranged from strong to very strong (Table 2), with the highest correlation being with the median of the IRI values. The negative Pearson coefficients indicate that the relationship between SERVQUAL and IRI is inverse, meaning that as IRI increases, SERVQUAL tends to decrease.

Table 1. Distribution of survey

City	Town	Way	Survey	Population INEC-2022	% error
Cuenca	El Valle, Pacha, Chiquintad	Puente Quebrada Fornuyaico - Chiquintad, Panamericana (Redondel) - Paccha, Panamericana – Baguanchi San Miguel	331	29191	5.36%
Salcedo	Antonio Holguin, Pansaleo, Mulalillo, Cusubamba, Mulliquindil	Holguin-E35, Holguin-Panzaleo, Mulalillo - Cusubamba, Panzaleo-Mulalillo, Mulalillo-Holguin, Panzaleo-E35, Salcedo-E35, Salcedo-Mulliquindil, Salcedo-Panzaleo	379	16463	4.87%
Guaranda	Salinas, Simiatug, Santa Fe, Julio Moreno	Salinas-Simiatug, GUARANDA- SANTA FE, Guaranda-Salinas, Guaranda-Julio Moreno	375	9675	4.96%
Guano	Ilapo, San Andrés, Valparaíso, San Gerardo, San Isidro de Patulú	Guano-Ilapo, Guano-San Andrés, Guano-Valparaíso, Guano - San Gerardo, San Andrés - E35, San Andrés - San Isidro de Patulú, Urbina-E35, Mallas	187	12663	7.11%
Riobamba	Calpi, San Juan, San Luis, Punin, Cacha, Quimiag, Cubijies	Calpi - San Juan, San Luis - Punin, Cacha - Yaruquies, Quimiag - Cubijies	395	27101	4.89%
TOTAL			1667		

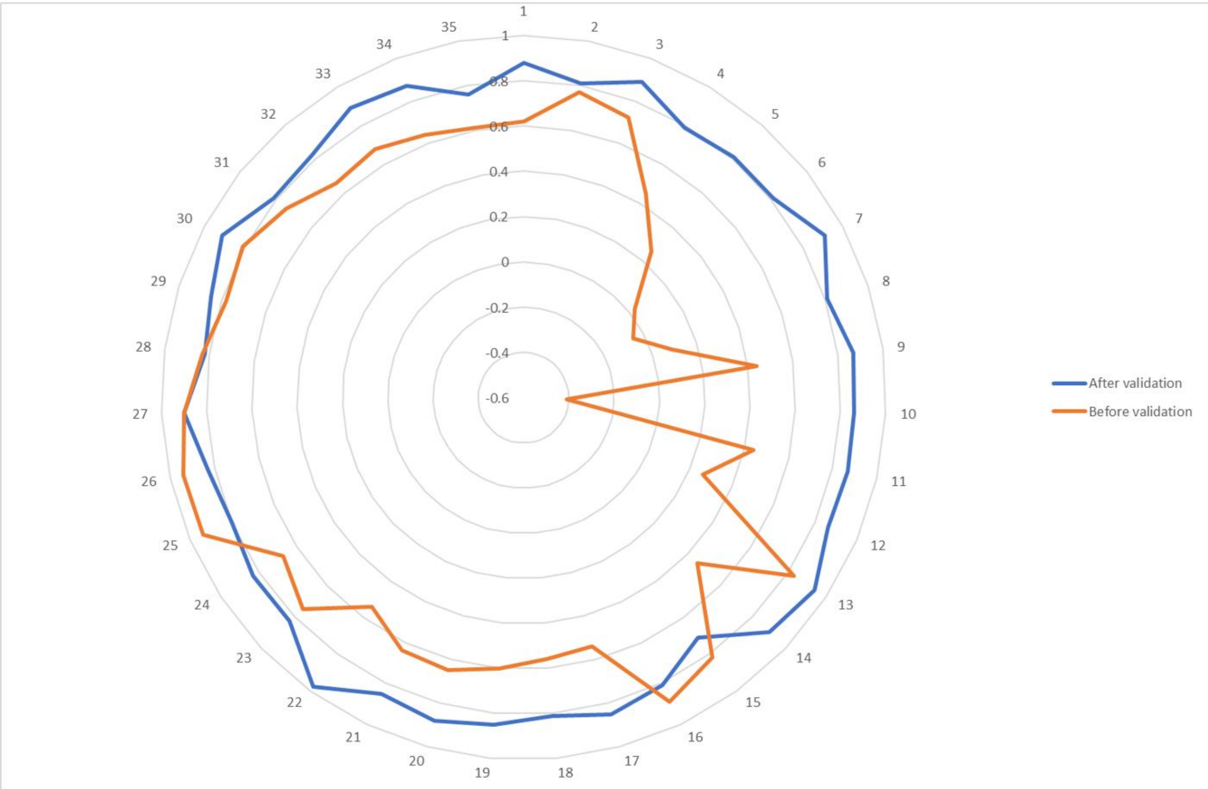


Figure 4. Cronbach's Alpha

Table 2. Pearson coefficient calculation

Variables	Pearson
ServQual with IRI Maximum limit	-0.782
ServQual with IRI Quartile 3 limit	-0.816
ServQual with IRI Average	-0.814
ServQual with IRI Median	-0.820
ServQual with IRI Quartile 3 limit	-0.791
ServQual with IRI Minimum limit	-0.741

