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Evaluation of Riding Quality Index (RQI) Based on Panel Ratings and Root Mean Square (RMS) Vertical Acceleration Method with Validation Using Pavement Condition Index (PCI): A Case Study of Pathlaiya to Hetauda Road Section.

By

Bibek Gupta Rauniyar

A THESIS

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The undersigned certify that they have read and recommended to Institute of Engineering for acceptance, a thesis entitled **"Evaluation of Riding Quality Index (RQI) Based on Panel Ratings and RMS Method with Validation Using Pavement Condition Index (PCI): A Case Study of Pathlaiya to Hetauda Road Section."** submitted by Bibek Gupta Rauniyar in partial fulfillment of the requirement for degree of Master of Science in Transportation Engineering.

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ABSTRACT

Accurate evaluation of pavement condition is required for the road maintenance and management. The aim of this study is to validate the Riding Quality Index (RQI), a pavement ride quality indicator developed based on panel-rated evaluation and smartphone-based vertical vibration measurement (RMS). The reliability of the proposed methodology was checked by referring Pavement Condition Index (PCI). Field data were collected from selected road sections. Panel RQI was derived from multiple panel members rating ride quality independently and RMS values were obtained by recording vehicle vibrations using smartphone accelerometers. We have developed a Hybrid RQI by combining panel ratings and RMS measurements for better representation of pavement condition. Statistical analysis of correlation, regression and Intra-class Correlation Coefficient (ICC) were conducted to assess the relationships among PCI, Panel RQI, RMS and Hybrid RQI. Results showed that PCI and Panel RQI were highly correlated (R2 = 0.7169), PCI and RMS were moderately correlated (R2 = 0.3842), and PCI and Hybrid RQI were most correlated (R2 = 0.7429) with weights of 0.80 for PCI and 0.20 for Panel RQI. ICC analysis showed good panel agreement (ICC = 0.939). The results show that panel-based RQI is a reliable measure of pavement condition and smartphone-based RMS is a fast and low-cost tool for measuring roughness. The hybrid approach successfully combines subjective perception and objective measurements, offering a comprehensive, accurate and scalable method for pavement condition assessment that can be applied to large road networks.

Keywords: Riding Quality Index, Panel Rating, RMS Acceleration, Pavement Condition Index, Hybrid RQI, Pavement Roughness, ICC, Regression Analysis

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

RQI	Riding Quality Index
RMS	Root Mean Square
PCI	Pavement Condition Index
IRI	International Roughness Index
GPS	Global Positioning System
ICC	Intra-Class Correlation Coefficient
Panel_RQI	Panel Based Riding Quality Index
Hybrid_RQI	Hybrid based Riding Quality Index
RQI_RMS	Root Mean Square based Riding Quality Index
DoR	Department of Roads
CDV	Corrected Deduct Value
SD	Standard Deviation
HDM	Highway Development and Management Model
RMS_{max}	Maximum Root Mean Square of Vertical Acceleration
RMS_{min}	Minimum Root Mean Square of Vertical Acceleration
RMS_{norm}	Normalized Root Mean Square

CHAPTER 1

1. INTRODUCTION

1.1. Background

“Any country’s economic development and social integration depend on robust road infrastructure. Road transport is the lifeline of mobility in Nepal, especially in the hilly and Terai regions. Assessment of pavement condition is required for the purpose of maintenance planning, public safety and riding comfort. Traditional methods of evaluation such as Pavement Condition Index (PCI) and International Roughness Index (IRI) have been widely used. However, the cost of equipment and manpower is high in developing countries posing a challenge for their application (ASTM, 2018; Sayers et al., 1986). Moreover, the PCI is mainly the basis for pavement condition assessment, which reflects mainly surface distresses and does not reflect the ride quality perceived by users. This limitation requires an integrated evaluation approach including functional performance measures. The laser scanners and profilers used as automated data collection devices for IRI are very expensive to buy, operate and maintain. City officials in developing countries rarely use such a device for data collection, monitoring the whole condition of the road network is done frequently (Firoozi et al., 2019).

To overcome this limitation, the ride quality index (RQI) based on human perception of ride comfort is a promising alternative to assess the functionality of the road. The RQI is easier to implement and less resource intensive, but the reliance on panel ratings is subjective, and raises questions about the reliability and repeatability of the data.

Recently, low-cost vertical accelerometer measurements have been found to be useful as means for measuring ride quality objectively (Bisconsini et al., 2018; Firoozi et al., 2017). With respect to the achievements made by scholars within the field of smartphones, various inexpensive sensors are found in smartphones, including the

3D-accelerometer, a gyroscope, and GPS. Although these inexpensive sensors can be used in many applications of smartphones, including games and navigation apps, they can also be employed in engineering research, particularly transport engineering (Firoozi et al., 2019). Inexpensive sensors measure the vertical movements of vehicles on the road surface, which are expressed through indicators such as Root Mean Square (RMS) of acceleration.

However, despite the advantages associated with the concept, there is insufficient literature on the feasibility of applying accelerometers in RQI calculations in Nepal. Furthermore, little effort has been made in devising hybrid RQIs based on both subjective and objective evaluation techniques. Additionally, the relationship between the new RQIs and PCI remains unknown. Lastly, panel evaluation methods have yet to be proven reliable via empirical testing in Nepal.

Hence, the present research seeks to investigate whether, in many developing nations such as Nepal, the implementation of comprehensive pavement assessment systems such as PCI is restricted by the scarcity of financial and human resources and large-scale field surveys. In such instances, RQI could be applied as a robust technique for measuring the road's condition during early stages of evaluation. PCI emphasizes the distress characteristics of the road, whereas RQI denotes the performance of roads in relation to their ride quality. Therefore, RQI could be vital in evaluating the segments of the road network that influence road users directly. Given technological advancements, RQI could now be calculated quickly and efficiently using accelerometers embedded in mobile phones. Thus, the RQI-assessment technique might be employed to help identify what parts of the road require inspection and maintenance in light of a more comprehensive evaluation process due to the limited availability of funds.

1.2. Statement of the Problem

Ride Quality is yet another important indicator in assessing pavement performance. Unfortunately, the current approach used in Nepal for assessing pavement performance is PCI. The PCI is a procedure used for assessing distress in pavements and not in assessing their performance. Even though the PCI approach has been widely used all over the world in assessing pavement performance, it is very tedious and time-consuming as it involves detailed field work. Consequently, PCI becomes a very expensive and infrequent process to be performed on big roads such as Pathlaiya-Hetauda Road that consists of 31.00 kilometers of road length. The disadvantage with PCI in terms of pavement performance assessment is that it disregards one of the most important indicators of pavement performance, which is ride quality.

On the other hand, the RQI approach is used to measure pavement performance through a function, making it more user-oriented compared to other procedures for measuring pavement performance as RQI measures performance based on ride quality experienced by the driver. Traditional approaches in assessing RQI involve panel ratings, which are biased as raters tend to give different responses during ratings. Therefore, it is vital to statistically evaluate the validity of the panel rating approach through ICC (2,k).

Given the developments in smartphone-based sensing technology, the objective assessment of RQI through RMS and standard deviation calculations from triaxial accelerometer data can be accomplished. However, since no study has been conducted in Nepal to validate the validity of the computed RQI using sensors, it is not possible to validate the relationship between the computed RQI and human perception and PCI measurements.

Additionally, no previous studies have been conducted in Nepal where the assessment of RQI included both panel RQI and objective RQI measures. Under such conditions, it becomes impossible to establish the relationship between panel RQI, RMS RQI, hybrid RQI, and PCI measures, which makes it difficult to ascertain the effectiveness of RQI as an alternative to PCI.

1.3. Research Objectives

The main objective is to develop a hybrid Riding Quality Index (RQI) model by integrating panel-based ratings and RMS-based vertical acceleration data. The specific objectives are:

1. To design a standardized RQI evaluation framework based on both panel ratings and vertical accelerometer (RMS) data.
2. To compute PCI based on visual distress surveys following ASTM D6433 guidelines.
3. To model and statistically validate the relationship between hybrid RQI and PCI.

1.4. Scope of Study

The following scope of study has been planned:

1. To evaluate the pavement condition using the Riding Quality Index (RQI) by combining panel-rated subjective assessments and smartphone-based RMS acceleration measurements**.**
2. To developed a Hybrid RQI model by integrating panel ratings and RMS data
3. To use Pavement Condition Index (PCI) as the reference standard,
4. To evaluate statistical analyses including correlation, regression and ICC to validate relationships and panel consistency.

1.5. Limitation of Study

The project report was prepared under following limitations:

1. The data was collected using a single test vehicle, the Hyundai i20, so the ride quality and accelerometer readings are based on the way this specific vehicle behaves.
2. The survey was done at speeds between 30 and 50 km/h. Changes in speed within this range can affect how people rate the ride and the calculated acceleration values.
3. The smartphone accelerometers were placed in fixed positions inside the car. The results depend on where and how the devices were placed.
4. Different smartphones may have different sensitivity and accuracy in their accelerometers. This can cause small differences in the acceleration measurements.
5. The RMS value from the phone shows how rough the road is, but it doesn't show details like cracks, potholes, or other surface issues.

CHAPTER 2

2. LITERATURE REVIEW

The various literatures related to the evaluation of riding quality index based on panel rating and RMS methods can be summarized as below:

2.1. Pavement Condition Index (PCI)

Pavement Condition Index (PCI) is a numerical rating system ranging from 0-100 to indicate the general condition of the road section in consideration. “0” refers to the worst condition of the road whereas, “100” refers to the best condition of the road. A total of 7 groupings of road condition are developed in the standard rating scale of PCI which are also colour graded as shown in figure 2.1. The determination of PCI requires manual visual inspection survey of the pavement. The Pavement Condition Index was originally developed by United States Army Corps of Engineers as an airfield pavement rating system, but it was later modified by ASTM for highway and parking. Lower value of PCI refers to high degree of deterioration of road whereas, higher value of PCI represents better roads with lower degree of road deterioration. The PCI is considered to be one of the most comprehensive and widely used measures of pavement performance evaluation (ASTM, 2018).

Figure 2.1: ASTM PCI Rating Scale

The evaluation of the condition of pavement is an integral component of asset management in infrastructure. PCI is one such tool to evaluate the condition of roads which has been developed by the U.S. Army Corps of Engineers and standardized by ASTM D6433. This method uses visual distress scoring and depends on information about the severity and extent of distress (Shahin, 2005). However, conducting six PCIs is very cumbersome and time-consuming.

2.2. International Roughness Index (IRI)

The International Roughness Index (IRI) uses laser profilers or inertial measuring system and gives accurate assessment of longitudinal surface profiles, but it uses sophisticated and expensive instruments to measure IRI values (Sayers et al., 1986). In recent times, IRIs are used very frequently in some major national projects of Nepal, and IRI based contract execution has taken place in various national projects including four years execution of an improvement project of East-West highway. Although the use of IRI is not common in Nepal, yearly data collection on IRI values is done (IQL III). The application of IRI in pavement maintenance in Nepal could turn out to be a difficult undertaking because of the lack of adequate resources for maintenance in Nepal, considering the relatively small amount of roads in the country. In current scenario, the majority of roads in Nepal are in bad condition and hence need special maintenance efforts to improve their condition.

2.3. Riding Quality Index (RQI)

Alternatively, the adoption of the Riding Quality Index (RQI), which relies on the subjective evaluation of the quality of ride comfort by humans, can be perceived as an adequate method to investigate the functionality of the road. This approach to the riding quality index has been applied in situations where there was a requirement for a quick and cost-efficient investigation of the roads. According to Firoozi et al. (2017), when the calibration of the panelists is effectively conducted, then consistent evaluations from the panelists concerning the quality of ride will occur. Panel ratings have been applied to evaluate the quality of ride of the pavement (Fwa et al., 1989).

2.4. Vertical Accelerometer Based Riding Quality Index

With recent technological advancements, it has become possible to use accelerometer sensors of smartphones for measuring the vertical acceleration as an indicator of the surface condition of the roads (Bisconsini et al., 2018; Firoozi et al., 2017). In an effort to find out whether there was any relationship between smartphone-measured roughness value and profilers, Hanson et al. (2014) conducted an experiment using eleven segments of one-kilometer of secondary roads in New Brunswick, Canada. It was found out that there is a high correlation between both outputs. In a research study conducted by Tai et al. (2010), it was suggested to use the application of smartphones with 3-axis accelerometer while riding on the motorcycle to detect road anomalies as well as evaluate road quality with a very high level of accuracy of 78.5%.

In a study carried out by Firoozi et al. (2017), the relationship between pavement roughness determined through smartphone installed on vehicles and the opinions of users regarding the ride quality of the pavement derived from panel ratings was examined and it was found that there was a strong correlation (R^2=0.8) between users' opinion about pavement roughness and measurement by the smartphone. The result indicates that the smartphone could effectively indicate the level of pavement roughness, which matches the comfort felt by travelers. It means that the smartphone only measures the roughness of roads. In addition, it was confirmed that there was a correlation of (R^2=0.76) between the pavement roughness measures made using the smartphone and the roughness measures derived through the use of International Roughness Index (IRI) using Road Surface Profiler. The effectiveness of RMS and standard deviation of vertical acceleration in evaluating vibration severity caused by surface roughness has been investigated. The results from these investigations imply that the use of both subjective and objective methods is recommended while developing a composite RQI.

2.5. Reliability Testing: Intra-Class Correlation Coefficient

It is important to discuss the reliability of the panel as well. The importance of ICC as a tool used in rating reliability research was emphasized by Koo & Li (2016). According to Fang et al. (2025), the need to consider inter-rater reliability is significant within oncology as it ensures the correctness and reliability of measurements associated with the estimation of biomarker level and tumor sizes by radiation oncologists. The importance of consistency in rating is obvious and ICC can be considered an appropriate tool of evaluation of agreement in health and behavioral sciences.

The reliability of manual pavement distress rating as an important problem was discussed by Bianchini et al. (2010) due to the fact that it is widely used by transportation authorities. There is a standardized procedure; however, manual pavement distress rating is influenced by subjective evaluations due to various experience levels. The application of new statistics that would help estimate agreement in multi-categorical rating according to chi-square distribution in case of perfect or imperfect inter-rater/inter crew reliability is suggested.

This study concerns itself with the inspection of pavements but can be useful for any scientific paper that employs the panel ratings or surveys. According to Bianchini et al., it is crucial to determine the differences between the raters, thus ensuring that the collected data is consistent. This concept is highly relevant to the proposed study, where household-level data and perception-based indicators are expected to vary between respondents. Therefore, the discussion about testing for the reliability and validity of the agreement serves as justification for using ICC as a measure of intraclass variability and the need for multilevel modeling. Overall, this article by Bianchini et al. (2010) represents a valuable theoretical framework for reliability assessment in scientific research involving human ratings or subjective observations.

Despite the evident advantages of the methodology, the use of accelerometer-based RQI in Nepal remains insufficiently studied. Furthermore, the available literature on the joint application of subjective and objective ride quality indexes and their relationship with PCI is scarce. Lastly, the assessment of the reliability of panel ratings through ICC remains poorly validated in Nepal.

CHAPTER 3

3. METHODOLOGY

3.1. Research Design

Steps involved in the research design were literature review, problem definition, selection of area to conduct the research, segmenting and collecting of primary data. Primary data was collected by assessing the reliability index for panel members, collecting measurements of the RMS_RQI through the use of a vertical accelerometer. Evaluation of PCI, statistical analysis and conclusion formation were finally done. The research will be guided according to the steps as shown in Figure – 3.1:

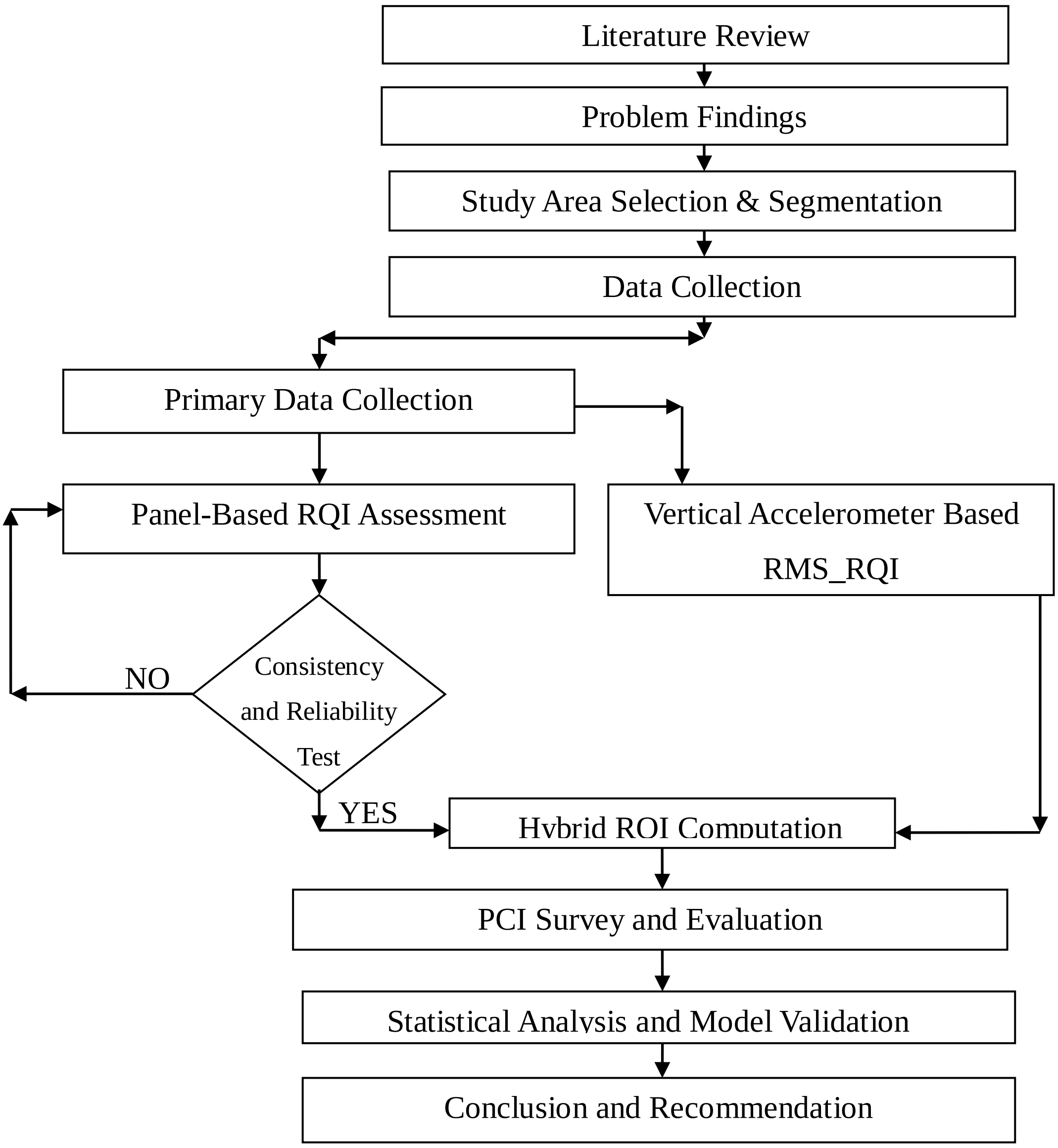

Figure-3.1: Research Design

3.1.1. Study Area Selection and Segmentation

The chosen route from Pathlaiya to Hetauda, being one of the routes on the Mahendra Raj Marg highway, is 31.00 km long. This particular route of the road has an important significance regarding the transportation of goods as well as people in various industries situated both in the Terai and hilly areas. This route of the road has been divided into segments of 0.5 kilometers each using the GPS and google earth coordinates. Each segment have been uniquely coded (e.g., S01 to S62) for uniform data collection across RQI, RMS, and PCI surveys.

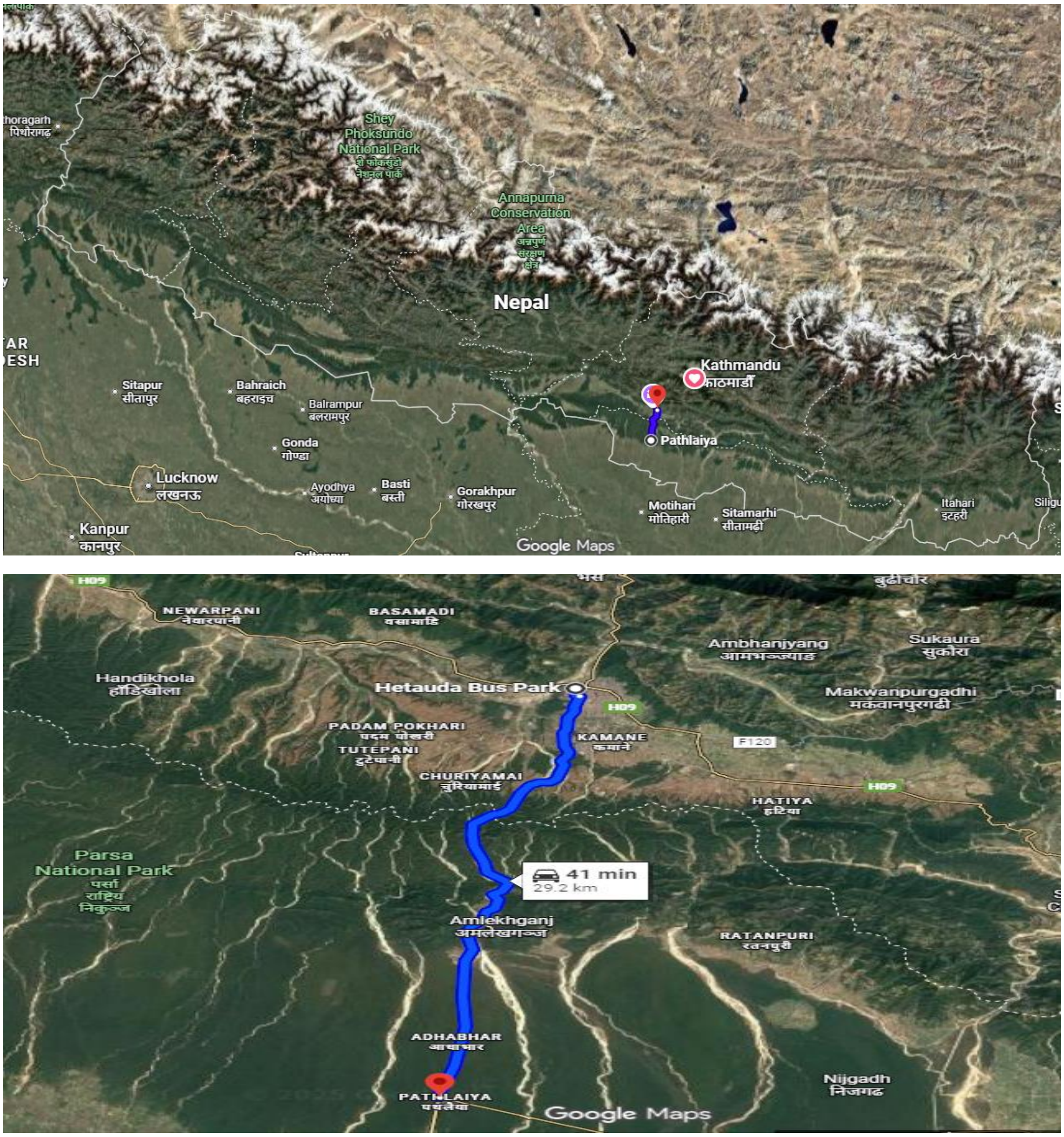

Figure-3.2: Site Selection

3.1.2. Panel-Based RQI Assessment

Panel based RQI (Riding Quality Index) assessment had been performed for evaluation of the pavement performance as perceived by users. The evaluation procedure was based on subjective perception of riding quality, as in this process the panel members would rate the roads in terms of their riding quality while traveling in the test vehicle (Hyundai I20). The subjective reaction of road users towards pavement surface irregularities had been assessed by using the RQI method.

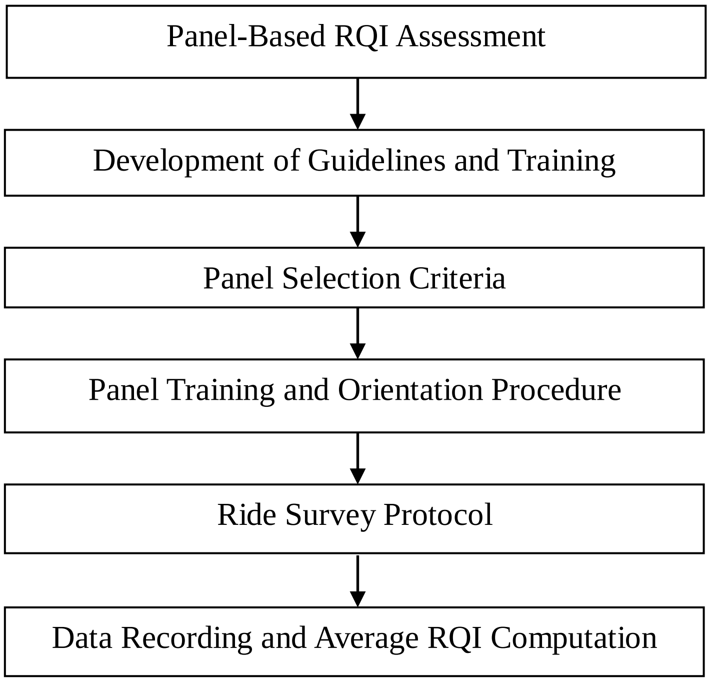

Figure 3.3: Flowchart For Panel-based Assessment

a) Development of RQI Rating Framework and Evaluation Guidelines

RQI rating system and criteria used for their evaluation were developed systematically through a step-by-step procedure in order to ensure uniformity in the subjective assessment. For instance, a numerical scale from 0 to 5 had already been recommended as a means of categorizing riding quality based on the severity of vertical vibrations (Table 3.1). From Table 3.1, it is clear that the numerical values ranging from 0 to 5 were categorized into five categories of riding quality, namely Very Good (VG), Good (G), Fair (F), Poor (P) and Very Poor (VP). To aid in the understanding of the rating process and avoid ambiguity when interpreting the results, anchors were provided for each of the categories mentioned above (Table 3.2) to emphasize the effects of vertical vibrations on ride comfort. Examples of such anchors include various types of pavements that could be associated with specific categories of riding quality.

In view of the development of the rating scale, standards that would be used to judge the effectiveness of the rating scale were put in place to ensure consistency in its use. The panelists must rate the road segment based on their vertical comfort only; they should not rate it based on how the road surface looks. Panelists should judge the road segment as a whole and should not focus on minute imperfections. To prevent bias based on opinions of other panelists, each panelist should record their ratings individually without discussion. Further, there must be consistent vehicle speed throughout the rating process to ensure consistency. Finally, to eliminate any inaccuracies that arise from forgetfulness, panelists should record their ratings immediately after their ride on each road segment. The above procedures of creating a rating scale, developing descriptive anchors, and formulating criteria ensured consistency among the panelists.

Table 3.1: Ride Quality Index Rating

Verbal Rating	Numerical Rating
Very Good	4.0 – 5.0
Good	3.0 – 4.0
Fair	2.0 – 3.0
Poor	1.0 – 2.0
Very Poor	0.0 – 1.0

b. Panel Selection Criteria

There had been a well-structured procedure of identification, screening, evaluation, and validation to select panelists to ensure reliability and representativeness in the subjective assessment of the ride quality of the Pathlaiya - Hetauda road stretch. For gaining different views about ride quality, a panel had been formed by selecting five members from among a surveyor, a highway engineer, a driver, an experienced traveler, and an elderly person. Potential candidates for the panel had initially been identified via professional and personal contacts, and then they were screened out based on their travel experience on the particular road stretch. Screening had been done to eliminate any potential candidates with visual and vestibular impairment, which might hamper their ability to judge. The availability of the panelist throughout the experiment period had been ensured; otherwise, the candidate would not be considered. Furthermore, the knowledge and competence level of the candidates regarding the rating criteria mentioned in Table 3.2 had been assessed. Only those candidates who could understand and participate had been considered.

Table 3.2: Descriptive Anchor Ride Quality Index with Examples

Rating	Descriptive Anchor with Examples
5 – Very Good	**Negligible severity**: The ride shall be smooth throughout the segment. Vertical vibrations are barely perceptible and do not affect occupant comfort. **Example**: Newly constructed or well-maintained asphalt pavement where the vehicle glides smoothly with no noticeable bouncing or jolts at normal operating speed.
4 – Good	**Low severity**: Minor vertical vibrations are perceptible at isolated locations, but overall ride comfort remains satisfactory. **Example**: Pavement with occasional shallow patches, minor undulations, or slight settlement where brief vibrations are felt but quickly dissipate.
3 – Fair	**Moderate severity**: Vertical vibrations are clearly perceptible and occur repeatedly or continuously; ride comfort is reduced but remains acceptable. **Example**: Pavement exhibiting moderate roughness, frequent patching, or mild corrugation where occupants feel continuous vibration but can travel without significant discomfort.
2 – Poor	**High severity**: Frequent and pronounced vertical vibrations occur over a substantial portion of the segment, resulting in uncomfortable riding conditions. **Example**: Pavement with severe roughness, uneven patches, or depressions causing noticeable bouncing that forces occupants to brace themselves or reduce travel speed.
1 – Very Poor	**Very high severity**: Severe, continuous vertical vibrations dominate the segment and produce an unacceptable level of ride comfort. **Example**: Highly deteriorated pavement with deep potholes, severe rutting, or broken surface where travel is difficult and ride comfort is unacceptable even at low speeds.

c. Panel Training and Orientation Procedure

Afterwards, a systematic method for conducting the training for the exercise before the survey in the field was adopted to make sure that all the panelists have the same knowledge about the procedure of the RQI exercise so that the exercise can be conducted in an impartial way when collecting data. First of all, a briefing was organized to enlighten all the participants on the purpose of conducting the whole activity as well as the need to measure the riding quality when doing the pavement analysis. In this regard, the significance of RQI, as well as other related concepts like RMS and PCI, was introduced to them. This is followed by a detailed explanation of the criteria used to determine the scores on the RQI scale (0 to 5). All five rating scales, ranging from Very Poor to Very Good, have been explained with defined anchors based on the severity and frequency of vibrations in a vertical direction. Real-life instances of the state of the road surface have also been presented under each rating scale.

In addition, there was the demonstration stage where trials were conducted in selected sections of the road around Hetauda. As far as the pilot study was concerned, the participants had to go through different levels of paving quality of the road and had to score them based on the assigned scale. This would make them familiar with the theoretical side of the concept. Furthermore, in order to maintain consistency, a calibration process was carried out where all the participants assessed the same road sections in identical conditions. Comparison was made among their results and if there was any variation, then it would be sorted out by discussion about the standards of evaluation and scoring. Finally, guidelines for field data recording were also clearly laid out to the panelists. All the panelists were well-informed about the correct procedure of rating the segments right after analyzing each one of them, thus being independent in their ratings as well as standardized in the process of documentation of the same. Importance was placed on ensuring the correct speed control of the vehicles during the evaluations.

d. Ride Survey Protocol

In the present experiment, the survey procedure was standardized as a means of ensuring that the data collection process remained consistent, thus eliminating any form of variability when evaluating the subjective aspects of the ride quality in the selected section. In the present experiment, a standard suspension four wheeled was used as the survey vehicle. This was meant to prevent any effect of the suspension system on the evaluation of ride quality. All participants were provided with fixed seats in the selected vehicle throughout the survey process in order to avoid any form of variation in the observations caused by the position of the seating position. Seats such as the front passenger seat, driver seat and the three on both side and middle at the rear of the car were chosen. The test vehicle was travelled in a steady speed range between 30-50 km/hr throughout all the road sections. The above mentioned speed range had been determined from previous studies (HDM-4, 2002), in which it was observed that this speed range was good enough in minimizing the vibrations induced by the movement of the vehicle itself and at the same time enable the pavement surface irregularity vibrations to be experienced. It is vital to travel the vehicle in a steady speed when assessing the riding quality since the variation in speed will lead to inconsistencies in evaluating the riding quality.

The road sections were divided into segments of equal lengths (0.5km). The riding quality of each part of the road was assessed individually. As the vehicle moved through each segment, each panelist would assess the riding quality based on the vibration and comfort level felt while travelling through the segment. To ensure minimal errors in the assessment process, it was suggested that the panelists should write down their assessments right after finishing the assessment of the segment. The panelists were provided with datasheets in which they were supposed to write down their assessments, together with the segment identification number and its corresponding.

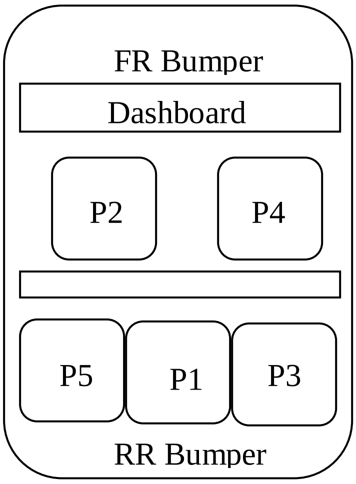

Figure 3.4: Typical Layout of the Panel Member placement inside car

e. Data Recording and Average RQI Computation

The pilot survey initially used structured panel rating approach where five different panels were considered including that of surveyor, highway engineer, driver, frequent local user, and senior citizen. Guidelines on various forms of distresses on asphalt pavements, distress level, and distress density as well as standard ride quality rating criteria that range from very good, good, moderate, poor, and very poor have been provided to all participating panel members. The trainer instructed the driver to drive continuously within a speed limit of 30-50 kmph on a certain section of the road, while other panels including driver individually assessed ride quality based on their experience inside the car. Technical experts and road users were required for the unbiased, objective, and accurate assessment process that takes into account expert opinion and comfort level of ordinary passengers on the road networks. These subjective evaluations were subsequently aggregated to compute the Average Riding Quality Index (RQI) for each road segment considered in the study.

The rating scores of the panelists were then systematically encoded in the MS Excel application on a segment-by-segment basis for better organization and traceability of the data. The RQI score per segment was calculated based on the average of the scores of the panelists for each particular segment. For the further analysis of the data, the scores were normalized between 0-1 based on Equation 3.1 below:

$$RQI_{norm} = \frac{RQI_{raw}}{5} \quad \text{...} (3.1)$$

3.1.3. Vertical Accelerometer-Based Ride Quality (RMS_RQI Method)

a) Sensor Setup

The smartphone, with the tri-axial accelerometer sensor, was mounted in the vehicle by mounting on the floor of the car just above the rear axle, and at three different locations such as in front of the front passenger seat, in the rear left seat, and in the rear right seat location. The data from all three smartphones, with the Phyphox app installed in the car, for vertical acceleration was exported to .csv file for data analysis.
The **Phyphox** app (RWTH Aachen University) will be used to log:

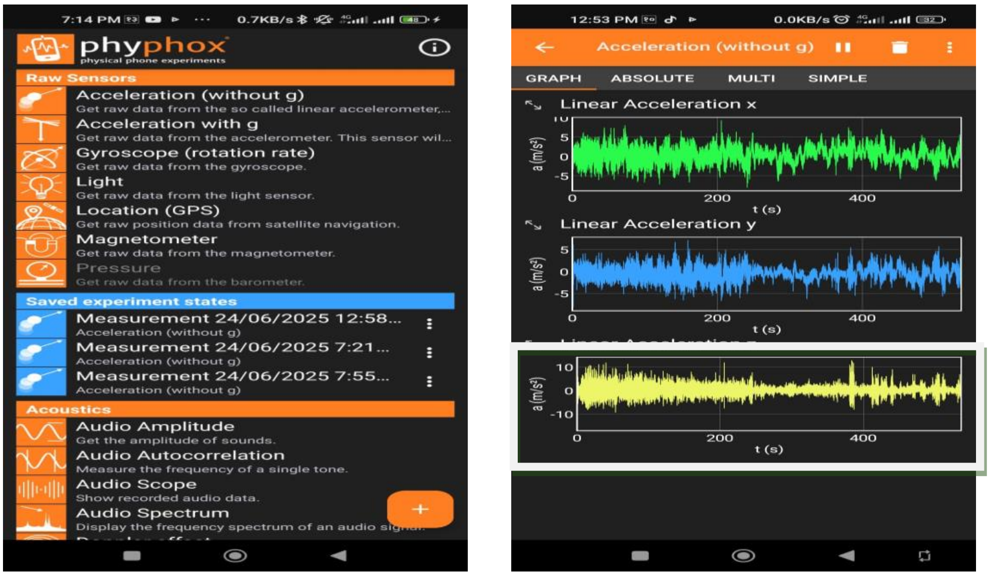

Figure 3.5: Interface showing the RMS_RQI Data collection from Phyphox Application

- Time
- Acceleration in the X, Y, and Z directions
- Sampling frequency: at least **100 Hz**, ensuring sufficient resolution for road surface vibrations.

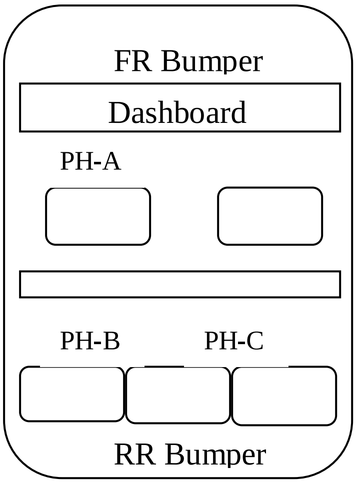

Figure 3.6: Typical Layout of the Sensor placement inside car

b. Data collection, Signal Processing and RMS Calculation Procedure

Data acquisition for vibrations was carried out constantly throughout the entire road stretch in order to obtain the data on vertical vibration response. Manually, the signaling of each road segment was made using the blasting of a horn so as to synchronize the data collection process with spatial data acquisition. The vibration data collected was then exported in CSV file format and analyzed using Microsoft

Excel software. The vibration data along the Z-axis was analyzed because the Z-axis was the one that was mostly influenced by the road vibrations.

Filtered acceleration values were next used to determine RMS for each of the segments. It was determined that the most appropriate value that could be used as the roughness measure would be RMS because it is a solid statistic that describes vibration intensity in the segment without being influenced by any peak acceleration value at any moment in time. Different from maximum and instant acceleration measures, RMS does not depend on any peak values within short periods of time and can be considered adequate in evaluating ride comfort according to human perception. Arithmetic mean was not selected as a method for calculation in this case because vertical acceleration contains both positive and negative values depending on the dynamics of the vehicle. Therefore, simple mean calculation will result in errors as two values will neutralize each other.

The RMS value has been calculated using:

$$RMS = \sqrt{\frac{1}{n} * \sum_{i=1}^{n} a_{i}^{2}} \quad \ldots\ldots(3.2)$$

Where ai is the filtered vertical acceleration and n is the number of samples in the segment.

c. Normalization and Scaling

The vibration data recorded using the Phyphox app was later exported and analyzed systematically on the Microsoft Excel spreadsheet to determine the RMS value of RQI for every pre-determined road section. The Root Mean Square (RMS) value was computed based on the filtered vibration data of vertical acceleration of the vehicle. The RMS value was regarded as an appropriate objective index for assessing the quality of ride for every individual road section. The normalized value of RQI was subsequently determined based on the RMS value obtained.

Since the RMS represents the measure of vibration intensity, high RMS indicates low ride quality. To normalize the data, which was performed at the outset, we employed the equation below, converting the measure into a dimensionless scale between 0 and 1:

$$RMS_{norm} = \frac{RMS_{max} - RMS}{RMS_{max} - RMS_{min}} \quad \text{...}(3.3)$$

Here RMS_max and RMS_min are maximum and minimum RMS values that have been calculated from all the segments, respectively. It is ensured by this method that number 1 represents the best case of road surface quality while number 0 represents the worst case of the quality of the road surface due to vibration, just like RQI.

Subsequently, the normalized values were linearly rescaled to match the 0–5 RQI framework using:

$$RQI_{rms} = 5 \times RMS_{norm} \quad \text{...}(3.4)$$

As a result, it became possible to perform comparative analysis of objectivity-oriented RMS measurement of ride quality with subjectivity-oriented RQI measurement of ride quality. The process of normalization and scaling ensured that consistent results were achieved, unit independent results were derived, and the two measures of ride quality could be combined effectively.

3.1.4. Hybrid RQI Computation

For the combination of human perception and car vibration response, there was a design of a method for RQI which used panel rating and vibration response RMS, called the Hybrid RQI. The reason why such a method is used is to enhance the efficacy of RQI using the benefits of both panel and RMS. Firstly, the RQI values obtained from the panels needed to be standardized to a range of 0 to 1 for ease of comparison with the objective database. In addition to that, the RMS-derived RQI values, which had already been converted to a comparable range of 0 to 5, were employed as an objective criterion for assessing ride quality.

The Hybrid RQI is expressed as:

$$Hybrid_{RQI} = w_1 \times RQI_{Panel_{norm}} + w_2 \times RQI_{rms} \quad ……………………………(3.5)$$

Where:

$RQI_{Panel_{norm}}$: normalized average panel score (0 to 1)

RQI_{rms}: RMS-derived score (already scaled between 0 to 1)

Weights w_1 and w_2 are tentatively 0.80 and 0.20, respectively, reflecting a higher reliance on subjective human perception while still incorporating objective vibration measurements for improved reliability and reduced bias.

The rationale for increased weight given to the panel data was due to the fact that ride quality is inherently a subjective criterion because it involves human perception, whereas RMS is an objective criterion that can be used to quantify the vibration caused by the road surface. In using the RMS data in computing the index, it adds stability to the index because it is an objective criterion. This way, we are sure that our hybrid ride quality index contains all the criteria of ride quality evaluation.

3.1.5. Panel Rating Reliability: Intra-class Correlation Coefficient (ICC)

Intra-class Correlation Coefficient (ICC) had been calculated using **SPSS** to measure inter-rater reliability of the panelists. The two-way random effects model ICC (2, k) had been appropriate as all segments were rated by all of the raters:

$$ICC(2,k) = \frac{BMS-EMS}{BMS+(k-1)EMS+\frac{k(JMS-EMS)}{n}}$$

…………………………………..……….(3.6)

Where:

- BMS = Between-targets (subjects/segments) Mean Square
- JMS = Between-raters Mean Square
- EMS = Error Mean Square
- k = number of raters
- n = number of segments

Interpretation follows Koo & Li (2016):

- **ICC (2, k) > 0.75** = good reliability
- **0.5 <= ICC (2, k) < 0.75** = moderate
- **ICC(2, k) < 0.5** = poor reliability

Immediately after collection of all the segments by all the panel members at once, data was then entered into excel in order to conduct the analysis further. Initially, for testing the reliability among raters, data was then entered into SPSS software and subjected to two way random effect analysis model.

3.1.6. PCI Survey and Evaluation

Assessment of the Pavement Condition Index (PCI) is one procedure that aided in analyzing the condition of the pavement through visual inspection for any distress in the pavement. The PCI index score was assigned as a means of evaluating the state of the pavement. The PCI score ranged between 0 and 100 where higher numbers showed good pavement condition while lower scores showed poor pavement condition.

In this research, the PCI assessment of the selected portions of the Pathlaiya-Hetauda road corridor is conducted in accordance with the criteria for pavement condition assessment outlined in the ASTM D6433 07. A visual inspection was conducted on the pavements to determine different types of distress existing, such as cracking, potholes, rutting, raveling, and patching. Different types of distresses are identified with respect to their levels of distress (low, moderate, and high) and the frequency of their occurrence.

These sub-divisions were then further broken down into small sample areas. The nature of the distresses, along with their frequencies and levels, was recorded. Based on the data collected from the observations, the deduct values were determined based on the PCI scoring chart. The deduct values indicate the influence that each distress exerts on the general condition of the pavement. Where there were two types of distresses in one sample area, the correct deduct value (CDV) was determined.

Lastly, the PCI score for each sample was determined by subtracting the deduction score from the highest score of 100. The PCI scores that were derived above helped classify the status of the road surface into either excellent, good, fair, poor, and failure. In this case, the PCI scores served as the benchmark indicator, which provided an opportunity to validate the ratings of RQI panel and RMS smartphone data.

3.1.7. Statistical Analysis and Model Validation

The statistical analysis has been performed to examine the relationship between PCI, RQI, based on subjective rating of panels, RMS_RQI, and the Hybrid RQI technique. The purpose of performing this kind of analysis is to validate the proposed pavement condition index system.

a. Correlation Analysis

A correlation analysis was performed to ascertain the relationship between the independent variable and dependent variables employed in this research paper. The Pearson Correlation Coefficient (r) was applied in measuring the correlation coefficients for the relationships among selected linear variables. The correlation coefficient can be measured within -1 and +1; where values closer to +1 denote strong correlation relations while those close to zero imply weak correlation relationships. A correlation analysis was performed in this paper on the basis of the correlation between Pavement Condition Index (PCI) and Ride Quality Indicators (RQI) collected from a field survey. Correlations were checked for PCI versus Panel RQI, PCI versus RMS-RQI Acceleration Value, PCI versus Hybrid RQI. The above analysis was performed using paired observation data for each pavement segment analyzed in this paper. The purpose of performing the above correlation analysis was to ascertain if there is any variation in pavement conditions and ride quality indicators.

b. Regression Analysis

A regression analysis was conducted to examine the influence of PCI on the ride quality indices used in this study. Linear regression models were constructed to analyze the predicting power of Panel_RQI, RMS_RQI acceleration, and Hybrid_RQI in predicting PCI scores. The above analysis was conducted based on the set of data obtained from each section of the road corridor under examination. The coefficient of determination (R^2) was used to evaluate the strength of prediction of the linear regression model. When R^2 is greater than zero, it gives an indication of the amount of the explained variance between the dependent and independent variables.

c. Intra-class Correlation Coefficient (ICC) Analysis

The Intra-Class Correlation Coefficient (ICC) technique was used in order to determine the reliability and consistency of the ratings that had been obtained using the panel ratings in the ride quality study. Since there were multiple panelists involved in the evaluation of the segments, ICC was used in order to establish the level of consistency between the different raters. The two-way random effects model with absolute agreement ICC was applied, which is used in the determination of reliability where more than one observer is involved. The ICC was conducted using the ratings that were obtained from the panel members for all segments included in the study.

d. Model Validation

The validation of the model was done in order to evaluate the effectiveness of the ride quality indices generated within the framework of this study. The process of the model validation involved using the paired data of the pavements and comparing them with regards to the Panel_RQI, RMS_RQI acceleration, and Hybrid_RQI models in comparison to the PCI values. This decision was taken since the PCI is an indicator of the physical state of the road pavement assessed visually. The technique of regression analysis was used during the model validation process to identify the relation between the ride quality index and the PCI. The outcome of this procedure would be indicative of the efficiency of the generated index in terms of evaluating the state of the pavement.

CHAPTER 4

4. RESULT AND DISCUSSION

4.1. Overview of Pavement Condition Evaluation

This section shows the results of this study conducted on the Pathlaiya to Hetauda stretch of road whose results were obtained after conducting field surveys and performing statistical analyses for the purpose of assessing the riding quality on the road. This study has used three pavement conditions indices for the assessment of riding quality which are namely Panel-based Riding Quality Index (Panel RQI), RMS based RQI using smart phone and PCI.