3.3. Correlation Equations

Based on the field results, curve fitting was performed as shown in Figure 5, where SERVQUAL is represented on the x-axis and the IRI values on the y-axis. Five correlation equations were obtained, as indicated in Table 3.

It is observed that the R^2 values obtained for each fit are in the range between 0.6 and 0.7, with the exception of the curve modeling the minimum range.

3.4. Simulation and Method Validation

For the validation of the method, the average IRI of three roads is evaluated in the field while SERVQUAL surveys are conducted with the users of these roads.

Using the SERVQUAL values obtained, the different IRI values are evaluated by applying the equations from Table 4 and comparing them with the values obtained in the field.

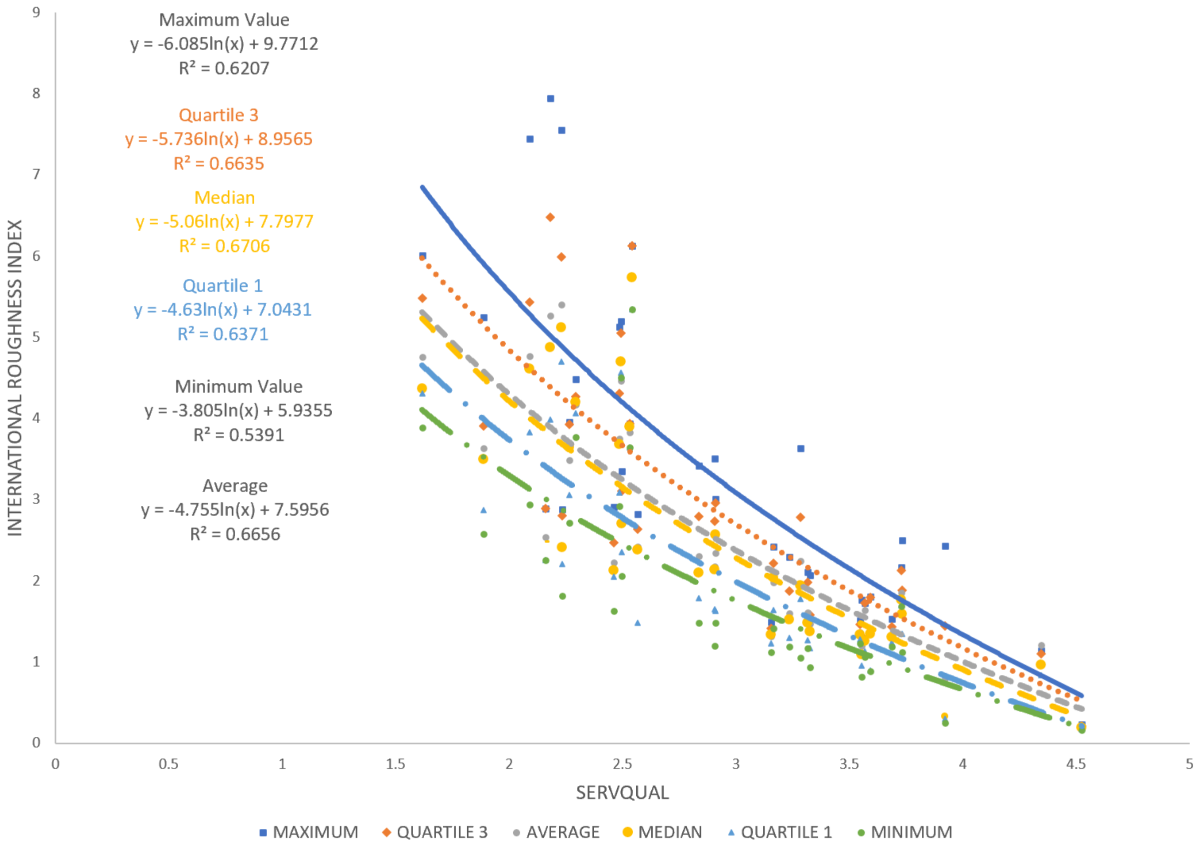


Figure 5. Curve Fitting

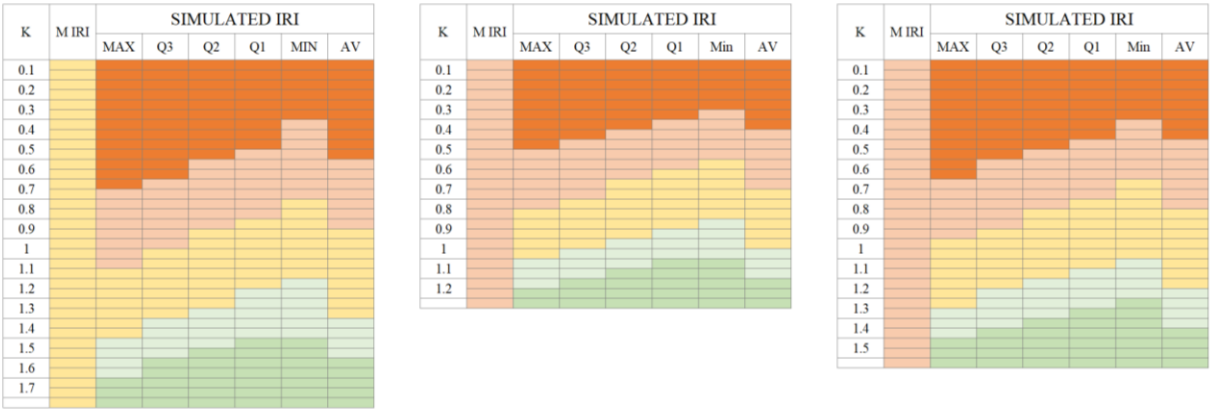
Table 3. Correlation Equations

Range	Ecuation	R^2
Maximum	$IRI_{max} = -6.136\ln(S) + 9.8181$	0.638
Quartile 3	$IRI_{Q3} = -5.736\ln(S) + 8.9565$	0.664
Median	$IRI_{Q2} = -5.06\ln(S) + 7.7977$	0.671
Quartile 1	$IRI_{Q1} = -4.63\ln(S) + 7.0431$	0.637
Minimum	$IRI_{min} = -3.954\ln(S) + 6.085$	0.595
Average	$IRI_{p} = -4.755\ln(S) + 7.5956$	0.665

Table 4. Method validation on three roads

Road	IRI	Condition	SERVQUAL
1	2.71	Fair	2.6
2	4.35	Poor	3.54
3	5.24	Poor	2.93

Figure 6 shows the results obtained from the different simulations conducted on the three roads. The field results are:



a. b. c.

Figure 6. Model Simulation considering adjustment (factor K) and the Measure IRI (M IRI). a) Road 1, b) Road 2, c) Road 3

Table 5. Frequency Data

Servqual Range		0-2	2-3	3-4	4-5
Data Frecuency	> max	0.0%	23.5%	7.14%	50.0%
	[max, Q3)	0.0%	17.6%	14.29%	0.0%
	[Q3, Q2)	0.0%	5.8%	28.57%	50.0%
	[Q2, Q1)	0.0%	23.5%	28.57%	0.0%