This section of the road had been subdivided into various segments in order to make it easier for the panelists to collect and analyze information about the condition of the roads. Each segment was evaluated separately based on the comfort level associated with driving on each individual segment, and the smartphone measured the vertical acceleration data. These data would later be used to calculate the RMS RQI values that would indicate the pavement roughness. The PCI test was conducted using the visual method according to the ASTM protocol.

As such, the database made it possible to conduct comparisons among three different types of pavement condition assessment methods, which include assessment through perception (Panel RQI), vibration assessment (RMS RQI), and distress assessment method (PCI). Some of the statistical analyses that were conducted in order to prove the validity of the methodology include regression analysis and ICC analysis.

4.2. Panel-Based Riding Quality Index (Panel RQI)

The panel rating approach has been used in the past as a subjective approach for the assessment of pavement riding quality according to user perception on the Pathlaiya-Hetauda road corridor. Five panel members have been selected from various categories such as surveyors, highway engineers, drivers, passengers, and an old person in order to ensure a well-represented sample that would include both technical knowledge and user experience. Training was provided to each panel member prior to conducting assessments in the field in accordance with established standards for the five levels of RQI scale (very poor to very good).

The whole survey area was divided into predefined road segments, labeled S1 to S124, and each road segment was evaluated individually. During the passage through each road segment, the road segment was evaluated by the panelists while moving through the predefined road segment with the standard four-wheel passenger car moving at a constant speed range of 30–50 km/hr. Evaluation was done immediately after the completion of the passage of the car through that particular road segment. The evaluation of each road segment was done independently by each member of the panel without any discussion after traveling each 0.5km road segment. Subsequently, individual evaluations were evaluated and the average of these evaluations provided the Panel RQI value of each road segment, which was normalized to a scale of 0-1 by applying Equation 3.1. (refer Annexure-1).

It was evident from the analysis that there was high spatial variation in the quality of rides along the corridor, and this was further confirmed by the directional comparison of road conditions. In the Hetauda to Pathlaiya direction, a relatively higher number of segments were rated as Very Good (34 segments) and Good (22 segments). On the other hand, the Pathlaiya → Hetauda direction had relatively lesser segments which were rated as Very Good (27 segments) and Good (11 segments) but more segments which were rated as Fair (18 segments) and Poor (6 segments). It clearly indicated that the ride quality along the Pathlaiya → Hetauda direction was relatively lower than that in the opposite direction due to poor surface quality. It is worth noting that none of the segments fell under the category of Very Poor in both directions.

Panel plots (P1-P5), illustrated in Figure 4.1, demonstrate consistent individual responses from the panellists in view of the similarity in the trend lines of rating curves in each segment, despite small variations in magnitude. This consistency shows the validity of the panel-based analysis approach. Coinciding dips in the ratings for all panellists distinctly indicate the significant segments, which are characterized by poor ride quality, while higher ratings indicate generally satisfactory conditions of the pavement. Consistent outcomes provide confidence that variations in measurements were due to varying pavement conditions and not personal perceptions. RQI values approaching unity have been observed in pavements with fewer vibrations. RQI values close to zero have been identified in segments with surface distress, such as potholes, rough pavements, deteriorating patches, and settlement.

In general, the panel-based assessment of the RQI is effective in representing the usability of the pavement according to the user's point of view. The integration of the directionality analysis reveals the changes in ride quality within the corridor, hence enabling one to get more details about the performance of the pavement. The raw scores (0 to 5) and normalized scores (0 to 1) of the RQI provide a very good database for incorporating the objective measurement from the RMS and confirming the ride quality.

Moreover, the panel ratings were similar for all the participants, as indicated in the reliability test provided in this study. The similarity of the ratings by the panel members proves that the panel-based RQI approach provides accurate results when the evaluators comply with the suggested guidelines and receive proper training.

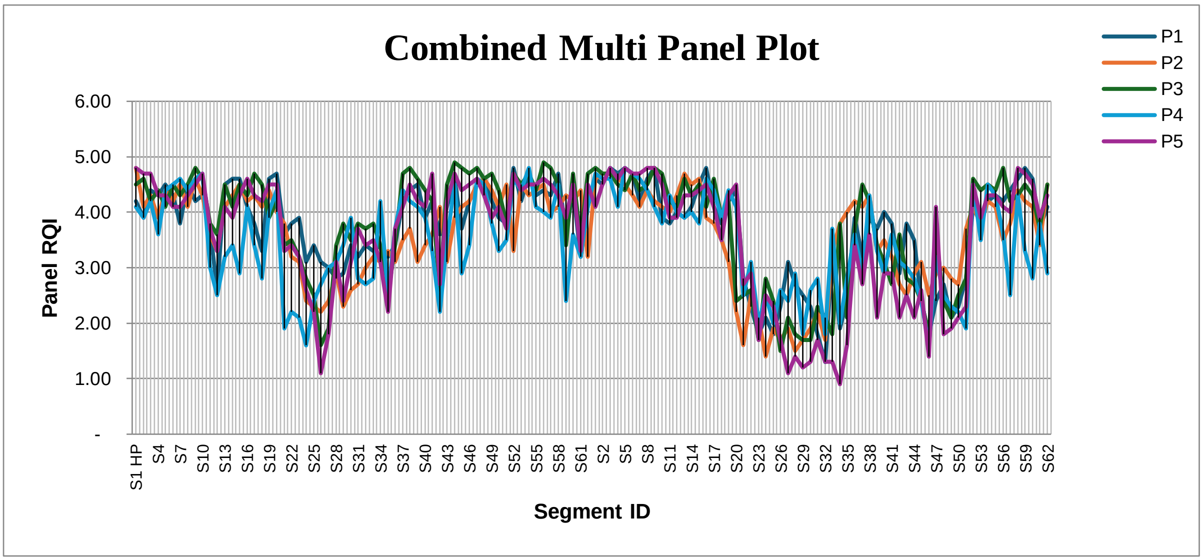

Figure-4.1: Combined Multi Panel Plot

4.3. Reliability Analysis of Panel Ratings (ICC)

Because panel-based evaluation involves subjectivity to a great extent, it is important to ensure the consistency of ratings given by the panel. Reliability of ratings provided by panel members was assessed by Intra-class Correlation Coefficient (ICC), applying two-way random effects model. Table below (Table 4.1) represents the results of case processing and reliability statistics for panel ratings of Ride Quality Index (Panel RQI). As seen from the table below, the total number of valid cases was used for calculating reliability statistics. These cases represent ratings provided by all members of the panel with regard to all road segments evaluated. All cases were included into the calculation of reliability statistics which means that no case has been excluded from the analysis.

According to reliability statistics, there is high consistency in panel member ratings when assessing the ride quality of road segments. Such consistency in the panel ratings indicates that the whole process of rating has been conducted properly, and all rating criteria have been applied consistently.

Table 4.1: Case Processing and Reliability Statistics

Case Processing Summary

		N	%
Cases	Valid	124	100.0
	Excluded[a]	0	.0
	Total	124	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.939	.940	5

The results of the Intra-class Correlation Coefficient (ICC) test done to measure the reliability and consistency of ride quality ratings provided by the panel have been presented in Table 4.2 below. The result of the ICC test carried out in this study reveals that there is an ICC value of 0.939 showing a very high level of agreement among the ratings of panel members. According to reliability standards of Koo & Li (2016), ICC values of greater than 0.75 show good to excellent reliability.

An ICC value of 0.939 in this study means that there is a high degree of agreement in the ride quality ratings given by panel members. Thus, this means that the technique used in this study for ride quality ratings is reliable statistically. Variability in Panel_RQI ratings in this case arises from the differences in pavements. In Conclusion, from the above discussion, it is clear that the panel technique used in this study for rating pavements is statistically reliable.

Table 4.2: Intra-class Correlation Coefficient

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.754[a]	.697	.807	16.336	123	492	.000
Average Measures	.939	.920	.954	16.336	123	492	.000

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

4.4. Smartphone-Based RMS Acceleration Analysis

Objective ride quality measurement of the pavement was done based on the information obtained from the vertical acceleration of the smartphone. The accelerometers present in smartphones were placed in the surveying vehicle in three different positions including the front passenger seat position, the second one being rear left passenger seat position, and the third one at rear right passenger seat position. Data collected using the accelerometers in the 124 road segments was used to calculate the vertical acceleration data which would determine the vertical acceleration of the car caused by the irregularities on the pavement. As a result of the acceleration being very vulnerable to noise caused by vibration from the engine or other sources of noise, the data collected was filtered using the Butterworth low-pass filter. Once the signals have been filtered, the Root Mean Square (RMS) of the vertical acceleration for each segment and phone ID was calculated. The average of the RMS values of each phone ID was calculated to get the average RMS value, hence normalizing using equation 3.3 and 3.4 whose calculation table is attached in annexure 4.2. The RMS value refers to the value representing the amount of vibration of the car on the particular segment. High RMS values mean high vibration and rough pavements, while low RMS values imply smooth pavements.

It is important to note that the RMS values computed from the survey exhibited variations in terms of the vibrations. Low RMS values were recorded when there were smooth pavements as there was minimum vibration within the car. Conversely, high RMS values were recorded for rough pavements because of high vibrations. While the use of RMS values provides a good representation of the roughness of the pavements, it should be noted that there are certain pavement distresses that cannot be identified by means of this parameter. Some of them may not generate high vertical vibrations but still deteriorate the pavements. Therefore, while the RMS values accurately represent the roughness of the pavements, they do not provide a full assessment of the performance of pavements.

The chart presented in Figure 4.2 illustrates an analysis of the pavement ride quality based on the values of RMS calculated for Phone A, Phone B, and Phone C and their averages. As can be seen, there is a clear trend of variation of RMS values depending on segment ID. Thus, it can be argued that the variations of the RMS values were not due to mistakes made during measurements but were actually generated by variations in the road conditions. However, it should also be pointed out that using smartphones for measuring RMS values has several benefits as well. Namely, the procedure is quick, cost-effective, and simple.

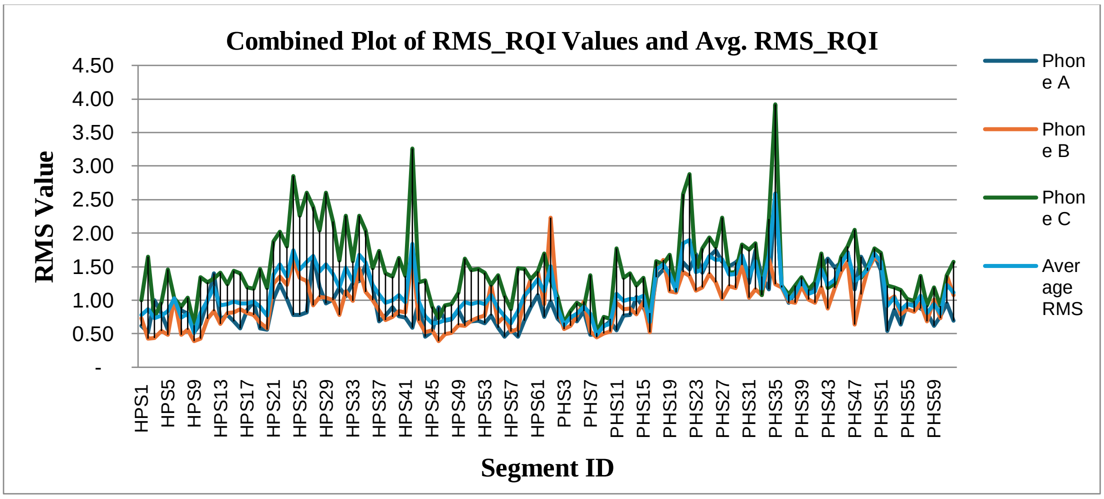

Figure 4.2: Combined Plot of RMS_RQI

4.5. Hybrid Riding Quality Index (Hybrid_RQI)

Hybrid_RQI index was developed by merging panel subjective assessment scores and RMS objective vibration measurements of the pavements. In such a way, the positive attributes of both subjective and objective methods of assessing the condition of pavements on the basis of the perceived ride quality and physical vibration, respectively, are used.

In the current study, the Hybrid_RQI index is the summation of the normalized panel assessment scores and RMS_RQI indices with their corresponding weights. Panel assessment score was provided a bigger weight because of its strong correlation with the condition of the pavements as w_1=0.80. RMS indices with weight of w_2=0.20 are objective measures of pavement surface roughness.

The values of Hybrid_RQI index are estimated for all segments using Eqn. 3.5. Higher Hybrid_RQI values are indicative of good ride quality and lack of vibrations on pavements, whereas lower Hybrid_RQI values show that pavements have bad ride quality and high vibrations.

The proposed hybrid technique allows making more accurate estimates of pavement condition than the subjective and objective methods separately. By integrating these two components, the Hybrid_RQI model offers a balanced representation of pavement performance.

4.6. Computation of Pavement Condition Index (PCI)

Pavement Condition Index (PCI) computations on the study sections were carried out based on the standardized procedure presented in ASTM D6433 (2007). The method used to calculate PCI involved systematically assessing and measuring distresses identified on the pavement based on their types, intensities, and extents. PCI calculation involved four steps, which included pavement segmentation, assessment of distress densities, estimation of distress values, and finally, making corrections to get the final value.

In calculating PCI for this study, a representative sample from the selected corridor of 10km length was used. The sample contained 40 road segments whose PCI was calculated using the procedure presented in ASTM D6433 (2018). The selection of length and number of road segments for PCI calculation was made with the objective of ensuring practicality and variations in pavement conditions. From this observation, it became evident that the PCI values obtained differed from one segment to another, indicating that the condition of the pavement on the route was not homogeneous. The PCI values ranged between low and high, indicating that the pavement had varied surface damage conditions. High PCI values indicate a minimum level of distress elements on the pavement segment. Low PCI values, on the other hand, indicate that there are many distress elements such as cracks, patches, potholes, and surface wear on the segment.

In consideration of figure 4.3, showing the plot of PCI value in respect of the total of 40 segments of the pavement, it is clear that the pavement condition is excellent since most of the PCI value lies between 0.80 to 0.92. But on the observation of the above figure, it becomes evident that this is not true with all the segments since there are few instances where the PCI values decrease in segment numbers 11 and 37 lying between the range of 0.60 to 0.65. This might imply that there are some segments along the highway with few defects such as potholes, cracks, and other patches. It is seen that the PCI values are relatively high, from 0.92 to 0.94, for segments falling within the range 20 to 30.

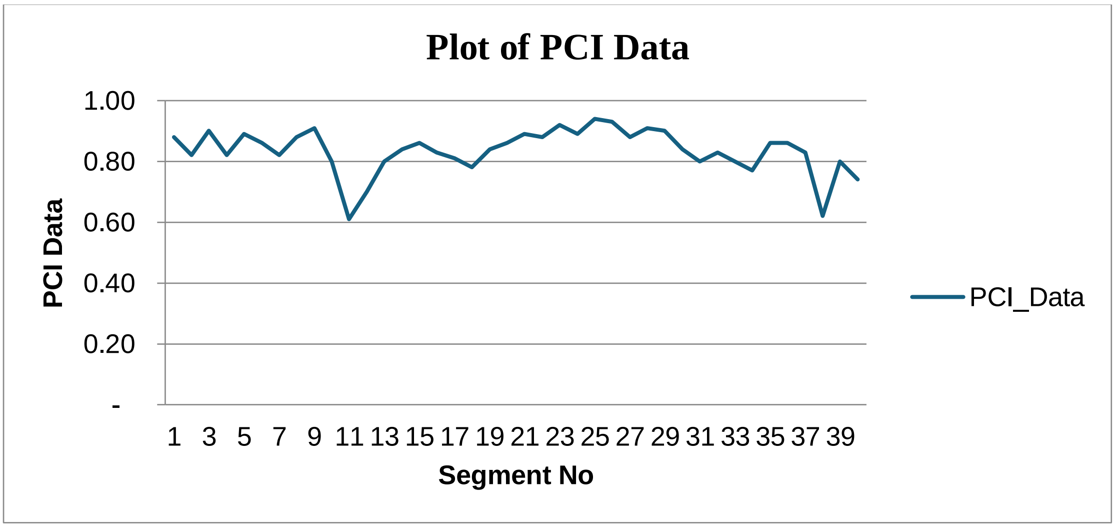

Figure 4.3: Plot of PCI Data

4.7. Model Analysis and Validation with PCI

In determining the reliability of RQI-based assessment techniques, the PCI has been employed as the standard index. PCI is an acceptable method for evaluating the condition of pavements that relies on the actual state of the pavement surfaces assessed visually based on factors like cracking, potholes, rutting, and raveling.

Regression analysis was applied in order to determine the relationship between PCI and the three indicators analyzed in this study, which include Panel_RQI, RMS_RQI, and Hybrid_RQI.

4.7.1. Pavement Condition Index (PCI) and Panel_RQI

From the regression analysis of the output results, it is clear that the correlation between PCI and Panel_RQI has yielded an estimate of coefficient of determination of: **$R^2 = 0.7169$** and the fitted equation**:**

PCI = 0.911*(Panel_RQI) + 0.0634 …………………………………………..(4.1)

In other words, PCI and Panel RQI are directly proportional to each other; hence, PCI can be said to be consistently proportional to user-perceived ride quality. As seen from the results in Table 4.3 and graphed in Figure 4.4, about 71.7% of the variations in PCI have been accounted for by Panel RQI; thus, a relatively high level of correlation can be deduced to exist between the two variables. It can also be noted that the relationship between the two variables is relatively good as denoted by the Multiple R, which is around ~0.847. Additionally, the statistical model has proved to be significant since its probability (P-value) is well below the cut-off point: $5.8 \times 10^{-12} \ll 0.05$. Finally, the model has a low Standard error of ~0.039.

It is evident from the results above that there is an evident positive relationship between the ride quality ratings based on the panel and the condition of the pavements. It is evident that there is a strong relationship between the human ride quality ratings and the distress condition of the pavements as captured through PCI. With increased pavement distress, both PCI and ride quality scores decrease.

Table 4.3:Regression Analysis Between PCI vs Panel_RQI

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.846729753							
R Square	0.716951274							
Adjusted R Square	0.709502624							
Standard Error	0.03919071							
Observations	40							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	0.147835353	0.14784	96.2525	5.7892E-12			
Residual	38	0.058364647	0.00154					
Total	39	0.2062						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.063392015	0.078892278	0.80353	0.42667	-0.096317051	0.223101081	-0.096317051	0.223101081
Panel_RQI	0.910989356	0.092855426	9.81084	5.8E-12	0.723013376	1.098965337	0.723013376	1.098965337

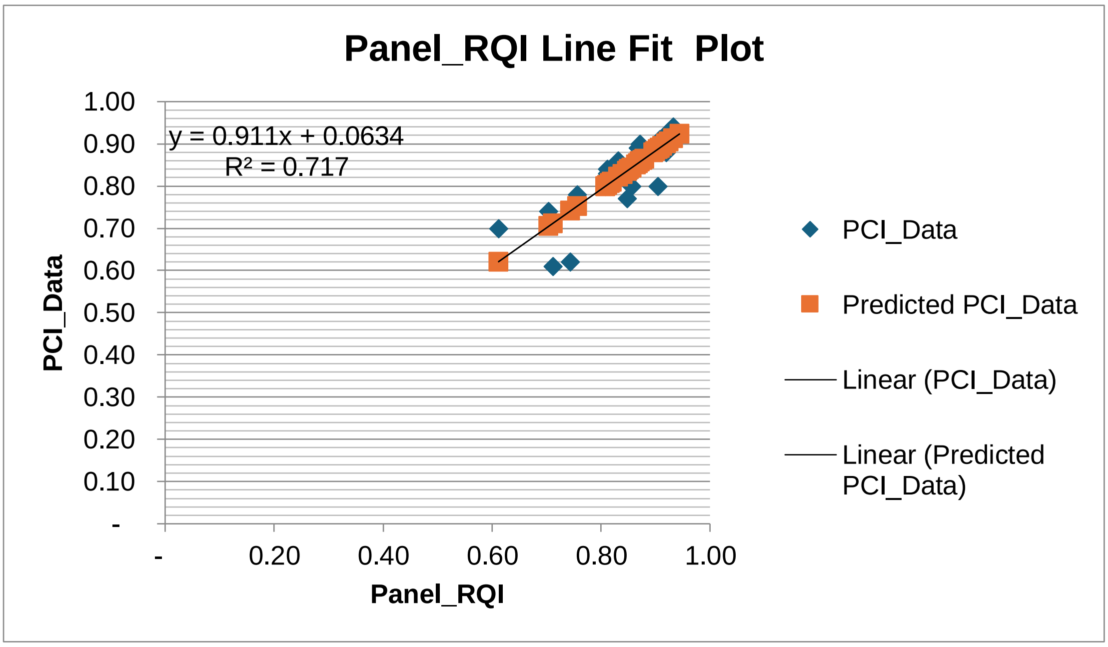

Figure 4.4: Plot Between PCI vs Panel_RQI

4.7.2. Pavement Condition Index (PCI) and RMS_RQI

The relationship between **PCI and RMS acceleration** produced a lower coefficient of determination of: **R^2 = 0.3842** and the fitted equation for

PCI = 0.6384*RMS_RQI + 0.2947 ……………………………………………...(4.2)

From the relationship between normalized inverted RMS_RQI and PCI, we observe a positive correlation which clearly indicates that ride quality improvement is related to the condition of pavements. An intercept of 0.2947 is required for the regression equation which is the regression constant required in estimating the best fit for the graph but does not mean any physical state because there was no zero value for ride quality recorded in our sample data set. Since no value close to zero was found in the sample data set, we can easily conclude that the value of the intercept was derived out of the sample data set hence having no physical meaning. The coefficient of determination, $R^2 = 0.3842$ indicates moderate correlation.

Table 4.4: Regression Analysis between PCI vs RMS_RQI Data

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.619852068							
R Square	0.384216586							
Adjusted R Square	0.36801176							
Standard Error	0.057805149							
Observations	40							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	0.07922546	0.079225	23.71001	1.99545E-05			
Residual	38	0.12697454	0.003341					
Total	39	0.2062						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.294742656	0.111327734	2.647522	0.011739	0.069371444	0.520113869	0.069371444	0.520113869
RMS_Data	0.638413183	0.131110051	4.869292	2E-05	0.372994763	0.903831603	0.372994763	0.903831603

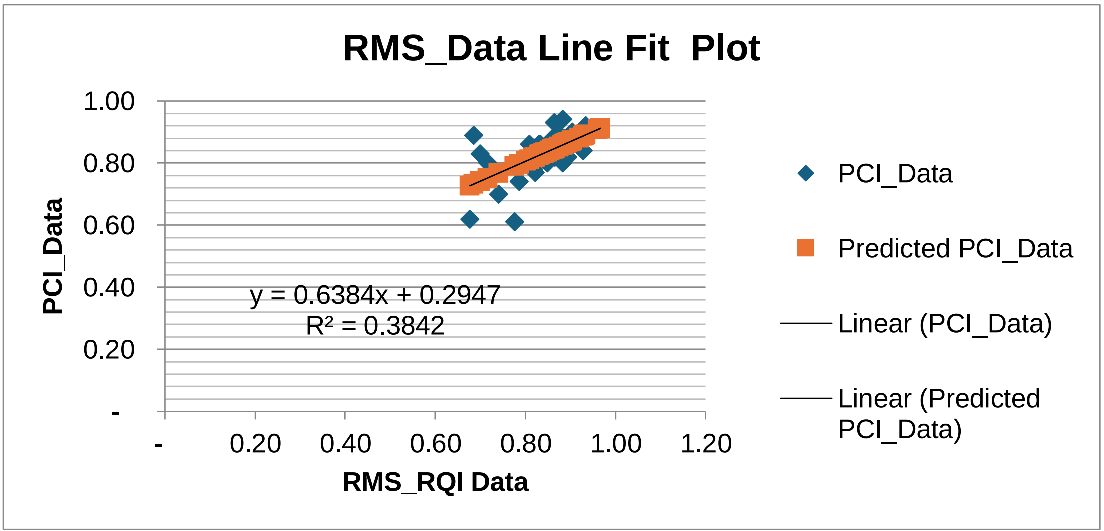

Figure 4.7: Plot Between PCI vs RMS_RQI Data

4.7.3. Pavement Condition Index (PCI) and Hybrid RQI

The relationship between normalized PCI and Hybrid RQI respectively produced the highest coefficient of determination at the optimal weighted factors $w_1\ and\ w_2$. The iterative for the model optimization have been worked out as under:

1. When $w_1 = 0.69\ and\ w_2 = 0.31$

The relationship between normalized PCI and Hybrid RQI respectively produced the coefficient of determination of $\mathbf{R^2 = 0.7347}$ and the fitted equation is

PCI = 1.007*(Hybrid RQI) – 0.0177 ……………………………………………(4.3)

The regression analysis done for normalized PCI versus Hybrid RQI, where Hybrid RQI has been allocated the two weight factors, shows that there exists a high positive correlation between pavement condition index and Hybrid RQI. As seen from the slope, 1.007, we realize that the relationship is almost exact and that any alteration on the value of hybrid RQI is directly proportionate to an alteration on the value of PCI. The small value of intercept factor of -0.0177 implies that there is no systematic error involved in the regression equation and hence physically consistent since both PCI and hybrid RQI approach zero with deterioration in pavement condition.

The coefficient of determination (R^2) is 0.7347 and means that there is 73.47% variance in the normalized PCI values accounted for by the Hybrid RQI values (table 4.5 & fig. 4.6).

2. When $w_1 = 0.70\ and\ w_2 = 0.30$

The relationship between normalized PCI and Hybrid RQI respectively produced the coefficient of determination of $\mathbf{R^2 = 0.7362}$ and the fitted equation is

PCI = 1.0065*(Hybrid RQI) – 0.0173 …………………………………………..(4.4)

Table 4.5: Regression Analysis between PCI vs Hybrid RQI (w1=0.69 and w2 = 0.31)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.86
R Square	0.73
Adjusted R Square	0.73
Standard Error	0.04
Observations	40.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	0.15	0.15	105.25	0.00
Residual	38.00	0.05	0.00		
Total	39.00	0.21			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	(0.02)	0.08	(0.21)	0.83	(0.19)	0.15	(0.19)	0.15
Hybrid_RQI, w1=0.69 and w2=0.31	1.01	0.10	10.26	0.00	0.81	1.21	0.81	1.21

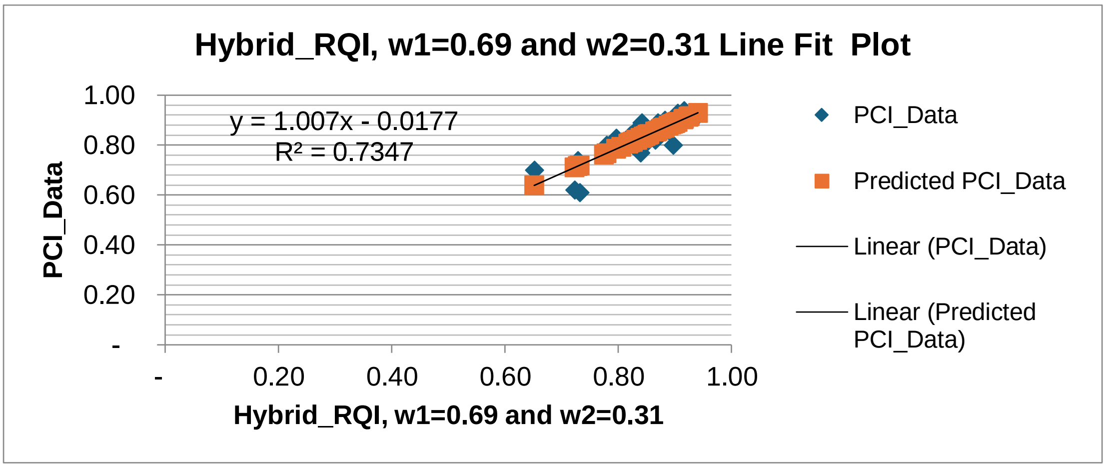

Figure 4.6: Plot of PCI Vs Hybrid RQI for $w_1 = 0.69\ and\ w_2 = 0.31$

From the regression analysis of normalized PCI against Hybrid RQI, (w_1=0.70, w_2=0.30) there is a strong positive correlation between road pavement conditions and the hybrid ride quality index. As illustrated by the slope of 1.0065, there is a nearly proportionate correlation between the two, suggesting a similarity in change between the hybrid index and the road conditions of interest. As indicated by the intercept value of -0.0173, the regression line is nearly zero, implying no major bias in the regression equation used for the analysis. Therefore, the physical relationship between the variables is maintained since both tend towards zero at extremely poor road conditions. The coefficient of determination (R^2 = 0.7362) reveals that 73.62% of the variability of normalized PCI can be explained by hybrid RQI as demonstrated by table 4.6 and figure 4.7 below. There is thus a high level of correlation between hybrid RQI and normalized PCI in explaining the condition of pavements.

Table 4.6: Regression Analysis between PCI vs Hybrid RQI (w1=0.70 and w2 = 0.30)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.858
R Square	0.736
Adjusted R Sc	0.729
Standard Erroı	0.038
Observations	40.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	0.15	0.15	106.06	0.00
Residual	38.00	0.05	0.00		
Total	39.00	0.21			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	(0.02)	0.08	(0.21)	0.84	(0.19)	0.15	(0.19)	0.15
Hybrid_RQI	1.01	0.10	10.30	0.00	0.81	1.20	0.81	1.20

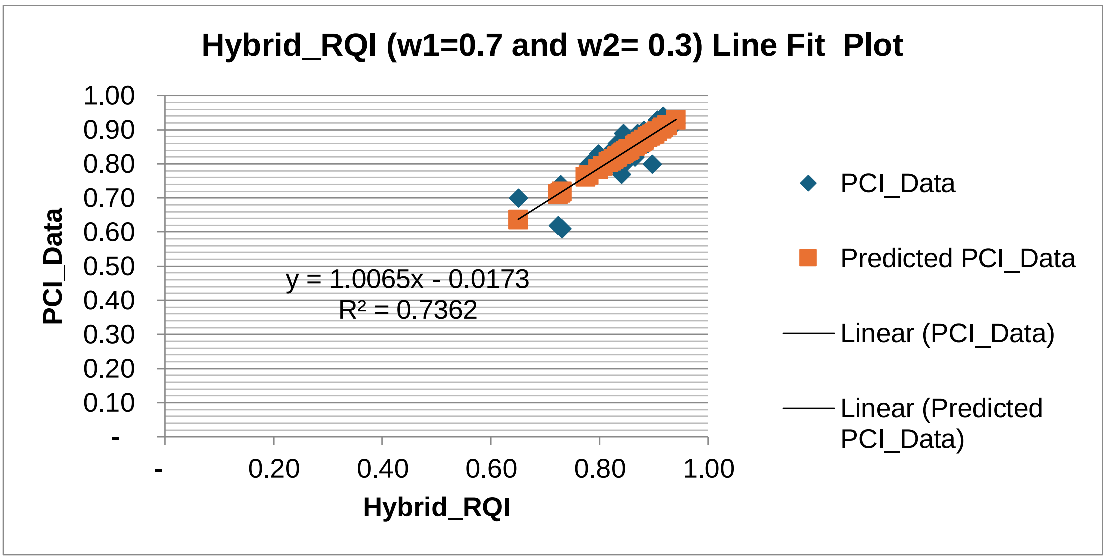

Figure 4.7: Plot Between PCI vs Hybrid RQI

3. When $w_1 = 0.80$ *and* $w_2 = 0.20$

The relationship between normalized PCI and Hybrid RQI respectively produced the coefficient of determination of **R² = 0.7429** and the fitted equation is

PCI = 0.9906*(Hybrid RQI) – 0.0038 …………………………………………..(4.5)

The regression model for normalized PCI and hybrid RQI (w_1 = 0.80, w_2 = 0.20) demonstrates a significant positive correlation between the structural characteristics of pavements and the functional characteristics of ride quality indexes. Moreover, the positive slope of 0.9906 suggests that Hybrid_RQI and PCI have a perfect correlation;

hence, any alteration in hybrid ride quality index will have an identical effect on pavement condition index. The insignificant constant of -0.0038 suggests that as the hybrid ride quality index approaches zero, PCI is expected to approach zero too. Therefore, there is a physical correlation between the two normalized indexes.

Additionally, the coefficient of determination of R^2 = 0.7429 signifies a highly correlated model; therefore, approximately 74.29% of the variation in PCI is caused by hybrid ride quality index. It is important to emphasize that the R^2 value is much higher compared to other regression models.

Table 4.7: Regression Analysis between PCI and Hybrid_RQI (w1 = 0.8 and w2 =0.2)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.8619
R Square	0.7429
Adjusted R Square	0.7361
Standard Error	0.0374
Observations	40.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	0.15	0.15	109.79	0.00
Residual	38.00	0.05	0.00		
Total	39.00	0.21			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	(0.00)	0.08	(0.05)	0.96	(0.17)	0.16	(0.17)	0.16
HY_RQI 80_20	0.99	0.09	10.48	0.00	0.80	1.18	0.80	1.18

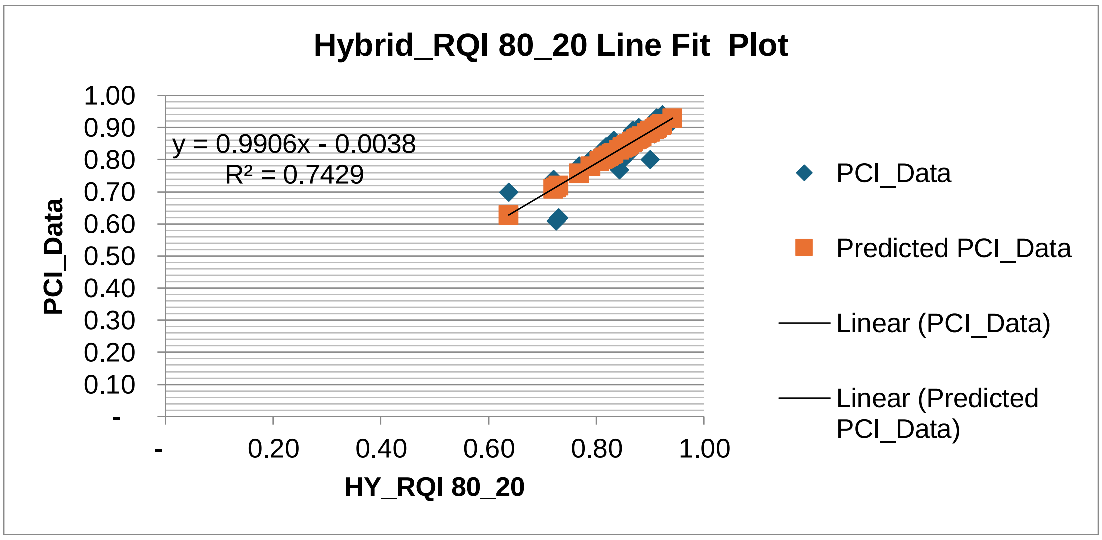

Figure 4.8: Plot of PCI Vs Hybrid_RQI (w1=0.80 and w2 = 0.20)

4. When $w_1 = 0.81$ *and* $w_2 = 0.19$

The relationship between normalized PCI and Hybrid RQI respectively produced the coefficient of determination of **R^2 = 0.7427** and the fitted equation is

PCI = 0.9879*(Hybrid RQI) – 0.0016 …………………………………………..(4.6)

The regression analysis between normalized PCI and Hybrid RQI (with weighting factors $w_1 = 0.81$ *and* $w_2 = 0.19$) indicates a strong positive linear relationship between pavement condition and the hybrid ride quality index. The slope value of 0.9879 suggests a near one-to-one correspondence between Hybrid RQI and PCI, indicating that changes in the hybrid index closely reflect variations in pavement condition across the study segments.

The intercept value of -0.0016 is negligibly small and close to zero, indicating minimal bias in the regression model and confirming strong physical consistency within the normalized framework. This suggests that both PCI and Hybrid RQI approach zero under severely deteriorated pavement conditions, supporting the robustness of the normalization approach and model formulation. The coefficient of determination (R^2 = 0.7427) indicates that approximately 74.27% of the variation in normalized PCI is explained by Hybrid RQI. This represents a strong correlation, demonstrating that the hybrid index effectively integrates both subjective ride quality and objective vibration-based measurements to represent pavement condition.

Table 4.8: Regression Analysis between PCI Vs Hybrid RQI (w1 =0.81 and w2=0.19)

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.8618
R Square	0.7427
Adjusted R Square	0.7360
Standard Error	0.0374
Observations	40.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	0.15	0.15	109.71	0.00
Residual	38.00	0.05	0.00		
Total	39.00	0.21			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	(0.00)	0.08	(0.02)	0.98	(0.16)	0.16	(0.16)	0.16
Hybrid_RQI, w1=0.81 and w2=0.19	0.99	0.09	10.47	0.00	0.80	1.18	0.80	1.18

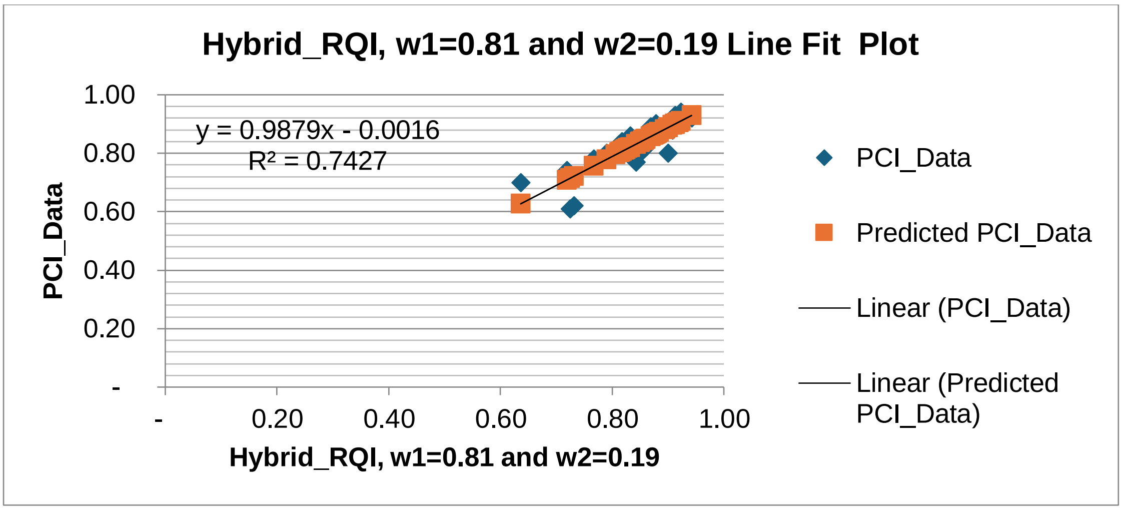

Figure 4.9: Plot Between PCI Vs Hybrid RQI (w1=0.81 and w2=0.19)

5. Model Calibration and Sensitivity Analysis

Calibration and Sensitivity Analysis was used to evaluate the accuracy of the proposed Hybrid RQI for representing the state of the pavement surface. The Hybrid RQI has been formulated using the concept of a combined index based on both subjective (Panel RQI) and objective (Root Mean Square [RMS] RQI of vertical acceleration), with each of the two indices being attributed to a certain weight factor (w_1 for Panel_RQI; w_2 for RMS_RQI). The influence of changing weight was explored through the use of various weighting systems, in which different weight factors (w_1= 0.69 to 0.81) were utilized. The findings indicate that irrespective of the weights chosen, there exists a highly linear correlation between Hybrid_RQI and PCI, characterized by the R^2 values of 0.7347 and 0.7429. This is confirmed through the regression models of the case studies, in which the slopes are almost unity while the intercepts are minimal.

From the analysis, it can be seen that model results are minimally sensitive to the variation of weighting factors within the selected range. The best predictive results are achieved when the model uses the weighting factor combination of w_1 = 0.80 and w_2 = 0.20, providing the highest R^2 value = 0.7429. However, at the same time, it should be noted that for other values of weighting factors falling outside the optimal interval (in particular, for weighing factors smaller than 0.69 or larger than 0.81), a reduction in the R^2 value occurs. Such correlation testifies about the existence of the correct correlation between the effects of the two factors used (Panel RQI and

RMS_RQI) in the hybrid model. It means that the Hybrid_RQI parameter correctly evaluates the contribution of each of the two factors (human perception and vibration characteristics), while the imbalance results in inefficient modeling of pavement condition, reducing its correlation with PCI. However, at the same time, one can see that no matter what the exact value of R^2 is, its variance will not be higher than 0.12.

Therefore, it is clear from this calibration that the hybrid-RQI method is quite useful for the classification of pavement surfaces. The proposed weighting system of w_1 = 0.80 and w_2 = 0.20 is highly recommended based on its excellent statistical performance, while the noticeable decline in the R^2 value after the range of 0.69 to 0.81 shows that there is an optimal weighting window.

4.8. Segment-wise Analysis of Pavement Ride Quality

In an effort to analyze the differences in pavement condition along the studied corridor, segment-based pavement condition assessment of the Pathlaiya-Hetauda road section was performed. The road was segregated into several equal-length segments, and each segment was analyzed for ride quality using Panel RQI, RMS acceleration, Hybrid RQI, and PCI values. From the findings, it can be observed that there is significant variance in the quality of ride along the corridor. In some segments, there were smooth riding surfaces with low vibrations, while other segments showed irregular surfaces causing lower ride quality. Based on the ratings of RQI and PCI values, the segments could be classified into categories of good, fair, and poor ride quality.

Table 4.9: Comparison of Road Condition Categories

Condition	Hetauda → Pathlaiya	Pathlaiya → Hetauda
VG	34	27
G	22	11
F	6	18
P	0	6
VP	0	0

Table 4.4 is a graphical representation of the pavement ride quality classes in each travel direction of the study corridor. For the Hetauda–Pathlaiya route, the bulk of the road sections lie in the Very Good (VG) and Good (G) ride quality classes. On the other hand, the Pathlaiya–Hetauda route contains more road sections that are

considered Fair (F) and Poor (P). From the findings, it can be seen that there are variations in terms of the condition of the pavements and their ride qualities based on the two travel directions.

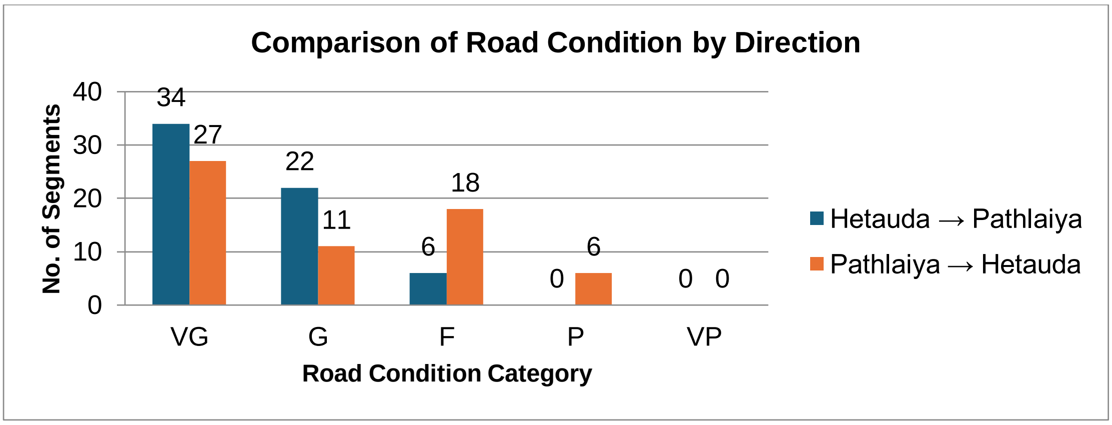

Figure 4.10: Comparison of Road Condition by Direction

CHAPTER 5

5. CONCLUSION AND RECOMMENDATION

5.1. CONCLUSION

This particular study was performed to investigate the ride quality of the pavement by employing a combined method of subjective evaluation by the panel and vibration measurements by the accelerometer present in smartphones. The overall objective of performing this study was to develop a convenient and economical method for testing the ride quality of the pavement, and the results of the study were validated by correlating with PCI value, which is the structural quality of the pavement. This particular experiment was conducted at the path linking Pathlaiya and Hetauda.

In this study, the panel rating survey was conducted to subjectively assess ride comfort felt by riders while using the road corridor. It was found out that there were variations in the level of ride comfort in terms of the smoothness of the pavements. The sections with smoother pavements had higher ratings while the ones with visibly rough pavements like potholes, cracks and other pavement irregularities had lower ratings. The reliability of the panel rating test was checked through the computation of Intra-Class Correlation Coefficient (ICC). The result was an ICC value of 0.939 which is a high agreement rate proving that the panel ratings were consistent in their evaluation of the road corridor's ride quality. Vibration measurement using objective means has been done by measuring the RMS of the vertical acceleration using smartphone accelerometers installed inside the test vehicle. High RMS values were found in those pavement sections that were rough. These showed high vibrations in the vehicle's suspension system. This proves that RMS acceleration values effectively measure vehicle vibrations while travelling on rough pavement surfaces.

As mentioned above, the PCI assessment had been done using routine visual distress rating techniques, which were intended to evaluate the general physical state of the pavements being studied. The PCI rating varied along the research corridor depending on the type and level of distresses of the pavement being examined. Segments with high PCI values had relatively smooth pavements compared to the low PCI values, which had visible distresses such as cracks and potholes. A regression analysis had been conducted to examine the relationship between PCI and ride quality indices derived from panel RQI, RMS acceleration, and the hybrid ride quality index. Through regression analysis, it was established that a positive correlation existed between PCI and Panel RQI with a coefficient of determination of approximately 0.7169.

Moderate results were achieved by the linear regression analysis between PCI and RMS acceleration values, with the coefficient of determination (R^2) value equal to 0.3842. It is evident that the RMS acceleration values have been very useful in estimating both pavement roughness and vehicle vibrations; however, they might not be sufficient when depicting several pavement distress parameters applied in PCI computation.

In order to solve this problem, a hybrid technique based on Hybrid_RQI was developed through including panel rating values alongside with the RMS acceleration values. The analysis between PCI and hybrid RQI resulted in the highest coefficient of determination ($R^2 \approx 0.7429$) with respect to w1 = 0.80 and w2 = 0.20. In this case, the above-mentioned method yields better outcomes than any of the two approaches. The integration of the objective and subjective assessment processes appeared to be extremely efficient in characterizing the pavement condition.

The analysis conducted on several road segments within the chosen road corridor has revealed that there exist differences in the state of the pavement in different segments of the road corridor to the effect that while certain road segments provide good road rideability, others might provide average or poor rideability.
From this research, therefore, it can be concluded that the adopted hybrid approach provides a viable way of measuring the quality of road rides. The proposed hybrid approach successfully combines both subjective and objective methods of evaluation, and with the high level of correlation found with PCI scores, it can be effectively employed as an alternative in road ride quality assessment in situations where pavement profile instrumentation is not easily available.

5.2. RECOMMENDATIONS

First of all, the conducted analysis proves the benefits of hybrid RQI models, based on subjective panel scores and objective measurements taken by the smartphones' acceleration sensors. Hence, the transportation agencies should focus on hybrid measurement of road quality, combining user-based ratings and sensor-generated information to determine the road's ride ability.

The second recommendation implies that measuring vertical vibrations of roads using accelerometers of smartphones represents a cost-effective tool for evaluating their quality. Being available and convenient to use, these devices can be used for the evaluation of road condition by transportation authorities, whose budgets do not allow them to apply more sophisticated equipment (e.g., laser profilers). Nevertheless, a standard procedure of device deployment and data processing is required to ensure consistency of research findings.