	[Q1, min]	100.0%	11.7%	14.29%	0.0%
	< mín	0.0%	17.6%	7.14%	0.0%

The simulation conducted is presented in Figure 6, where the dependent variable term of the equations obtained in Table 2 is affected by a factor K, such as the equation 3, where IRI_{Qi} is obtained from a Montecarlo Simulation with equations from Table 3; IRI^*_{Qi} means the IRI modified and K is the adjustment factor.

$$IRI^*_{Qi} = K * \quad IRI_{Qi} \qquad (3)$$

This investigation used Montecarlo Simulation because the S value implies various IRI values as defined in Table 3. The data frequency used is shown in Table 5. Their presented values are obtained from the results of the samples collected.

Figure 6 shows in column 1 the factor K used as an adjustment; column 2 represents the condition of the road according to the IRI calculated in the field, and columns 3 to 8 show the condition of the road based on the IRI calculated using SERVQUAL. For better understanding, the states are color-coded, with the most acceptable value of K being the one that results in a similar characterization to that obtained with the IRI calculated in the field.

If we consider using the IRI_Q2 (median) equation, the recommended K values to apply are:

a) 0.95 to 1.35 for road 1,
b) 0.45 to 0.70 for road 2, and
c) 0.55 to 0.85 for road 3.

3.5. Summary of Key Findings

The adapted SERVQUAL model effectively captured user satisfaction across three dimensions of road serviceability.

The strong correlation between SERVQUAL scores and IRI values validates the methodology and highlights its potential for practical and economical road serviceability assessment.

The determination coefficients obtained for each fitted curve are in the range of 0.6 to 0.7, which implies that the proposed model partially explains the variability of the data.