Moreover, the strong relationship between Panel_RQI and PCI shows that the public perception regarding the quality of riding the road is highly dependent on the quality of the surface. User perception of the road can provide useful information regarding the performance of the roads. Performing surveys involving the user’s panel rating survey will help identify the deteriorated parts of the road before it becomes a problem.

The third most important recommendation for maintaining roads that have been identified through the results of the research is conducting regular pavement inspections. As seen from the results of the study, there are vast differences in road conditions along one particular route, and some parts of the road may be in good condition, while others require urgent repairs. Therefore, the road management body should regularly inspect deteriorated road segments to prevent further damage. Last but not least, the fourth important recommendation for maintaining roads involves implementing preventive maintenance. Road segments that are in fair condition need preventive maintenance measures such as crack sealing, patching, resurfacing, or thin overlay.

Finally, further investigation is required on various road configurations, traffic conditions, and vehicle speeds to enhance the performance of the Hybrid RQI system. The application of the algorithm with larger databases and in more extensive road networks can lead to increased accuracy.

To conclude, the combination of subjective perceptions of road users with objective information from the sensors can provide an effective way for road quality evaluation. Such approaches can serve as a basis for more informed road management.

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ANNEXURE - 1

Panel Based Ride Survey Data

Figure: Panel Training by the Trainer

RQI Field Data Collection From Panel_Member P1 to P5									
S. No.	**Segment ID**	**P1**	**P2**	**P3**	**P4**	**P5**	**Average RQI**	**Descriptive Anchor**	**Panel RQI Scaling, RQI/5**
1	H to P S1	4.20	4.80	4.50	4.10	4.80	4.48	VG	0.90
2	S2	3.90	4.10	4.60	3.90	4.70	4.24	VG	0.85
3	S3	4.40	4.30	4.20	4.20	4.70	4.36	VG	0.87
4	S4	4.30	3.90	4.40	3.60	4.30	4.10	VG	0.82
5	S5	4.50	4.40	4.10	4.40	4.30	4.34	VG	0.87
6	S6	4.30	4.20	4.50	4.50	4.10	4.32	VG	0.86
7	S7	3.80	4.50	4.30	4.60	4.10	4.26	VG	0.85
8	S8	4.50	4.10	4.50	4.40	4.30	4.36	VG	0.87
9	S9	4.20	4.60	4.80	4.60	4.50	4.54	VG	0.91
10	S10	4.30	4.30	4.60	4.70	4.70	4.52	VG	0.90
11	S11	3.70	3.60	3.80	3.00	3.70	3.56	G	0.71
12	S12	2.60	3.30	3.60	2.50	3.30	3.06	G	0.61
13	S13	4.50	4.10	4.50	3.20	4.10	4.08	VG	0.82
14	S14	4.60	4.30	4.10	3.40	3.90	4.06	VG	0.81
15	S15	4.60	4.50	4.50	2.90	4.30	4.16	VG	0.83
16	S16	4.10	4.20	4.30	4.10	4.60	4.26	VG	0.85
17	S17	3.80	4.30	4.70	3.40	4.30	4.10	VG	0.82
18	S18	3.30	4.10	4.50	2.80	4.20	3.78	G	0.76
19	S19	4.60	4.40	3.90	4.00	4.50	4.28	VG	0.86
20	S20	4.70	4.00	4.20	4.40	4.50	4.36	VG	0.87
21	S21	3.60	3.80	3.40	1.90	3.30	3.20	G	0.64
22	S22	3.80	3.20	3.50	2.20	3.40	3.22	G	0.64
23	S23	3.90	3.10	3.20	2.10	3.20	3.10	G	0.62
24	S24	3.10	2.40	2.80	1.60	2.60	2.50	F	0.50
25	S25	3.40	2.30	2.50	2.40	2.20	2.56	F	0.51
26	S26	3.10	2.20	1.60	2.70	1.10	2.14	F	0.43
27	S27	3.00	2.40	1.90	3.00	1.80	2.42	F	0.48
28	S28	2.80	2.90	3.40	3.10	3.10	3.06	G	0.61
29	S29	2.90	2.30	3.80	3.40	2.40	2.96	F	0.59
30	S30	3.40	2.60	3.50	3.90	3.10	3.30	G	0.66
31	S31	3.20	2.70	3.80	2.80	3.70	3.24	G	0.65
32	S32	3.40	3.00	3.70	2.70	3.40	3.24	G	0.65
33	S33	3.30	3.20	3.80	2.80	3.50	3.32	G	0.66
34	S34	3.40	3.10	3.40	4.20	3.10	3.44	G	0.69
35	S35	3.20	3.30	2.50	2.50	2.20	2.74	F	0.55
36	S36	3.40	3.10	3.40	3.70	3.70	3.46	G	0.69
37	S37	4.20	3.50	4.70	4.40	4.10	4.18	VG	0.84
38	S38	4.40	3.70	4.80	4.20	4.50	4.32	VG	0.86
39	S39	4.50	3.10	4.60	4.10	4.20	4.10	VG	0.82
40	S40	3.90	3.40	4.40	3.90	4.10	3.94	G	0.79
41	S41	4.20	3.60	4.20	3.30	4.70	4.00	G	0.80
42	S42	3.60	4.10	2.60	2.20	2.70	3.04	G	0.61
43	S43	4.10	3.10	4.50	3.50	4.20	3.88	G	0.78
44	S44	4.60	3.90	4.90	4.50	4.70	4.52	VG	0.90
45	S45	3.70	4.10	4.80	2.90	4.40	3.98	G	0.80
46	S46	4.20	4.20	4.70	3.40	4.50	4.20	VG	0.84
47	S47	4.50	4.50	4.80	4.60	4.60	4.60	VG	0.92
48	S48	4.60	4.60	4.60	4.50	4.30	4.52	VG	0.90
49	S49	4.20	4.40	4.70	3.80	3.90	4.20	VG	0.84
50	S50	3.90	4.10	4.40	3.30	4.10	3.96	G	0.79
51	S51	3.80	4.50	3.80	3.50	3.70	3.86	G	0.77
52	S52	4.80	3.30	4.70	4.60	4.70	4.42	VG	0.88
53	S53	4.20	4.50	4.50	4.40	4.40	4.40	VG	0.88
54	S54	4.70	4.30	4.70	4.80	4.50	4.60	VG	0.92
55	S55	4.30	4.40	4.40	4.10	4.50	4.34	VG	0.87
56	S56	4.40	4.50	4.90	4.00	4.60	4.48	VG	0.90
57	S57	4.30	4.00	4.80	3.90	4.50	4.30	VG	0.86
58	S58	4.70	4.10	4.50	4.50	4.30	4.42	VG	0.88

59	S59	3.60	4.30	3.40	2.40	3.90	3.52	G	0.70
60	S60	4.40	4.20	4.70	3.60	4.50	4.28	VG	0.86
61	S61	3.20	4.40	3.50	3.20	3.30	3.52	G	0.70
62	S62	4.10	3.20	4.70	4.10	4.50	4.12	VG	0.82
63	P to H S1	4.60	4.60	4.80	4.70	4.10	4.56	VG	0.91
64	S2	4.50	4.70	4.70	4.60	4.50	4.60	VG	0.92
65	S3	4.80	4.70	4.70	4.60	4.80	4.72	VG	0.94
66	S4	4.70	4.60	4.50	4.10	4.60	4.50	VG	0.90
67	S5	4.80	4.50	4.40	4.80	4.80	4.66	VG	0.93
68	S6	4.70	4.30	4.70	4.70	4.70	4.62	VG	0.92
69	S7	4.20	4.10	4.40	4.60	4.70	4.40	VG	0.88
70	S8	4.60	4.40	4.50	4.40	4.80	4.54	VG	0.91
71	S9	4.80	4.20	4.80	4.10	4.80	4.54	VG	0.91
72	S10	3.90	4.10	4.70	3.80	4.50	4.20	VG	0.84
73	S11	3.80	4.00	4.20	4.30	3.90	4.04	VG	0.81
74	S12	4.00	4.30	4.10	4.00	3.90	4.06	VG	0.81
75	S13	3.90	4.70	4.60	3.90	4.30	4.28	VG	0.86
76	S14	4.10	4.50	4.30	4.00	4.30	4.24	VG	0.85
77	S15	4.50	4.60	4.50	3.80	4.40	4.36	VG	0.87
78	S16	4.80	3.90	4.10	4.60	4.50	4.38	VG	0.88
79	S17	4.10	3.80	4.60	4.40	4.10	4.20	VG	0.84
80	S18	3.80	3.50	3.90	3.90	3.50	3.72	G	0.74
81	S19	4.20	3.10	4.20	4.40	4.30	4.04	VG	0.81
82	S20	4.40	2.20	2.40	4.10	4.50	3.52	G	0.70
83	S21	2.80	1.60	2.50	2.50	2.70	2.42	F	0.48
84	S22	2.30	2.50	2.60	3.10	2.90	2.68	F	0.54
85	S23	1.80	2.10	1.70	2.00	1.70	1.86	P	0.37
86	S24	2.10	1.40	2.80	2.50	2.50	2.26	F	0.45
87	S25	1.80	1.90	2.40	2.00	2.30	2.08	F	0.42
88	S26	2.30	1.70	1.50	2.60	1.70	1.96	P	0.39
89	S27	3.10	1.90	2.10	2.40	1.10	2.12	F	0.42
90	S28	2.70	1.50	1.80	2.90	1.40	2.06	F	0.41
91	S29	2.50	1.70	1.70	1.80	1.20	1.78	P	0.36
92	S30	2.30	1.90	1.70	2.60	1.30	1.96	P	0.39
93	S31	1.80	2.20	2.30	2.80	1.70	2.16	F	0.43
94	S32	1.30	1.70	2.10	1.80	1.30	1.64	P	0.33
95	S33	3.20	3.30	1.80	3.70	1.30	2.66	F	0.53
96	S34	1.90	3.80	3.80	2.00	0.90	2.48	F	0.50
97	S35	2.40	4.00	2.10	2.80	1.60	2.58	F	0.52
98	S36	3.90	4.20	3.70	3.60	3.40	3.76	G	0.75
99	S37	3.20	4.10	4.50	2.90	2.70	3.48	G	0.70
100	S38	3.90	4.30	4.20	4.30	3.60	4.06	VG	0.81
101	S39	3.70	3.30	3.40	3.30	2.10	3.16	G	0.63
102	S40	4.00	3.50	3.10	2.90	2.90	3.28	G	0.66
103	S41	3.80	3.20	2.70	3.60	2.90	3.24	G	0.65
104	S42	2.90	2.70	3.60	3.10	2.10	2.88	F	0.58
105	S43	3.80	2.50	2.80	3.00	2.50	2.92	F	0.58
106	S44	3.50	2.90	2.70	2.80	2.10	2.80	F	0.56
107	S45	2.40	3.10	2.40	2.40	2.60	2.58	F	0.52
108	S46	1.80	2.50	1.80	1.60	1.40	1.82	P	0.36
109	S47	2.40	2.90	3.60	3.20	4.10	3.24	G	0.65
110	S48	2.70	3.00	2.40	2.50	1.80	2.48	F	0.50
111	S49	2.10	2.80	2.10	2.30	1.90	2.24	F	0.45
112	S50	2.30	2.70	2.50	2.20	2.10	2.36	F	0.47
113	S51	2.80	3.70	2.80	1.90	2.30	2.70	F	0.54
114	S52	4.10	4.10	4.60	4.50	4.50	4.36	VG	0.87
115	S53	3.80	3.80	4.40	3.50	3.90	3.88	G	0.78
116	S54	4.20	4.20	4.50	4.50	4.30	4.34	VG	0.87
117	S55	4.30	4.10	4.40	4.30	4.30	4.28	VG	0.86
118	S56	4.20	3.50	4.80	3.60	4.10	4.04	VG	0.81
119	S57	4.40	3.80	4.20	2.50	4.00	3.78	G	0.76

120	S58	4.60	4.40	4.30	4.30	4.80	4.48	VG	0.90
121	S59	4.80	4.20	4.50	3.30	4.70	4.30	VG	0.86
122	S60	4.60	4.10	4.30	2.80	4.50	4.06	VG	0.81
123	S61	3.70	3.40	3.70	3.80	3.90	3.70	G	0.74
124	S62	4.10	4.50	4.50	2.90	4.30	4.06	VG	0.81

ANNEXURE - 2

Vertical Accelerometer Based Ride Survey Data

Data Analysis: Root Mean Square Based Vertical Accelerometer							
S.No	**Phone A**	**Phone B**	**Phone C**	**Avg. RMS**	**Max_RMS**	**Min_RMS**	**RMS_RQI**
1	0.62	0.73	1.00	0.78	3.92	0.39	0.89
2	0.52	0.43	1.65	0.87			0.86
3	1.00	0.44	0.74	0.73			0.90
4	1.10	0.54	0.97	0.87			0.86
5	0.56	0.48	1.46	0.83			0.87
6	0.91	1.03	1.03	0.99			0.83
7	0.91	0.48	0.90	0.76			0.89
8	0.80	0.56	1.04	0.80			0.88
9	0.56	0.39	0.63	0.53			0.96
10	0.65	0.43	1.34	0.81			0.88
11	1.55	0.72	1.27	1.18			0.78
12	1.76	0.84	1.32	1.31			0.74
13	0.71	0.65	1.41	0.92			0.85
14	0.78	0.81	1.24	0.94			0.84
15	0.68	0.82	1.44	0.98			0.83
16	0.58	0.87	1.40	0.95			0.84
17	0.86	0.81	1.19	0.95			0.84
18	1.16	0.78	1.17	1.04			0.82
19	0.58	0.67	1.47	0.91			0.85
20	0.56	0.58	1.18	0.77			0.89
21	1.42	1.25	1.88	1.52			0.68
22	1.24	1.35	2.02	1.54			0.68
23	1.52	1.23	1.80	1.52			0.68
24	1.63	1.60	2.85	2.03			0.54
25	1.74	1.33	2.26	1.78			0.61
26	1.63	1.29	2.60	1.84			0.59
27	1.89	0.92	2.39	1.73			0.62
28	1.46	1.05	2.04	1.52			0.68
29	1.61	1.04	2.60	1.75			0.61
30	1.63	1.00	2.17	1.60			0.66
31	1.42	0.78	1.59	1.26			0.75
32	1.42	1.13	2.26	1.60			0.66
33	1.32	0.99	1.58	1.30			0.74
34	1.29	1.47	2.26	1.67			0.64
35	1.62	1.12	2.04	1.59			0.66
36	1.32	1.00	1.48	1.27			0.75
37	0.68	0.85	1.73	1.09			0.80
38	0.77	0.70	1.40	0.96			0.84
39	0.89	0.75	1.35	1.00			0.83
40	0.76	0.84	1.63	1.08			0.81
41	0.74	0.82	1.36	0.97			0.83
42	0.59	1.68	3.26	1.84			0.59
43	0.98	0.69	1.27	0.98			0.83
44	0.46	0.52	1.30	0.76			0.90

45	0.96	0.55	0.90	0.80			0.88
46	0.89	0.39	0.73	0.67			0.92
47	0.69	0.49	0.92	0.70			0.91
48	0.71	0.51	0.94	0.72			0.91
49	0.85	0.63	1.11	0.86			0.87
50	0.66	0.62	1.62	0.97			0.84
51	0.68	0.69	1.45	0.94			0.84
52	0.69	0.74	1.47	0.97			0.84
53	0.65	0.77	1.41	0.94			0.84
54	0.77	1.23	1.23	1.08			0.81
55	0.59	0.67	1.37	0.88			0.86
56	0.46	0.76	1.07	0.76			0.89
57	0.56	0.53	0.87	0.65			0.93
58	0.46	0.57	1.48	0.84			0.87
59	1.23	1.03	1.47	1.24			0.76
60	0.84	1.31	1.31	1.15			0.78
61	1.08	1.43	1.43	1.31			0.74
62	0.76	0.94	1.70	1.13			0.79
63	0.98	2.23	1.30	1.50			0.68
64	0.72	0.88	1.05	0.88			0.86
65	0.63	0.57	0.67	0.62			0.93
66	0.77	0.62	0.84	0.74			0.90
67	0.68	0.77	0.96	0.80			0.88
68	0.74	0.98	0.89	0.87			0.86
69	0.49	0.53	1.37	0.80			0.88
70	0.56	0.45	0.51	0.51			0.97
71	0.65	0.50	0.75	0.63			0.93
72	0.68	0.53	0.72	0.64			0.93
73	0.55	0.96	1.77	1.09			0.80
74	0.77	0.87	1.33	0.99			0.83
75	0.78	0.88	1.40	1.02			0.82
76	1.05	0.79	1.22	1.02			0.82
77	0.89	0.97	1.33	1.06			0.81
78	0.69	0.52	0.81	0.67			0.92
79	1.34	1.44	1.58	1.45			0.70
80	1.46	1.60	1.53	1.53			0.68
81	1.37	1.13	1.68	1.39			0.72
82	1.15	1.11	1.18	1.15			0.79
83	1.56	1.42	2.58	1.85			0.59
84	1.46	1.36	2.88	1.90			0.57
85	1.74	1.14	1.42	1.43			0.70
86	1.41	1.19	1.77	1.46			0.70
87	1.65	1.39	1.93	1.66			0.64
88	1.98	1.27	1.79	1.68			0.63
89	1.57	1.02	2.23	1.61			0.66
90	1.51	1.21	1.41	1.38			0.72
91	2.12	1.18	1.42	1.57			0.66
92	2.30	1.52	1.83	1.88			0.58

93	2.10	1.04	1.75	1.63			0.65
94	2.32	1.16	1.85	1.78			0.61
95	1.35	1.08	1.08	1.17			0.78
96	1.16	1.62	2.21	1.66			0.64
97	2.59	1.24	3.92	2.58			0.38
98	1.21	1.19	1.22	1.21			0.77
99	0.96	0.98	1.09	1.01			0.82
100	1.11	0.96	1.22	1.10			0.80
101	1.31	1.21	1.34	1.29			0.75
102	1.36	1.01	1.16	1.18			0.78
103	1.18	0.96	1.27	1.14			0.79
104	1.49	1.19	1.70	1.46			0.70
105	1.62	0.88	1.18	1.23			0.76
106	1.49	1.18	1.25	1.31			0.74
107	1.56	1.43	1.65	1.55			0.67
108	1.96	1.57	1.80	1.78			0.61
109	1.16	0.64	2.05	1.28			0.75
110	1.85	1.09	1.33	1.42			0.71
111	1.85	1.44	1.49	1.59			0.66
112	1.68	1.64	1.77	1.70			0.63
113	1.47	1.57	1.71	1.58			0.66
114	0.54	0.99	1.22	0.92			0.85
115	0.86	1.06	1.19	1.04			0.82
116	0.64	0.79	1.15	0.86			0.87
117	0.94	0.87	1.02	0.94			0.84
118	0.93	0.83	0.99	0.92			0.85
119	0.88	0.95	1.36	1.06			0.81
120	0.82	0.68	0.92	0.81			0.88
121	0.62	1.01	1.19	0.94			0.84
122	0.76	0.73	0.91	0.80			0.88
123	0.95	1.37	1.37	1.23			0.76
124	0.69	1.08	1.57	1.11			0.80

ANNEXURE - 3

Data Analysis: Hybrid Riding Quality Index Based on Weighted Factors

Data Analysis: Hybrid_RQI with varying weighted factor								
S.No	**Segment ID**	**RMS_RQI**	**Panel RQI Scaling**	**Hybrid_RQI, w1=0.69, w2=0.31**	**Hybrid_RQI, w1=0.70, w2=0.30**	**Hybrid_RQI, w1=0.80, w2=0.20**	**Hybrid_RQI, w1=0.81, w2=0.19**	**Remarks**
1	H to P S1	0.89	0.90	0.8937	0.8937	0.8945	0.8946	
2	S2	0.86	0.85	0.8532	0.8531	0.8514	0.8512	
3	S3	0.90	0.87	0.8820	0.8817	0.8785	0.8781	
4	S4	0.86	0.82	0.8337	0.8332	0.8288	0.8284	
5	S5	0.87	0.87	0.8700	0.8699	0.8693	0.8692	
6	S6	0.83	0.86	0.8535	0.8538	0.8572	0.8575	
7	S7	0.89	0.85	0.8651	0.8647	0.8604	0.8600	
8	S8	0.88	0.87	0.8757	0.8756	0.8744	0.8743	
9	S9	0.96	0.91	0.9245	0.9240	0.9187	0.9181	
10	S10	0.88	0.90	0.8972	0.8974	0.8996	0.8998	
11	S11	0.78	0.71	0.7319	0.7313	0.7248	0.7242	
12	S12	0.74	0.61	0.6518	0.6505	0.6377	0.6364	
13	S13	0.85	0.82	0.8262	0.8259	0.8226	0.8223	
14	S14	0.84	0.81	0.8217	0.8214	0.8182	0.8179	
15	S15	0.83	0.83	0.8323	0.8323	0.8322	0.8322	
16	S16	0.84	0.85	0.8487	0.8488	0.8499	0.8500	
17	S17	0.84	0.82	0.8263	0.8261	0.8241	0.8239	
18	S18	0.82	0.76	0.7749	0.7742	0.7682	0.7676	
19	S19	0.85	0.86	0.8553	0.8553	0.8555	0.8556	
20	S20	0.89	0.87	0.8780	0.8778	0.8759	0.8757	
21	S21	0.68	0.64	0.6527	0.6522	0.6482	0.6478	
22	S22	0.68	0.64	0.6537	0.6533	0.6502	0.6499	
23	S23	0.68	0.62	0.6389	0.6382	0.6322	0.6316	
24	S24	0.54	0.50	0.5113	0.5109	0.5073	0.5069	
25	S25	0.61	0.51	0.5415	0.5406	0.5310	0.5301	
26	S26	0.59	0.43	0.4780	0.4764	0.4602	0.4586	
27	S27	0.62	0.48	0.5260	0.5246	0.5111	0.5097	
28	S28	0.68	0.61	0.6333	0.6326	0.6258	0.6251	
29	S29	0.61	0.59	0.5990	0.5988	0.5965	0.5963	
30	S30	0.66	0.66	0.6591	0.6592	0.6594	0.6595	
31	S31	0.75	0.65	0.6804	0.6794	0.6689	0.6679	
32	S32	0.66	0.65	0.6506	0.6505	0.6497	0.6496	
33	S33	0.74	0.66	0.6885	0.6877	0.6798	0.6790	
34	S34	0.64	0.69	0.6720	0.6725	0.6777	0.6782	
35	S35	0.66	0.55	0.5824	0.5813	0.5702	0.5691	
36	S36	0.75	0.69	0.7105	0.7099	0.7039	0.7033	
37	S37	0.80	0.84	0.8257	0.8260	0.8293	0.8297	
38	S38	0.84	0.86	0.8564	0.8566	0.8591	0.8593	
39	S39	0.83	0.82	0.8225	0.8224	0.8216	0.8215	
40	S40	0.81	0.79	0.7934	0.7932	0.7915	0.7913	
41	S41	0.83	0.80	0.8108	0.8104	0.8069	0.8066	
42	S42	0.59	0.61	0.6019	0.6021	0.6041	0.6043	
43	S43	0.83	0.78	0.7936	0.7931	0.7874	0.7868	
44	S44	0.90	0.90	0.9013	0.9014	0.9022	0.9023	
45	S45	0.88	0.80	0.8229	0.8221	0.8134	0.8125	
46	S46	0.92	0.84	0.8650	0.8642	0.8561	0.8553	
47	S47	0.91	0.92	0.9176	0.9177	0.9184	0.9185	
48	S48	0.91	0.90	0.9048	0.9048	0.9045	0.9045	
49	S49	0.87	0.84	0.8482	0.8479	0.8453	0.8450	
50	S50	0.84	0.79	0.8058	0.8054	0.8009	0.8005	

51	S51	0.84	0.77	0.7944	0.7937	0.7864	0.7857	
52	S52	0.84	0.88	0.8693	0.8698	0.8745	0.8750	
53	S53	0.84	0.88	0.8685	0.8689	0.8726	0.8729	
54	S54	0.81	0.92	0.8845	0.8857	0.8971	0.8983	
55	S55	0.86	0.87	0.8662	0.8662	0.8668	0.8669	
56	S56	0.89	0.90	0.8955	0.8955	0.8956	0.8957	
57	S57	0.93	0.86	0.8803	0.8796	0.8731	0.8724	
58	S58	0.87	0.88	0.8809	0.8810	0.8820	0.8821	
59	S59	0.76	0.70	0.7208	0.7203	0.7149	0.7143	
60	S60	0.78	0.86	0.8336	0.8343	0.8416	0.8423	
61	S61	0.74	0.70	0.7147	0.7143	0.7109	0.7105	
62	S62	0.79	0.82	0.8134	0.8137	0.8172	0.8175	
63	P to H S1	0.68	0.91	0.8415	0.8438	0.8665	0.8688	
64	S2	0.86	0.92	0.9015	0.9021	0.9080	0.9086	
65	S3	0.93	0.94	0.9409	0.9410	0.9420	0.9421	
66	S4	0.90	0.90	0.9001	0.9001	0.9001	0.9001	
67	S5	0.88	0.93	0.9168	0.9173	0.9222	0.9227	
68	S6	0.86	0.92	0.9054	0.9060	0.9120	0.9126	
69	S7	0.88	0.88	0.8815	0.8815	0.8810	0.8809	
70	S8	0.97	0.91	0.9263	0.9257	0.9198	0.9192	
71	S9	0.93	0.91	0.9152	0.9149	0.9126	0.9124	
72	S10	0.93	0.84	0.8674	0.8665	0.8576	0.8568	
73	S11	0.80	0.81	0.8058	0.8059	0.8066	0.8067	
74	S12	0.83	0.81	0.8176	0.8174	0.8156	0.8154	
75	S13	0.82	0.86	0.8453	0.8457	0.8491	0.8495	
76	S14	0.82	0.85	0.8398	0.8401	0.8427	0.8430	
77	S15	0.81	0.87	0.8525	0.8532	0.8595	0.8601	
78	S16	0.92	0.88	0.8896	0.8891	0.8847	0.8843	
79	S17	0.70	0.84	0.7962	0.7976	0.8118	0.8132	
80	S18	0.68	0.74	0.7232	0.7239	0.7306	0.7313	
81	S19	0.72	0.81	0.7794	0.7803	0.7896	0.7905	
82	S20	0.79	0.70	0.7293	0.7285	0.7203	0.7195	
83	S21	0.59	0.48	0.5155	0.5144	0.5043	0.5033	
84	S22	0.57	0.54	0.5472	0.5469	0.5432	0.5429	
85	S23	0.70	0.37	0.4751	0.4717	0.4385	0.4352	
86	S24	0.70	0.45	0.5282	0.5257	0.5012	0.4987	
87	S25	0.64	0.42	0.4859	0.4837	0.4611	0.4589	
88	S26	0.63	0.39	0.4672	0.4648	0.4405	0.4381	
89	S27	0.66	0.42	0.4957	0.4934	0.4703	0.4680	
90	S28	0.72	0.41	0.5076	0.5045	0.4737	0.4706	
91	S29	0.66	0.36	0.4517	0.4486	0.4178	0.4147	
92	S30	0.58	0.39	0.4493	0.4475	0.4290	0.4271	
93	S31	0.65	0.43	0.4992	0.4970	0.4753	0.4732	
94	S32	0.61	0.33	0.4145	0.4118	0.3838	0.3810	
95	S33	0.78	0.53	0.6086	0.6061	0.5814	0.5789	
96	S34	0.64	0.50	0.5404	0.5390	0.5247	0.5232	
97	S35	0.38	0.52	0.4734	0.4748	0.4885	0.4899	
98	S36	0.77	0.75	0.7572	0.7570	0.7553	0.7552	
99	S37	0.82	0.70	0.7358	0.7345	0.7217	0.7204	
100	S38	0.80	0.81	0.8082	0.8083	0.8096	0.8097	
101	S39	0.75	0.63	0.6673	0.6662	0.6548	0.6537	
102	S40	0.78	0.66	0.6936	0.6923	0.6802	0.6790	
103	S41	0.79	0.65	0.6915	0.6901	0.6761	0.6747	
104	S42	0.70	0.58	0.6135	0.6123	0.6002	0.5990	

105	S43	0.76	0.58	0.6395	0.6377	0.6198	0.6180	
106	S44	0.74	0.56	0.6159	0.6141	0.5961	0.5943	
107	S45	0.67	0.52	0.5645	0.5629	0.5473	0.5457	
108	S46	0.61	0.36	0.4394	0.4370	0.4126	0.4102	
109	S47	0.75	0.65	0.6787	0.6777	0.6678	0.6668	
110	S48	0.71	0.50	0.5615	0.5594	0.5383	0.5361	
111	S49	0.66	0.45	0.5134	0.5113	0.4902	0.4881	
112	S50	0.63	0.47	0.5209	0.5194	0.5036	0.5020	
113	S51	0.66	0.54	0.5778	0.5766	0.5644	0.5632	
114	S52	0.85	0.87	0.8654	0.8656	0.8678	0.8680	
115	S53	0.82	0.78	0.7887	0.7882	0.7842	0.7838	
116	S54	0.87	0.87	0.8676	0.8677	0.8678	0.8678	
117	S55	0.84	0.86	0.8520	0.8522	0.8534	0.8536	
118	S56	0.85	0.81	0.8213	0.8208	0.8166	0.8161	
119	S57	0.81	0.76	0.7725	0.7720	0.7667	0.7661	
120	S58	0.88	0.90	0.8916	0.8918	0.8932	0.8933	
121	S59	0.84	0.86	0.8551	0.8553	0.8568	0.8570	
122	S60	0.88	0.81	0.8343	0.8336	0.8264	0.8257	
123	S61	0.76	0.74	0.7468	0.7466	0.7444	0.7442	
124	S62	0.80	0.81	0.8068	0.8069	0.8086	0.8088	

ANNEXURE - 4

Data Analysis: Pavement Condition Index Data Computation (PCI)

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Hetauda to Pathlaiya	**Section**	0+000 to 0+500	**Sample Unit**	1.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1250.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY									TOTAL	DENSITY %	DEDUCT VALUE
1L	7.7	1.2	2.4	3.5						14.8	1.18	12.00
10L	4.5	4	9							17.5	1.40	0.42
2L	0.64	0.6	0.64							1.88	0.15	-
11M	5.52									5.52	0.44	5.80

Adjustment of Number of Deduct Values

	No. of Deduct Values	m	9.08	<=	10							
#	Deduct Values				Total	q	CDV					
1	12	5.8	0.42	0	18.22	2	12					
2	12	2	0.42	0	14.42	1	12.6					
						Maximum CDV	**12.6**					
						PCI	**87.4**					
						Scale	0.87					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR

SKETCH:

Branch	Hetauda to Pathlaiya	**Section**	0+500 to 1+000	**Sample Unit**	2.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	2500.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
10L	13									13	0.52	-
1L	7.2	9.1								16.3	0.65	8.00
1M	11.2	2.1								13.3	0.53	15.80
6M	2.1									2.1	0.08	7.10

Adjustment of Number of Deduct Values

	No. of Deduct Values	m	8.73	<=	10							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1	15.80	8.00	7.10	-	30.90	3.00	16.80					
2	15.80	8.00	2.00	-	25.80	2.00	17.60					
3	15.80	2.00	2.00	-	19.80	1.00	17.75					
						Maximum CDV	**17.75**					
						PCI	**82.25**					
						Scale	0.82					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Hetauda to Pathlaiya	**Section**	1+000 to 1+500	**Sample Unit**	3.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	2500.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
1L	10.40									10.40	0.42	5.20
13L	0.04	0.04	0.04	0.04						0.16	0.01	2.10
2M	0.80									0.80	0.03	1.20

Adjustment of Number of Deduct Values

	No. of Deduct Values	m	9.71	<=	10		
#	**Deduct Values**				**Total**	**q**	**CDV**
1	5.20	2.10	1.20	-	8.50	2.00	10.00
2	5.20	2.00	1.20	-	8.40	1.00	9.50
						Maximum CDV	**10.00**
						PCI	**90.00**
						Scale	0.90

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Hetauda to Pathlaiya	**Section**	1+500 to 2+000	**Sample Unit**	4.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	2500.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY								TOTAL	DENSITY %	DEDUCT VALUE
13M	0.28								0.28	0.01	5.00
6M	6.00								6.00	0.24	9.00
16M	6.00	21.00							27.00	1.08	10.00
11M	12.00								12.00	0.48	6.00
5L	21.00	12.00	21.00						54.00	2.16	4.80
11M	7.00	1.69	3.15						11.84	0.47	6.80
19L	9.00								9.00	0.36	1.30

Adjustment of Number of Deduct Values

	No. of Deduct Values	m	9.27	<=	10						
#	Deduct Values							Total	q	CDV	
1	10.00	9.00	6.80	6.00	5.00	4.80	1.30	42.90	6.00	16.00	
2	10.00	9.00	6.80	6.00	5.00	2.00	1.30	40.10	5.00	16.00	
3	10.00	9.00	6.80	6.00	2.00	2.00	1.30	37.10	4.00	16.00	
4	10.00	9.00	6.80	2.00	2.00	2.00	1.30	33.10	3.00	18.00	
5	10.00	9.00	2.00	2.00	2.00	2.00	1.30	28.30	2.00	18.00	
6	10.00	2.00	2.00	2.00	2.00	2.00	1.30	21.30	1.00	18.50	
									Maximum CDV	**18.50**	
									PCI	81.50	
									Scale	0.82	

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch Hetauda to Pathlaiya **Section** 2+000 to 2+500 **Sample Unit** 5.00

Surveyed By Bibek Gupta Rauniyar **Date** 26/02/2026 **Sample Area, M^2** 1750.00

1. Alligator Cracking
2. Bleeding
3. Block Cracking
4. Bumps and Slags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/ Shoulder Drop off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Revealing

DISTRESS SEVERITY	QUANTITY								TOTAL	DENSITY %	DEDUCT VALUE
5L	10.4								10.4	0.59	1.10
16M	0.6	1.8							2.4	0.14	3.00
10M	15.5	13							28.5	1.63	4.80
10L	13	11.8	12.6	5.9					43.3	2.47	0.80
1L	3.52								3.52	0.20	4.60
Adjustment of Number of Deduct Values											
	No. of Deduct Values	m	9.74	<=	10						
#	**Deduct Values**							**Total**	**q**	**CDV**	
1	4.80	4.60	3.00	1.10	0.80	-	-	14.30	3.00	-	
2	4.80	4.60	2.00	1.10	0.80	-	-	13.30	2.00	8.20	
3	4.80	2.00	2.00	1.10	0.80	-	-	10.70	1.00	11.50	
									Maximum CDV	**11.50**	
									PCI	88.50	
									Scale	0.89	

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Hetauda to Pathlaiya	**Section**	2+500 to 3+000	**Sample Unit**	6.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY								TOTAL	DENSITY %	DEDUCT VALUE
5M	9.20								9.20	0.53	10.00
19L	9.30								9.30	0.53	1.30
2L	3.00								3.00	0.17	0.90
16L	0.60								0.60	0.03	-

Adjustment of Number of Deduct Values

	No. of Deduct Values	m	9.27	<=	10						
#	**Deduct Values**				**Total**	**q**	**CDV**				
1	10.00	1.30	0.90	-	12.20	1.00	14.00				
						Maximum CDV	**14.00**				
						PCI	**86.00**				
						Scale	0.86				

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Hetauda to Pathlaiya	**Section**	3+000 to 3+500	**Sample Unit**	7.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
5L	16.00	12.60	8.00							36.60	2.09	4.40
5M	12.00									12.00	0.69	11.00
6L	1.00	1.20								2.20	0.13	4.10
15M	5.04	8.40								13.44	0.77	13.50
11M	4.48	4.34								8.82	0.50	6.00
1L	4.90									4.90	0.28	4.70
10L	14.00									14.00	0.80	-

Adjustment of Number of Deduct Values

	No. of Deduct Values	m	8.94	<=	10							
#	**Deduct Values**							**Total**	**q**	**CDV**		
1	13.50	11.00	6.00	5.00	4.40	4.10	-	44.00	6.00	16.00		
	13.50	11.00	6.00	5.00	4.40	2.00		41.90	5.00	16.00		
2	13.50	11.00	6.00	5.00	2.00	2.00	-	39.50	4.00	16.20		
	13.50	11.00	6.00	2.00	2.00	2.00		36.50	3.00	18.00		
3	13.50	11.00	2.00	2.00	2.00	2.00	-	32.50	2.00	17.90		
4	13.50	2.00	2.00	2.00	2.00	2.00	-	23.50	1.00	17.90		
									Maximum CDV	**18.00**		
									PCI	82.00		
									Scale	0.82		

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Hetauda to Pathlaiya	**Section**	3+500 to 4+000	**Sample Unit**	8.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
10L	8.00									8.00	0.46	-
16M	1.88									1.88	0.11	4.00
15M	7.80									7.80	0.45	11.20
										-	-	
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	9.16	<=	10							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1	11.20	4.00	-	-	15.20	2.00	10.00					
2	11.20	2.00	-	-	13.20	1.00	12.00					
						Maximum CDV	**12.00**					
						PCI	**88.00**					
						Scale	0.88					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Hetauda to Pathlaiya	**Section**	4+000 to 4+500	**Sample Unit**	9.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
1L	2.10									2.10	0.12	4.10
10L	15.00	16.78								31.78	1.82	-
5M	3.00	4.00								7.00	0.40	9.00
										-	-	
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	9.36	<=	10							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1	9.00	4.10	-	-	13.10	2.00	8.80					
2	9.00	2.00	-	-	11.00	1.00	9.00					
						Maximum CDV	**9.00**					
						PCI	**91.00**					
						Scale	0.91					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Hetauda to Pathlaiya	**Section**	4+500 to 5+000	**Sample Unit**	10.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY									TOTAL	DENSITY %	DEDUCT VALUE
5L	12.00	4.50	10.00	3.00	30.80					60.30	3.45	6.80
1L	15.00	16.80	8.00							39.80	2.27	17.20
16M	0.60	1.80								2.40	0.14	2.40
6L	3.60	9.60								13.20	0.75	5.00
15L	16.32									16.32	0.93	8.20
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	8.60	<=	10							
#	**Deduct Values**							**Total**	**q**	**CDV**		
1	17.20	8.20	6.80	5.00	2.40	-	-	39.60	5.00	14.20		
2	17.20	8.20	6.80	5.00	2.00	-	-	39.20	4.00	15.90		
	17.20	8.20	6.80	2.00	2.00	-	-	36.20	3.00	16.80		
	17.20	8.20	2.00	2.00	2.00	-	-	31.40	2.00	20.00		
3	17.20	2.00	2.00	2.00	0.80	-	-	24.00	1.00	20.00		
									Maximum CDV	**20.00**		
									PCI	80.00		
									Scale	0.80		

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Hetauda to Pathlaiya	**Section**	5+000 to 5+500	**Sample Unit**	11.00	
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M²**	1750.00	

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
1L	13.23	18.62	18.78	12.60	7.20					70.43	4.02	22.00
5L	12.00									12.00	0.69	1.80
5M	56.00	51.25	30.00							137.25	7.84	36.20
6L	3.20	0.36								3.56	0.20	4.00
11L	2.40	1.10	3.00	7.20	9.00	7.50				30.20	1.73	4.20
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	6.86	<=	10							
#	**Deduct Values**							**Total**	**q**	**CDV**		
1	36.20	22.00	4.20	4.00	1.80	-	-	68.20	4.00	34.00		
	36.20	22.00	4.20	2.00	1.80	-		66.20	3.00	37.30		
2	36.20	22.00	2.00	2.00	1.80	-	-	64.00	2.00	38.60		
	36.20	2.00	2.00	2.00	1.80	-		44.00	1.00	38.00		
									Maximum CDV	**38.60**		
									PCI	61.40		
									Scale	0.61		

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Hetauda to Pathlaiya	**Section**	5+500 to 6+000	**Sample Unit**	12.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1500.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
5L	10	7.2								17.2	1.15	2.1
11L	24	41.82	29.2	18	16.5	13.5	8	33	33	217.02	14.47	17.5
19L	8									8	0.53	1.2
1L	52									52	3.47	21.8
6M	30									30	2.00	10.5
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	8.18	<=	10							
#	**Deduct Values**							**Total**	**q**	**CDV**		
1	21.80	17.50	10.50	2.10	1.20	-	-	53.10	4.00	26.00		
	21.80	17.50	10.50	2.00	1.20	-		53.00	3.00	30.00		
2	21.80	17.50	2.00	2.00	1.20	-	-	44.50	2.00	29.00		
	21.80	2.00	2.00	2.00	1.20	-		29.00	1.00	27.00		
									Maximum CDV	**30.00**		
									PCI	70.00		
									Scale	0.70		

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Hetauda to Pa	**Section**	6+000 to 6+500	**Sample Unit**	13.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1500.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**								**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
5M	9.00	23.40							32.40	2.16	21.00
5L	66.00	24.60							90.60	6.04	8.50

Adjustment of Number of Deduct Values

No. of Deduct Values	m	8.26	<=	10							
#	**Deduct Values**				**Total**	**q**	**CDV**				
1	21.00	8.50	-	-	29.50	2.00	19.00				
2	21.00	2.00	-	-	23.00	1.00	20.00				
						Maximum CDV	**20.00**				
						PCI	**80.00**				
						Scale	0.80				

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Hetauda to Pa	**Section**	6+500 to 7+000	**Sample Unit**	14.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1500.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY									TOTAL	DENSITY %	DEDUCT VALUE
5L	83.50	46.00								129.50	8.63	11.00
11L	105.00									105.00	7.00	12.30
Adjustment of Number of Deduct Values												
No. of Deduct Values	m	9.05	<=	10								
#	**Deduct Values**				**Total**	**q**	**CDV**					
1	12.30	11.00	-	-	23.30	2.00	16.00					
2	12.30	2.00	-	-	14.30	1.00	14.00					
						Maximum CDV	**16.00**					
						PCI	**84.00**					
						Scale	0.84					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Hetauda to Pathlaiya	**Section**	7+000 to 7+500	**Sample Unit**	15.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
1L	31.50									31.50	1.80	15.50
7L	1.20									1.20	0.07	-
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	8.76	<=	10							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1	15.50	-	-	-	15.50	1.00	14.00					
						Maximum CDV	**14.00**					
						PCI	**86.00**					
						Scale	0.86					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Hetauda to Pathlaiya	**Section**	7+500 to 8+000	**Sample Unit**	16.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M²**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
5L	56.80	44.80	12.00							113.60	6.49	9.50
16M	1.50									1.50	0.09	3.50
11M	13.86	8.96	2.80	12.60	3.60	3.20				45.02	2.57	16.00
10L	16.00									16.00	0.91	-
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	8.71	<=	10							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1	16.00	9.50	3.50	-	29.00	3.00	16.00					
2	16.00	9.50	2.00		27.50	2.00	17.50					
3	16.00	2.00	2.00	-	20.00	1.00	17.00					
						Maximum CDV	**17.5**					
						PCI	**82.5**					
						Scale	0.83					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Hetauda to Pa	**Section**	8+000 to 8+500	**Sample Unit**	17.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY									TOTAL	DENSITY %	DEDUCT VALUE
1L	2.00									2.00	0.11	4.00
6L	2.00									2.00	0.11	4.00
5M	4.80									4.80	0.27	7.00
11L	165.00									165.00	9.43	15.00
5L	24.00									24.00	1.37	2.80
10L	2.24									2.24	0.13	-
Adjustment of Number of Deduct Values												
No. of Deduct Values		m	8.81	<=	10							
#	**Deduct Values**							**Total**	**q**	**CDV**		
1	15.00	7.00	4.00	4.00	2.80	-	-	32.80	5.00	11.00		
	15.00	7.00	4.00	4.00	2.00	-		32.00	4.00	13.00		
	15.00	7.00	4.00	2.00	2.00			30.00	3.00	16.00		
2	15.00	7.00	2.00	2.00	2.00	-	-	28.00	2.00	16.80		
	15.00	2.00	2.00	2.00	2.00	-		23.00	1.00	19.00		
									Maximum CDV	**19.00**		
									PCI	81.00		
									Scale	0.81		

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Hetauda to Pa	**Section**	8+500 to 9+000	**Sample Unit**	18.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
11L	6.30	8.96	2.80	2.40	1.68	14.40				36.54	2.09	5.00
5L	80.00	35.00								115.00	6.57	9.00
1M	12.00									12.00	0.69	18.00
16M	0.36									0.36	0.02	3.00

Adjustment of Number of Deduct Values

No. of Deduct Values	m	8.53	<=	10			
#	**Deduct Values**				**Total**	**q**	**CDV**
1	18.00	9.00	5.00	3.00	35.00	4.00	12.00
	18.00	9.00	5.00	2.00	34.00	3.00	19.00
	18.00	9.00	2.00	2.00	31.00	2.00	20.00
2	18.00	2.00	2.00	2.00	24.00	1.00	22.00
						Maximum CDV	**22**
						PCI	**78**
						Scale	0.78

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT						SKETCH:
Branch	Hetauda to Pa	**Section**	9+000 to 9+500	**Sample Unit**	19.00	
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M²**	1750.00	

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY									TOTAL	DENSITY %	DEDUCT VALUE
5L	112.50	24.00	117.00							253.50	14.49	15.20
1L	9.60	6.00								15.60	0.89	10.00
10L	16.00									16.00	0.91	-

Adjustment of Number of Deduct Values

No. of Deduct Values		m	8.79	<=	10		
#	Deduct Values				Total	q	CDV
1	15.20	10.00	-	-	25.20	2.00	16.00
2	15.20	2.00	-	-	17.20	1.00	16.00
						Maximum CDV	**16.00**
						PCI	**84.00**
						Scale	0.84

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Hetauda to Pat	**Section**	9+500 to 10+000	**Sample Unit**	20.00	
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00	

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**								**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
5L	36	42	30						108	6.17	8.6
1L	20	4							24	1.37	11.6
10L	15	9	3.8						27.8	1.59	0

Adjustment of Number of Deduct Values

No. of Deduct Values	m	9.12	<=	10								
#	**Deduct Values**				**Total**	**q**	**CDV**					
1	11.6	8.6	0	0	20.2	2	14					
2	11.6	2	0	0	13.6	1	12					
						Maximum CDV	**14**					
						PCI	**86**					
						Scale	0.86					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Pathlaiya to Hetauda	**Section**	0+000 to 0+500	**Sample Unit**	21.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1250.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
6M	4.95									4.95	0.40	8.00
2M	5.76									5.76	0.46	3.00
11L	5.76	4.68								10.44	0.84	1.80
10L	3.00	2.50	5.00							10.50	0.84	-
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	9.45	<=	10							
#	**Deduct Values**				**Total**	**q**	**CDV**					
	8.00	3.00	1.80	-	12.80	2.00	10.00					
1	8.00	2.00	-	-	10.00	1.00	11.00					
						Maximum CDV	**11.00**					
						PCI	**89.00**					
						Scale	0.89					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Pathlaiya to Hetauda	**Section**	0+500 to 1+000	**Sample Unit**	22.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	2500.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY									TOTAL	DENSITY %	DEDUCT VALUE
5L	1.20									1.20	0.05	0.80
6L	0.15									0.15	0.01	-
1L	9.10	7.00								16.10	0.64	8.00
1M	3.85									3.85	0.15	8.20
3L	4.20									4.20	0.17	-
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	9.43	<=	10							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1	8.20	8.00	0.80	-	17.00	2.00	12.50					
2	8.20	2.00	-	-	10.20	1.00	10.50					
						Maximum CDV	**12.50**					
						PCI	**87.50**					
						Scale	0.88					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Pathlaiya to Hetauda	**Section**	1+000 to 1+500	**Sample Unit**	23.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	2500.00