It is important to consider that the SERVQUAL responses are subject to individual variables for each user, such as educational level, mood, needs being met, age, and how they use the road, among others. In this context, the calculated R^2values are considered acceptable.

The correlation equations allow for the characterization of the condition of the road, and for this, it is necessary to adjust the obtained equation with a K parameter.

From the three roads used for method validation, it was observed that users tend to give a better rating as the road is in good condition; conversely, they tend to rate more negatively as the road deteriorates into poor condition.

The findings suggest that incorporating user perceptions into road evaluations provides a more comprehensive understanding of road quality, particularly beneficial for regions with limited resources for extensive technical evaluations.

4. Discussion

The results of this study provide significant insights into the effectiveness of using the SERVQUAL model for evaluating road serviceability. The strong consistency across the SERVQUAL dimensions underscores the validity and potential of this user-centered methodology.

4.1. Comparison with Traditional Methods

Traditional methods of road serviceability assessment, such as the Pavement Condition Index (PCI) and International Roughness Index (IRI) measurements, rely heavily on technical data collected using sophisticated equipment [20]. While these methods provide accurate and objective data, they are often expensive and time-consuming. The SERVQUAL model offers a cost-effective alternative by focusing on user perceptions, which can be categorized as Class 3 or 4 in terms of measurement precision. This approach aligns user expectations with road conditions, ensuring that maintenance priorities reflect actual user needs and experiences [21].

4.2. Implications for Road Management and Maintenance

The integration of SERVQUAL and IRI estimation offers practical and economic advantages for road management authorities. By leveraging user feedback, authorities can identify specific areas of concern that may not be evident through technical measurements alone [22]. For example, roads with high IRI values but low user dissatisfaction might indicate that users have adapted to certain road conditions, whereas low IRI values with high dissatisfaction might highlight issues not captured by roughness alone, such as inadequate lighting or poor signage [23].

This methodology empowers road management authorities to make more informed decisions, prioritize maintenance activities effectively in the short term, and allocate resources efficiently based on the needs demanded by the populations benefiting from the road. By addressing both technical and user-reported issues, authorities can enhance overall road serviceability and user satisfaction, leading to improved public trust and better utilization of maintenance budgets [24].

4.3. Limitations

While the findings are promising, there are several limitations to consider. The SERVQUAL model, although effective in capturing user perceptions, is inherently subjective [25]. User responses may be influenced by individual biases, recent experiences, or specific expectations, which can vary widely. To mitigate this, surveys should be designed to minimize bias and ensure a representative sample of road users [26].

The subjectivity present in the SERVQUAL survey responses can be corrected using the K factor, which we refer to as the subjectivity factor. This value should be analyzed based on the reality of each society benefiting from the road.

4.4. Future Research Directions

Future research should focus on validating this user-centered methodology in different geographic regions and road types. Expanding the sample size and diversity of road segments can provide more comprehensive insights into the methodology's applicability and reliability. Additionally, exploring the integration of technical measurements with user perceptions can further enhance the robustness and accuracy of road serviceability assessments.

5. Conclusions

This study successfully demonstrates the feasibility and effectiveness of integrating the SERVQUAL model with International Roughness Index (IRI) estimation for evaluating road serviceability. The key findings and contributions of this research are summarized as follows:

Validation of Methodology: The strong negative correlation between SERVQUAL scores and IRI values validates the integrated methodology. This correlation indicates that user perceptions, as captured by the SERVQUAL model, align well with technical measurements of road roughness obtained through mobile-based IRI estimation.

Holistic Road Quality Assessment: By incorporating user perceptions into the evaluation process, the methodology provides a more comprehensive understanding of road quality. The adapted SERVQUAL model effectively captures user satisfaction across various dimensions of road serviceability, offering insights that purely technical measurements may miss.

Enhanced Decision-Making for Road Management: The integrated methodology enables road management authorities to prioritize maintenance activities more effectively by considering both technical data and user feedback. This dual approach helps identify specific areas of concern, leading to more informed decision-making and better resource allocation.

Potential for Widespread Application: The study highlights the methodology's potential for broad application across different regions and road types. Its adaptability and cost-effectiveness make it a valuable tool for improving road management practices globally.

5.1. Recommendations for Future Research

Future research should focus on expanding the validation of this methodology across diverse geographic regions and varying road conditions. Investigating the integration of additional service quality dimensions and technical indicators can further enhance the robustness and comprehensiveness of road assessments. Additionally, exploring other mobile applications and sensors for IRI estimation can improve measurement accuracy and reliability.

By continuing to refine and validate this integrated approach, researchers and practitioners can contribute to more effective and user-centered road management practices, ultimately enhancing the quality of life for road users worldwide.

Additionally, it is important to conduct future research to gain a better understanding of the variation of the subjectivity factor K, which will lead to improved accuracy in the calculation of IRI and the subsequent characterization of the road's condition.

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