1. Alligator Cracking
2. Bleeding
3. Block Cracking
4. Bumps and Slags
5.Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/ Shoulder Drop off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Revealing

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
16H	4.40									4.40	0.18	9.00
										0	-	
										0	-	
Adjustment of Number of Deduct Values												
No. of Deduct Values		m	9.36	<=	10							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1	9.00	-	-	-	9.00	1.00	8.00					
						Maximum CDV	**8.00**					
						PCI	**92.00**					
						Scale	0.92					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch Pathlaiya to Hetauda **Section** 1+500 to 2+000 **Sample Unit** 24.00

Surveyed By Bibek Gupta Rauniyar **Date** 26/02/2026 **Sample Area, M^2** 2500.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY									TOTAL	DENSITY %	DEDUCT VALUE
5L	10.00	40.00								50.00	2.00	4.80
11L	10.00	2.64	7.50							20.14	0.81	2.00
16M	2.85									2.85	0.11	3.60
13L	2.85									2.85	0.11	2.00

Adjustment of Number of Deduct Values

	No. of Deduct Values	m	9.74	<=	10		
#	Deduct Values				Total	q	CDV
1	4.80	3.60	2.00	2.00	12.40	2.00	10.00
2	4.80	2.00	2.00	2.00	10.80	1.00	11.00
						Maximum CDV	**11.00**
						PCI	**89.00**
						Scale	0.89

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Pathlaiya to Hetauda	**Section**	2+000 to 2+500	**Sample Unit**	25.00		
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00		

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
5L	8.70	9.60	5.40							23.70	1.35	4.00
15L	5.80									5.80	0.33	2.00
10L	4.00									4.00	0.23	-
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	9.82	<=	10							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1	4.00	2.00	-	-	6.00	1.00	6.00					
						Maximum CDV	**6.00**					
						PCI	**94.00**					
						Scale	0.94					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Pathlaiya to Hetauda	**Section**	2+500 to 3+000	**Sample Unit**	26.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
5M	2.40									2.40	0.14	5.80
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	9.65	<=	10							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1	5.80	-	-	-	5.80	1.00	7.00					
						Maximum CDV	**7.00**					
						PCI	**93.00**					
						Scale	0.93					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Pathlaiya to Hetauda	**Section**	3+000 to 3+500	**Sample Unit**	27.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
5L	2.70	102.00	22.50							127.20	7.27	10.00
6L	2.60	8.00								10.60	0.61	4.00

Adjustment of Number of Deduct Values

No. of Deduct Values	m	9.27	<=	10	

#	**Deduct Values**				**Total**	**q**	**CDV**
1	10.00	8.60	-	-	18.60	2.00	12.00
2	10.00	2.00	-	-	12.00	1.00	11.00
						Maximum CDV	**12.00**
						PCI	**88.00**
						Scale	0.88

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Pathlaiya to Hetauda	**Section**	3+500 to 4+000	**Sample Unit**	28.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking
2. Bleeding
3. Block Cracking
4. Bumps and Slags
5.Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/ Shoulder Drop off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Revealing

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
5M	4.80									4.80	0.27	8.00
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	9.45	<=	10							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1	8.00	-	-	-	8.00	1.00	9.00					
						Maximum CDV	**9.00**					
						PCI	**91.00**					
						Scale	0.91					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Pathlaiya to Hetauda	**Section**	4+000 to 4+500	**Sample Unit**	29.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
5M	13.2									13.2	0.75	13
2L	3.6									3.6	0.21	0
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	8.99	<=	10							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1	13.00	-	-	-	13.00	1.00	10.50					
						Maximum CDV	**10.50**					
						PCI	**89.50**					
						Scale	0.90					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Pathlaiya to Hetauda	**Section**	4+500 to 5+000	**Sample Unit**	30.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
5L	14.00	43.20	60.00							117.20	6.70	10.00
1M	31.50									31.50	1.80	9.50
19L	4.00	7.20								11.20	0.64	1.90
6L	8.10									8.10	0.46	4.00
11L	2.60	4.00	3.63							10.23	0.58	1.80
16L	1.50									1.50	0.09	-
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	9.27	<=	10							
#	**Deduct Values**							**Total**	**q**	**CDV**		
1	10.00	9.50	4.00	1.90	1.80	-	-	27.20	3.00	15.00		
	10.00	9.50	2.00	1.90	1.80	-		25.20	2.00	16.00		
	10.00	2.00	2.00	1.90	1.80			17.70	1.00	16.00		
									Maximum CDV	**16.00**		
									PCI	84.00		
									Scale	0.84		

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Pathlaiya to Hetauda	**Section**	5+000 to 5+500	**Sample Unit**	31.00		
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00		

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**								**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
5L	255.00	165.00	3.20						423.20	24.18	20.10
13L	0.12								0.12	0.01	2.00
11L	4.32	3.00	4.50	8.40	3.00				23.22	1.33	3.80
Adjustment of Number of Deduct Values											
	No. of Deduct Values	m	8.34	<=	10						
#	**Deduct Values**				**Total**	**q**	**CDV**				
1.00	20.10	3.80	2.00	-	25.90	2.00	18.00				
2.00	20.10	2.00	2.00	-	24.10	1.00	20.00				
						Maximum CDV	**20.00**				
						PCI	**80.00**				
						Scale	0.80				

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch Pathlaiya to Hetauda **Section** 5+500 to 6+000 **Sample Unit** 32.00

Surveyed By Bibek Gupta Rauniyar **Date** 26/02/2026 **Sample Area, M^2** 1500.00

1. Alligator Cracking
2. Bleeding
3. Block Cracking
4. Bumps and Slags
5. Corrugation
6. Depression
7. Edge Cracking
8. Jt. Reflection Cracking
9. Lane/ Shoulder Drop off
10. Long & Trans Cracking
11. Patching & Util Cut Patching
12. Polished Aggregate
13. Potholes
14. Railroad Crossing
15. Rutting
16. Shoving
17. Slippage Cracking
18. Swell
19. Weathering/Revealing

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
5L	13.60									13.60	0.91	2.80
1L	7.20									7.20	0.48	6.80
11L	33.00	33.00	4.00	12.00	13.50					95.50	6.37	12.00
6L	9.00									9.00	0.60	4.00
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	9.08	<=	10.00							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1.00	12.00	6.80	4.00	2.80	25.60	4.00	10.00					
	12.00	6.80	4.00	2.00	24.80	3.00	12.00					
	12.00	6.80	2.00	2.00	22.80	2.00	15.50					
2.00	12.00	2.00	2.00	2.00	18.00	1.00	17.00					
						Maximum CDV	**17.00**					
						PCI	**83.00**					
						Scale	0.83					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Pathlaiya to Hetauda	**Section**	6+000 to 6+500	**Sample Unit**	33.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1500.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
5L	48.00									48.00	3.20	6.20
1L	12.00	5.20								17.20	1.15	10.50
6L	10.50									10.50	0.70	4.00
11L	11.55	55.20	6.75	14.00	54.00	11.20	7.20	6.00		165.90	11.06	16.00
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	8.71	<=	10.00							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1.00	16.00	10.50	6.20	4.00	36.70	4.00	16.00					
	16.00	10.50	6.20	2.00	34.70	3.00	18.80					
	16.00	10.50	2.00	2.00	30.50	2.00	20.00					
2.00	16.00	2.00	2.00	2.00	22.00	1.00	20.00					
						Maximum CDV	**20.00**					
						PCI	**80.00**					
						Scale	0.80					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Pathlaiya to Hetauda	**Section**	6+500 to 7+000	**Sample Unit**	34.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1500.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	QUANTITY									TOTAL	DENSITY %	DEDUCT VALUE
5L	71.72	24.00	33.00							128.72	8.58	11.00
1L	3.90	12.00	10.40	10.80						37.10	2.47	17.00
2L	2.73									2.73	0.18	-
11L	21.52	23.97	6.30	19.32	6.30	72.80				150.21	10.01	15.00

Adjustment of Number of Deduct Values

No. of Deduct Values	m	8.62	<=	10.00			
#	Deduct Values				Total	q	CDV
1.00	17.00	15.00	11.00	-	43.00	3.00	23.00
2.00	17.00	15.00	2.00	-	34.00	2.00	22.00
3.00	17.00	2.00	2.00	-	21.00	1.00	20.00
						Maximum CDV	**23.00**
						PCI	**77.00**
						Scale	0.77

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Pathlaiya to Hetauda	**Section**	7+000 to 7+500	**Sample Unit**	35.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
11L	22.11	5.28	14.19	24.27	11.42	76.00				153.27	8.76	14.80
1L	7.04									7.04	0.40	5.00
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	8.82	<=	10.00							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1.00	14.80	5.00	-	-	19.80	2.00	14.00					
2.00	14.80	2.00	-	-	16.80	1.00	13.50					
						Maximum CDV	**14.00**					
						PCI	**86.00**					
						Scale	0.86					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT								SKETCH:				
Branch	Pathlaiya to Hetauda	**Section**	7+500 to 8+000		**Sample Unit**	36.00						
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026		**Sample Area, M^2**	1750.00						
1. Alligator Cracking		6. Depression			11. Patching & Util Cut Patching				16. Shoving			
2. Bleeding		7. Edge Cracking			12. Polished Aggregate				17. Slippage Cracking			
3. Block Cracking		8. Jt. Reflection Cracking			13. Potholes				18. Swell			
4. Bumps and Slags		9. Lane/ Shoulder Drop off			14. Railroad Crossing				19. Weathering/Revealing			
5.Corrugation		10. Long & Trans Cracking			15. Rutting							
DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
5L	12.80	12.80	117.30							142.90	8.17	11.00
1L	2.24									2.24	0.13	4.00
11L	11.76									11.76	0.67	1.80
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	9.17	<=	10.00							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1.00	11.00	4.00	1.80	-	16.80	2.00	11.00					
2.00	11.60	2.00	1.80	-	15.40	1.00	14.00					
						Maximum CDV	**14.00**					
						PCI	**86.00**					
						Scale	0.86					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Pathlaiya to Hetauda	**Section**	8+000 to 8+500	**Sample Unit**	37.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
11L	10.44	95.00	6.40	7.50	23.70	34.25	8.84			186.13	10.64	15.00
1L	12.00									12.00	0.69	8.00
10L	2.24									2.24	0.13	-
3L	6.40	5.04								11.44	0.65	-
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	8.81	<=	10.00							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1.00	15.00	8.00	-	-	23.00	2.00	16.00					
2.00	15.00	2.00	-	-	17.00	1.00	17.00					
						Maximum CDV	**17.00**					
						PCI	**83.00**					
						Scale	0.83					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Pathlaiya to Hetauda	**Section**	8+500 to 9+000	**Sample Unit**	38.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
3L	4.80	14.00	45.00							63.80	3.65	4.20
1L	13.80	8.28	9.60	51.65	13.60	9.60				106.53	6.09	28.00
11L	12.80	32.10	10.50	50.40	46.00	71.02	174.90	65.85		463.57	26.49	25.00
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	7.61	<=	10.00							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1.00	28.00	25.00	4.20	-	57.20	3.00	36.00					
2.00	28.00	25.00	2.00		55.00	2.00	38.00					
3.00	28.00	2.00	2.00	-	32.00	1.00	34.00					
						Maximum CDV	**38.00**					
						PCI	**62.00**					
						Scale	0.62					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Pathlaiya to Hetauda	**Section**	9+000 to 9+500	**Sample Unit**	39.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	26/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
5L	36.00	18.40								54.40	3.11	6.20
1L	19.20	6.40								25.60	1.46	13.80
11M	3.60	4.00	4.00	9.00	6.00					26.60	1.52	11.00
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	8.92	<=	10.00							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1.00	13.80	11.00	5.00	-	29.80	3.00	17.00					
2.00	13.80	11.00	2.00	-	26.80	2.00	20.00					
3.00	13.80	2.00	2.00	-	17.80	1.00	17.00					
						Maximum CDV	**20.00**					
						PCI	**80.00**					
						Scale	0.80					

ASPHALT SURFACED ROADS AND PARKING LOTS CONDITION SURVEY DATA SHEET FOR SAMPLE UNIT

SKETCH:

Branch	Pathlaiya to Hetauda	**Section**	9+500 to 10+000	**Sample Unit**	40.00
Surveyed By	Bibek Gupta Rauniyar	**Date**	28/02/2026	**Sample Area, M^2**	1750.00

1. Alligator Cracking	6. Depression	11. Patching & Util Cut Patching	16. Shoving
2. Bleeding	7. Edge Cracking	12. Polished Aggregate	17. Slippage Cracking
3. Block Cracking	8. Jt. Reflection Cracking	13. Potholes	18. Swell
4. Bumps and Slags	9. Lane/ Shoulder Drop off	14. Railroad Crossing	19. Weathering/Revealing
5.Corrugation	10. Long & Trans Cracking	15. Rutting	

DISTRESS SEVERITY	**QUANTITY**									**TOTAL**	**DENSITY %**	**DEDUCT VALUE**
5L	75.00	24.00	105.00	30.00	36.00					270.00	15.43	17.00
1M	10.00									10.00	0.57	18.00
Adjustment of Number of Deduct Values												
	No. of Deduct Values	m	8.53	<=	10.00							
#	**Deduct Values**				**Total**	**q**	**CDV**					
1.00	18.00	17.00	-	-	35.00	2.00	26.00					
2.00	18.00	2.00	-	-	20.00	1.00	20.00					
						Maximum CDV	**26.00**					
						PCI	**74.00**					
						Scale	0.74					

ANNEXURE - 5

Model Development and Validation Data for 40 segment (PCI Vs Panel_RQI, RMS_RQI & Hybrid_RQI)

Model Development and its Validation

S.No.	Panel_RQI	RMS_Data	Hybrid_RQI, w1=0.7 and w2=0.3	PCI_Data	Hybrid_RQI, w1=0.80 and w2=0.20	Hybrid_RQI, w1=0.69 and w2=0.31	Hybrid_RQI, w1=0.81 and w2=0.19
1	0.90	0.89	0.89	0.88	0.89	0.89	0.89
2	0.85	0.86	0.85	0.82	0.85	0.85	0.85
3	0.87	0.90	0.88	0.90	0.88	0.88	0.88
4	0.82	0.86	0.83	0.82	0.83	0.83	0.83
5	0.87	0.87	0.87	0.89	0.87	0.87	0.87
6	0.86	0.83	0.85	0.86	0.86	0.85	0.86
7	0.85	0.89	0.86	0.82	0.86	0.87	0.86
8	0.87	0.88	0.88	0.88	0.87	0.88	0.87
9	0.91	0.96	0.92	0.91	0.92	0.92	0.92
10	0.90	0.88	0.90	0.80	0.90	0.90	0.90
11	0.71	0.78	0.73	0.61	0.72	0.73	0.72
12	0.61	0.74	0.65	0.70	0.64	0.65	0.64
13	0.82	0.85	0.83	0.80	0.82	0.83	0.82
14	0.81	0.84	0.82	0.84	0.82	0.82	0.82
15	0.83	0.83	0.83	0.86	0.83	0.83	0.83
16	0.85	0.84	0.85	0.83	0.85	0.85	0.85
17	0.82	0.84	0.83	0.81	0.82	0.83	0.82
18	0.76	0.82	0.77	0.78	0.77	0.77	0.77
19	0.86	0.85	0.86	0.84	0.86	0.86	0.86
20	0.87	0.89	0.88	0.86	0.88	0.88	0.88
21	0.91	0.68	0.84	0.89	0.87	0.84	0.87
22	0.92	0.86	0.90	0.88	0.91	0.90	0.91
23	0.94	0.93	0.94	0.92	0.94	0.94	0.94
24	0.90	0.90	0.90	0.89	0.90	0.90	0.90
25	0.93	0.88	0.92	0.94	0.92	0.92	0.92
26	0.92	0.86	0.91	0.93	0.91	0.91	0.91
27	0.88	0.88	0.88	0.88	0.88	0.88	0.88
28	0.91	0.97	0.93	0.91	0.92	0.93	0.92
29	0.91	0.93	0.91	0.90	0.91	0.92	0.91
30	0.84	0.93	0.87	0.84	0.86	0.87	0.86
31	0.81	0.80	0.81	0.80	0.81	0.81	0.81
32	0.81	0.83	0.82	0.83	0.82	0.82	0.82
33	0.86	0.82	0.85	0.80	0.85	0.85	0.85
34	0.85	0.82	0.84	0.77	0.84	0.84	0.84
35	0.87	0.81	0.85	0.86	0.86	0.85	0.86
36	0.88	0.92	0.89	0.86	0.88	0.89	0.88
37	0.84	0.70	0.80	0.83	0.81	0.80	0.81
38	0.74	0.68	0.72	0.62	0.73	0.72	0.73
39	0.81	0.72	0.78	0.80	0.79	0.78	0.79
40	0.70	0.79	0.73	0.74	0.72	0.73	0.72

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[IOEGC18] Editor Decision

Dr. Kshitij Charana Shrestha <ioegc17@gmail.com> Mon, Apr 20, 2026 at 9:14 PM
To: Bibek Gupta Rauniyar <bibekgupta8822@gmail.com>, "Dr. Pradeep Kumar Shrestha" <pradeep.shrestha@pcampus.edu.np>

Bibek Gupta Rauniyar, Dr. Pradeep Kumar Shrestha:

We have reached a decision regarding your submission to 18th IOE Graduate Conference, "Panel-Based Riding Quality Index (RQI): A Case Study of Pathlaiya to Hetauda Road Section.".

Our decision is to: Accept Submission

With Warm Regards,
IOEGC-18 Editorial Team

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Date: May 9, 2026

To Whom It May Concern:

This is to certify that the paper titled "*Panel-Based Riding Quality Index (RQI): A Case Study of Pathlaiya to Hetauda Road Section*" (Submission ID #831), with **Bibek Gupta Rauniyar** as the first author, was accepted through the peer-review process and has been presented at the 18th IOE Graduate Conference, organized at Pulchowk Campus, Lalitpur, Nepal, from May 7 to 9, 2026.

Please note that inclusion of the accepted manuscript in the conference proceedings is contingent upon timely compliance with any further editorial requirements during the publication process.

Prof. Sangeeta Singh
Convener
18th IOE Graduate Conference

Panel-Based Riding Quality Index (RQI): A Case Study of Pathlaiya to Hetauda Road Section.

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Abstract

Accurate evaluation of pavement performance requires indicators that capture both structural condition and user-perceived serviceability. This study critically examines the reliability and validity of the panel-based Riding Quality Index (RQI) as a functional measure of pavement condition. A rigorously designed panel survey was conducted using standardized rating protocols across segmented road sections to ensure consistency in subjective assessment. Inter-rater reliability was quantified using the Intra-class Correlation Coefficient (ICC) based on a two-way random-effects model with absolute agreement, yielding an ICC value of 0.939, indicative of excellent agreement among panelists. To establish external validity, Panel RQI was benchmarked against the Pavement Condition Index (PCI) using data from 40 representative segments. The analysis revealed a strong positive relationship ($R^2 = 0.7169$), demonstrating that perceived ride quality closely aligns with distress-based pavement condition. The findings provide robust evidence that, when implemented under controlled and standardized conditions, panel-based RQI offers a reliable, valid, and scalable approach for pavement evaluation. This method presents a practical alternative for large-scale network assessment, particularly in resource-constrained contexts where conventional instrumentation-based approaches are not feasible.

Keywords

Riding Quality Index, Panel Rating, Pavement Condition Index, Intra-class Correlation Coefficient, Regression Analysis

1. Introduction

1.1 Background

Road transportation plays a vital role in the economic development and social integration of a country. In Nepal, where terrain variability and limited transportation alternatives exist, the road network serves as the primary mode of mobility for both passengers and freight. Ensuring the performance and serviceability of road infrastructure is therefore essential for enhancing connectivity, safety, and user satisfaction.

Pavement condition evaluation is a fundamental component of road asset management systems. Traditionally, indices such as the Pavement Condition Index (PCI) have been widely used to assess pavement condition based on visual inspection of surface distresses. PCI provides a quantitative measure of structural and surface deterioration and supports maintenance decision-making. However, its implementation is often constrained by the requirement of skilled personnel, extensive field surveys, and considerable time, particularly for large road networks. These limitations make frequent monitoring difficult, especially in resource-constrained environments.

In recent years, increasing emphasis has been placed on the functional performance of pavements, particularly ride quality, which directly reflects user comfort and serviceability. The Riding Quality Index (RQI), based on human perception of ride comfort, has emerged as a practical and cost-effective alternative for evaluating pavement functionality. Panel-based RQI offers several advantages, including simplicity, rapid data collection, and minimal equipment requirements. However, its reliance on subjective judgment introduces concerns regarding variability and consistency among raters.

To ensure the credibility of panel-based assessments, it is necessary to evaluate the reliability of ratings using statistical measures. The Intra-class Correlation Coefficient (ICC) is a widely accepted method for assessing inter-rater reliability and determining the degree of agreement among multiple observers. A high ICC value indicates that the observed variability in ratings is primarily due to actual differences in pavement condition rather than inconsistencies among panelists.

Furthermore, for practical application, it is essential to validate panel-based RQI against established pavement condition indices. The Pavement Condition Index (PCI), being a standardized distress-based indicator, provides a suitable benchmark for this purpose. Establishing a strong relationship between Panel RQI and PCI would confirm that subjective ride quality assessments can effectively represent actual pavement conditions.

In this context, the present study is undertaken as a preliminary approach toward developing a reliable and scalable pavement condition evaluation framework by integrating panel-based ride quality assessment, reliability analysis using ICC, and validation against PCI.

2. Literature Review

Pavement condition assessment plays a vital role in infrastructure asset management. The Pavement Condition Index (PCI), developed by the U. S. Army Corps of Engineers and standardized by ASTM D6433 [1], remains a widely adopted method globally. PCI is based on visual distress data, quantified and weighted by severity and extent [2]. However, PCI surveys require skilled manpower, systematic field inspections and are time intensive making them difficult to implement frequently across large networks in Nepal.

The International Roughness Index (IRI), which uses laser profilers or inertial systems, offers precise measurements of longitudinal surface profiles but demands expensive instrumentation and calibration [3]. In recent years, IRI based contracts have been practiced in some major national projects in Nepal including the IRI based contract for improvement project of East-West Highway for an extended maintenance period for four years. Despite IRI not being used in Nepal to that extent, it is collected on a yearly basis (IQL III). The use and implementation of IRI in maintenance planning in country like Nepal can possess significant challenges because of limited budget for road maintenance especially for low volume roads. Most of the roads of Nepal in present are of poor condition therefore specific set of maintenance activities would be required in-order to uplift the pavement into Fair/Good condition. The use of IRI as metric in such cases can propose an expensive treatment and maintenance option which is a major constraint in country like Nepal [4]. As an alternative, the Riding Quality Index (RQI), which relies on human perception of ride comfort, offers a viable alternative for evaluating road functionality. RQI has been used in context where rapid and low cost evaluations are needed. Firoozi Yeganeh, S. et al. [5] found that trained panelists can rate ride quality reliably, provided adequate calibration and standardized protocols are in place. Panel rating has been applied to investigate the ride quality of pavement [6]. It is the best subjective method to collect the travelers' opinion about ride quality which can be effectively applied to validate the objective measurement of pavement roughness.

Firoozi Yeganeh, S. et. al. [5] examined the correlation between pavement roughness measured by smartphones mounted on a vehicle and user opinions obtained through the mean of panel rating on the ride quality of pavement and demonstrated that the travelers' opinions about pavement roughness had a good correlation ($R^2 = 0.80$) with smartphone-based roughness measures. It emphasizes that smartphones can express the pavement roughness which is compatible with travelers' sense of comfort. Thus, smartphones can merely express the road roughness. Also, this paper validated that the smartphone-based roughness measures expressed a good correlation ($R^2 = 0.76$) with the International Roughness Index (IRI) measured by the Road Surface Profiler conveying the validity of smartphones outputs. Thus, through the application of an inexpensive smartphone, IRI can be approximated which is conventionally measured using the Road Surface Profiler that is of high cost. The utility of RMS and SD of vertical acceleration in capturing vibration severity caused by surface irregularities have been investigated. These studies support integrating subjective and objective methods into hybrid RQI for enhanced reliability and consistency. Panel reliability is another critical concern. Koo and Li [7] highlighted the use of Intra-class Correlation Coefficient (ICC) for assessing rating reliability and consistency in health and behavioral sciences. Fang et. al. [8] demonstrated the Inter-rater reliability is critical in oncology to ensure consistent and reliable measurements across raters and methods, such as when evaluating biomarker levels in different laboratories or comparing tumor size assessments by radiation oncologists during therapy planning. This consistency is essential for informed decision-making in both clinical and research contexts, and the intra-class correlation coefficient (ICC) is widely recommended statistic for assessing agreement. Bianchini et. al. [9] address the critical issue of reliability in manual pavement distress evalutions, a process widely used by transportation agencies to monitor pavement conditions. Although standardized rating criteria exist, the authors highlight that manual inspections inevitably involve subjective judgment, influenced by rater experience and interpretation. To address this, the study proposes a new statistical approach for validating inter-rater or inter-crew reliability, using chi-square distribution to assess agreement levels in multinomial rating categories. Their method distinguishes between complete and partial agreement, acknowledging that some variability in visual assessments is expected. While focused on pavement inspections, the study's insights are broadly applicable to any research relying on panel rating or subjective survey responses. It emphasizes the importance of quantifying variability across raters to ensure data consistency and reliability. This logic aligns closely with the present research, where household-level data and perceptual indicators may vary across respondents. The methodological emphasis on validating agreement supports the use of Intra-Class Correlation Coefficient (ICC) in this study to assess variance across hierarchical levels and confirms the appropriateness of multilevel modeling. Overall, Bianchini et. al. [9] provide important conceptual grounding for reliability assessment in studies involving human judgment and observational data.

Furthermore, the statistical reliability of panel ratings using measures like the ICC has not been validated in the Nepalese context.

3. Study Area

3.1 Study Area Selection

The selected stretch of road between Pathlaiya to Hetauda, part of Existing East-West Highway (Mahendra Rajmarg), spans approximately 31.00 km. This section is crucial for freight and passenger movement between the Terai industrial zones and the hilly regions. The roads have been divided into 0.5 km segments using GPS logging and Google Earth coordinate tracking. Each segment have been uniquely coded (e.g., S01 to S62) for uniform data collection across RQI, ICC and PCI surveys. This segmentation follows similar approaches used by the Department of Roads, Nepal and previous highway studies conducted by [4].

4. Methodology

The present study adopts a structured methodology based on panel-based Riding Quality Index (RQI), reliability assessment using Intra-Class Correlation Coefficient (ICC), and validation through Pavement Condition Index (PCI). The panel RQI is

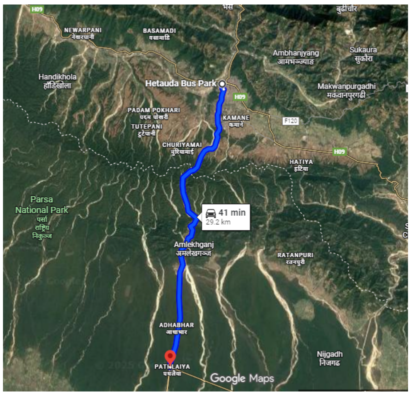

Figure 1: Location Map of Study Area

developed from subjective ratings provided by selected panel members to represent perceived ride quality of pavement sections. ICC analysis is used to evaluate the consistency and reliability of panel responses. Finally, the derived RQI values are validated against field-measured PCI to examine the relationship between perceived ride quality and actual pavement condition. The overall methodological framework is presented in the following sub-sections:

4.1 Data Collection

4.1.1 Panel-Based Riding Quality Index (Panel RQI)

The evaluation of pavement ride quality using the panel-based Riding Quality Index (Panel RQI) was carried out through a structured and systematic procedure to ensure consistency, reliability, and representativeness of subjective assessments. Initially, a panel consisting of five members was carefully selected to capture a diverse range of perceptions related to ride comfort. The panel included a transportation engineer and a surveyor to provide technical judgment, along with a driver, a frequent passenger, and an elderly road user to reflect typical user experiences. This combination ensured a balanced evaluation incorporating both professional expertise and real-world user perception of pavement conditions.

Following panel selection, a comprehensive training and calibration process was conducted to minimize subjective variability and ensure uniform understanding among panelists. The training involved detailed explanation of standardized RQI rating guidelines, including the interpretation of ride quality in terms of vertical vibrations, surface irregularities, and overall comfort level. Descriptive anchors were provided for each rating category to establish clear differentiation between levels of ride quality. To further enhance consistency, a pilot survey was conducted on selected trial segments, allowing panelists to practice rating under real conditions and align their judgments. Feedback from the pilot survey was used to refine the guidelines and correct any inconsistencies in perception among panel members.

The ride quality assessment was based on a five-point rating scale ranging from 1 to 5, where each level corresponded to a specific degree of ride comfort. A rating of 5 (Very Good) represented a smooth ride with negligible vibration and excellent comfort, typically associated with newly constructed or well-maintained pavement. A rating of 4 (Good) indicated minor and localized vibrations that do not significantly affect comfort. A rating of 3 (Fair) reflected moderate and continuous vibrations, leading to noticeable but tolerable discomfort. A rating of 2 (Poor) corresponded to strong and frequent vibrations causing an uncomfortable ride experience, often requiring speed reduction. Finally, a rating of 1 (Very Poor) represented severe and persistent vibrations resulting in highly uncomfortable and unacceptable ride conditions.

During the field survey, the panelists traveled in a standard passenger vehicle operated at a controlled speed range of 35 Kmph to 50 kmph to maintain uniform testing conditions. The road section was divided into predefined segments, and each panelist independently assigned a rating to each segment based on their real-time perception of ride quality. Care was taken to ensure that ratings were recorded immediately after traversing each segment to avoid recall bias. The collected ratings from all panelists were then compiled and averaged to obtain the Panel RQI value for each segment, representing the collective perception of ride quality.

$$AveragePanelRQI = (PanelRQI)/5 \quad \text{.........................(4.1)}$$

This systematic approach, involving careful panel selection, structured training, standardized rating criteria, and controlled survey conditions, ensured that the panel-based RQI assessment was both consistent and reliable, forming a strong basis for subsequent reliability analysis and validation.

4.1.2 Pavement Condition Index (PCI)

The Pavement Condition Index (PCI) data were collected through a systematic visual distress survey conducted in accordance with ASTM D6433 standard procedures to ensure consistency, reliability, and comparability. The entire study corridor was divided into uniform sample units corresponding to the predefined segments used for Panel-based Riding Quality Index (Panel RQI) assessment. In total, 124 segments were evaluated using the panel rating approach. However, due to the time-intensive nature of PCI surveys, a representative subset of 40 segments was selected for detailed PCI evaluation and subsequent validation analysis.

The selection of these 40 segments was carried out using a systematic corridor-based sampling approach, wherein an initial continuous 10 km stretch from the starting point was selected. Although formal stratified sampling was not implemented, the selected stretch exhibited sufficient variability in pavement condition, as reflected in the Panel RQI distribution (ranging from good to poor). Therefore, the dataset is considered representative of the overall condition variability of the study corridor. This approach minimized sampling bias and ensured that the validation dataset reflected the overall variability present in the full set of 124 segments.

For each selected segment, a detailed field inspection was performed to identify and quantify different types of pavement distresses, including cracking (alligator, longitudinal, transverse), potholes, rutting, raveling, patching, and surface deformations. Each distress was classified based on its severity level (low, medium, high) and extent of occurrence within the sample unit, following standardized distress identification guidelines.

The recorded distress data were then used to compute deduct values (DV) for each distress type using standard PCI evaluation charts. Where multiple distresses were present within a segment, a Corrected Deduct Value (CDV) was calculated to account for the combined effect of overlapping distresses. The PCI for each segment was subsequently determined using:

$PCI = 100 - CDV$ ....(4.2)

The computed PCI values were further categorized into standard pavement condition classes (e.g., excellent, good, fair, poor, and failed) to facilitate interpretation.

To ensure data quality and consistency, all field observations were conducted by trained personnel and cross-verification was performed during data recording and processing. The resulting PCI dataset for the selected 40 segments was then paired with the corresponding Panel RQI values obtained from the full datasets of 124 segments and used for statistical validation through correlation and regression analysis. This approach enabled efficient yet robust validation of the panel-based ride quality assessment against an established distress-based pavement condition indicator.

5. Data Analysis and Validation

5.1 Overview of Pavement Ride Quality Evaluation

This section presents the results obtained from the panel-based Riding Quality Index (Panel RQI), reliability assessment using the Intra-class Correlation Coefficient (ICC), and validation of Panel RQI with the Pavement Condition Index (PCI). The analysis aims to evaluate both the consistency of subjective ratings and their agreement with objective pavement condition measures.

A total of 124 road segments were evaluated using the panel rating method, while 40 representative segments were selected for PCI-based validation. The results are discussed in terms of statistical relationships, reliability, and engineering significance.

5.2 Panel-Based Riding Quality Index (Panel RQI)

The Panel RQI values were computed by averaging the ratings provided by five panelists for each segment. The results indicate noticeable variation in ride quality across the study corridor, reflecting differences in pavement condition.

Segments with higher Panel RQI values correspond to smoother surfaces with minimal vibration, whereas lower values indicate rough and deteriorated pavement conditions. The distribution of Panel RQI demonstrates that the study corridor includes a mix of good, fair, and poor pavement sections.

The panel-based method successfully captured user-perceived ride comfort, highlighting its effectiveness as a functional performance indicator.

Figure-2 : Charts titled "Avg. Panel Rating vs Segment ID (Hetauda, H to Pathlaiya, P)" is interpreted with S01 as the starting point at Hetauda and S62 as the end point at Pathlaiya. Thus, the ride quality variation is understood along the travel direction from Hetauda to Pathlaiya.

At the starting stretch near Hetauda (approximately S01-S11 and S13 - S20), the panel ratings are generally high, mostly ranging between 4.00 and 4.70, as seen from the taller bars and higher values in the corresponding portion of the chart. This indicates very good to excellent riding quality, suggesting that this section of the road is relatively smooth and well-maintained. In real-world conditions, travelers beginning their journey from Hetauda would experience comfortable and stable driving conditions with minimal surface irregularities.

As the journey progresses towards the mid-section (approximately S21–S36), the panel ratings begin to fluctuate and gradually decline to values around 2.14–3.50. This indicates a transition zone where the pavement condition becomes inconsistent. Field conditions in this stretch are likely characterized by patchy repairs, uneven surfaces, and moderate roughness, leading to noticeable variations in ride comfort.

A significant deterioration is observed in the central section (around S21 - S36), where the panel ratings drop sharply to approximately 2.14 at S26, which is clearly visible as the lowest portion of both the bar chart and the line graph. This represents the worst riding condition along the corridor in respect with other segments. In practical terms, this section likely suffers from severe pavement distress, such as potholes, rutting, corrugation, cracking, and possible structural failures. Travelers would experience high levels of discomfort, jerky motion, and reduced travel speeds, making this stretch a priority for immediate rehabilitation or reconstruction.

Beyond this critical zone, as the road approaches Pathlaiya (approximately S37 to S62), the panel ratings show a steady recovery, increasing back to values above 4.00. The final segments (near S62) again exhibit good to excellent ride quality. This suggests improved pavement condition near Pathlaiya, likely due to better maintenance practices, urban influence, or stronger pavement structure. Drivers would experience smooth and comfortable travel as they approach the endpoint.

Figure-3 : Charts titled "Avg. Panel Rating vs Segment ID (P to H)" should be interpreted with S62 as the starting point at Pathlaiya and S1 as the end point at Hetauda. Thus, the ride quality variation is understood along the travel direction from Pathlaiya → Hetauda.

At the starting stretch near Pathlaiya (approximately S62-S51), the panel ratings are generally high, generally ranging between 3.70 to 4.50, as seen from the taller bars and the higher values in the corresponding portion of the graph. This indicates good to excellent riding quality, suggesting that this section of the road is relatively smooth and well-maintained. In real-world conditions, travelers beginning their journey from Pathlaiya would experience comfortable and stable driving conditions with minimal surface irregularities.

As the journey progresses towards the mid-section (approximately S36–S51), the panel ratings begin to fluctuate and gradually decline to values around 1.80 – 3.50. This indicates a transition zone where pavement condition

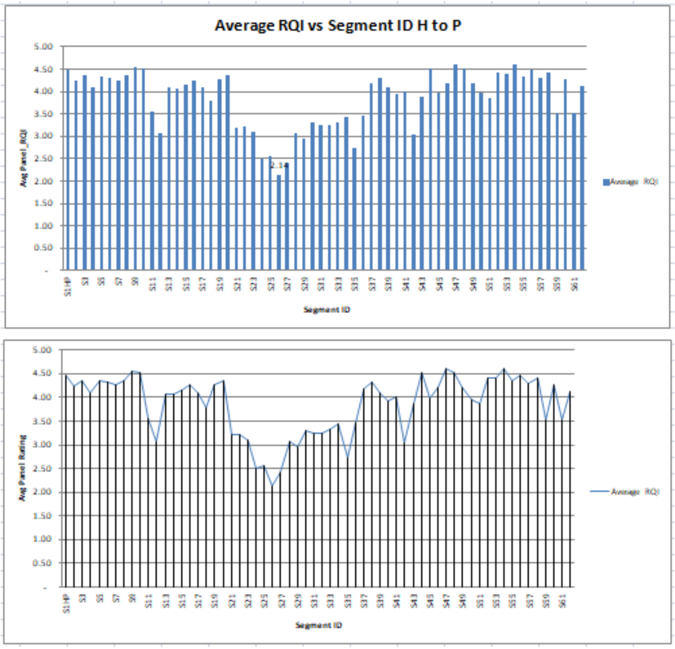

Figure 2: Chart for Segment ID Vs Avg Panel Rating H to P

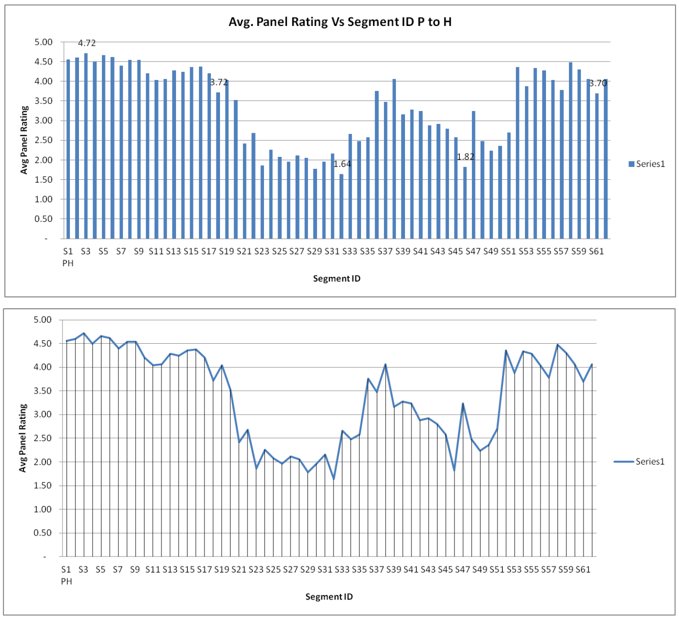

Figure 3: Chart for Segment ID Vs Avg Panel Rating P to H

becomes inconsistent. Field conditions in this stretch are likely characterized by patchy repairs, uneven surfaces, and moderate roughness, leading to noticeable variations in ride comfort.

A significant deterioration is observed in the central section (around S20–S35), where the panel ratings drop sharply to approximately 1.60 – 2.50, which is clearly visible as the lowest portion of both the bar chart and the line graph. This represents the worst riding condition along the corridor. In practical terms, this section likely suffers from severe pavement distress, such as potholes, rutting, cracking, and possible structural failures. Travelers would experience high levels of discomfort, jerky motion, and reduced travel speeds, making this stretch a priority for immediate rehabilitation or reconstruction.

Beyond this critical zone, as the road approaches Hetauda (approximately S19–S1), the panel ratings show a steady recovery, increasing back to values above 4.0. The final segments (near S1) again exhibit excellent ride quality. This suggests improved pavement condition near Hetauda, likely due to better maintenance practices, urban influence, or stronger pavement structure. Drivers would experience smooth and comfortable travel as they approach the endpoint.

Overall, the charts demonstrate a clear U-shaped spatial trend in ride quality from Pathlaiya to Hetauda. The road exhibits good conditions at both ends and a severely deteriorated middle section, highlighting non-uniform pavement performance.

5.3 Reliability Analysis of Panel Ratings Using ICC

The reliability of panel-based Riding Quality Index (Panel RQI) ratings was evaluated using the Intra-class Correlation Coefficient (ICC) to assess inter-rater agreement. A two-way random-effects model with absolute agreement (ICC (2, k)) was adopted, as all segments were rated by all panelists and the objective was to measure absolute consistency among raters. The analysis was performed using panel rating data for 124 segments arranged in a segment-by-rater matrix.

The computed ICC value was 0.939 ($p < 0.001$), indicating excellent reliability based on established criteria ($ICC > 0.90$). This result demonstrates a high degree of agreement among panelists, with minimal variability attributable to subjective differences. Graphical inspection of panel ratings across segments showed closely aligned trends among raters, further confirming consistency in perception.

The high ICC value indicates that the majority of variance in Panel RQI is due to actual differences in pavement condition rather than measurement error or rater inconsistency. This confirms that the panel-based assessment, when supported by standardized training and controlled survey conditions, provides reliable and reproducible results suitable for pavement performance evaluation.

Figure- 4 : Chart shows a high level of data consistency across all five panelists (P1–P5), as their ratings closely follow the same overall pattern with only minor variations. Most segments receive similar scores from each panelist, indicating strong agreement and reliability in the evaluation process. The trend line reveals that ratings generally remain in the higher range (around 4.0–4.8), with noticeable dips in specific segments—particularly around the mid-section (approximately S22–S30) and again near S21–S33 where all panelists simultaneously rate lower. After these declines, the ratings recover and stabilize again toward the higher end in later segments. This consistent rise-and-fall pattern across all panelists suggests that the observed fluctuations are driven by segment quality rather than individual bias, reinforcing both the coherence of the data and the validity of the overall trend.

Figure-5 presents the results of the Intra-class Correlation Coefficient (ICC) analysis conducted to evaluate the reliability and consistency of panel-based ride quality ratings. The ICC value obtained in this study is 0.939, which indicates an

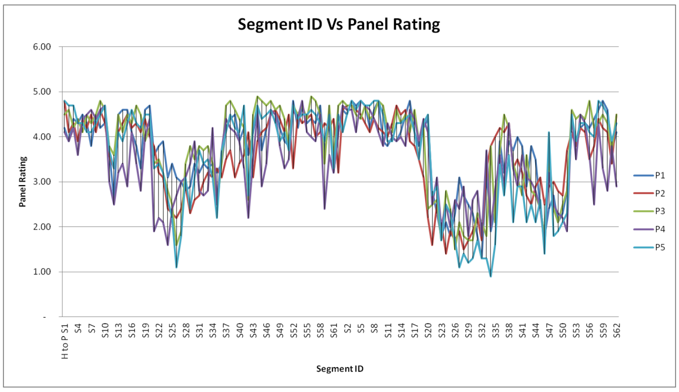

Figure 4: Chart Showing Trendline for Panel 1 to 5

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.754[a]	.697	.807	16.336	123	492	.000
Average Measures	.939	.920	.954	16.336	123	492	.000

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

Figure 5: Reliability Test : ICC Analysis

excellent level of agreement among the panel members. Also, the reported ICC corresponds to the Average Measures ICC, representing the reliability of the mean rating across all five panelists. The Single Measures ICC (0.754) indicates moderate-to-good reliability at the individual rater level and is more conservative. However, since the study utilizes the averaged Panel RQI as the final index, the Average Measures ICC is the appropriate statistic for assessing operational reliability. According to the reliability classification proposed by Koo and Li (2016), ICC values greater than 0.75 represent good to excellent reliability. The high ICC value demonstrates that the panel members provided highly consistent ride quality ratings across the surveyed pavement segments. This result confirms that the subjective panel rating method used in this study is reliable and that the observed variations in Panel RQI values are primarily due to differences in pavement conditions rather than inconsistencies in panel judgment. Therefore, the panel-based ride quality assessment method adopted in this study can be considered statistically reliable and suitable for evaluating pavement ride quality.

5.4 Validation with Pavement Condition Index (PCI)

The regression results as shown in Figure-6 that the relationship between normalized PCI and normalized Panel RQI produced a coefficient of determination of:

$R^2 = 0.7169$ and $PCI = 0.911 * (PanelRQI) + 0.0634$.............5.1

This result indicates a strong positive relationship between normalized panel-based ride quality ratings and the normalized physical condition of the pavement. The strong correlation suggests that human perception of ride comfort is closely associated with the level of pavement distress observed during PCI surveys. As pavement condition deteriorates and surface irregularities increase, both PCI values and perceived ride quality decrease simultaneously. The relatively tight clustering of data points around the regression line further confirms the strong correlation ($R^2 = 0.7169$) between pavement physical condition and perceived ride quality.

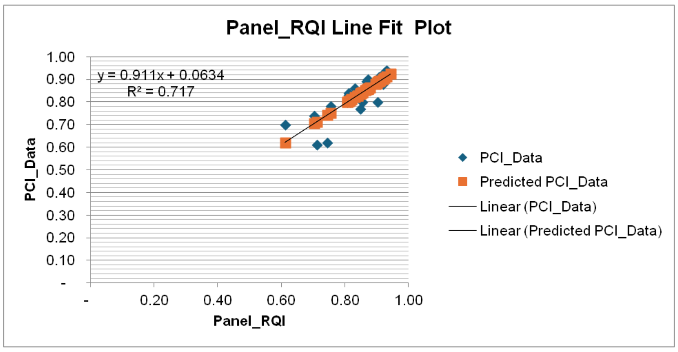

Figure 6: Chart for relationship between PCI and Panel RQI

6. Conclusion and Recommendation

6.1 Conclusion

This study evaluates the panel-based Riding Quality Index (Panel RQI) as a preliminary tool for assessing pavement condition, focusing on its reliability and validity. The results show that, when applied using a structured and standardized methodology, Panel RQI serves as a robust indicator of pavement performance. Reliability analysis using the Intra-class Correlation Coefficient (ICC) yielded a value of 0.939, indicating excellent agreement among panelists and minimal subjective variability. This confirms that panel-based assessments can produce consistent and reproducible results.

Validation with the Pavement Condition Index (PCI), based on 40 segments selected from 124, showed a strong positive relationship ($R^2 = 0.7169$), demonstrating that perceived ride quality closely reflects actual pavement condition. Minor differences between Panel RQI and PCI arise due to the distinction between functional and structural performance measures. The combined results confirm that Panel RQI is both reliable and valid for pavement evaluation. Its simplicity, low cost, and minimal equipment requirements make it suitable for large-scale and resource-constrained applications. Overall, Panel RQI can be effectively used as a preliminary and complementary tool, with potential for integration into comprehensive pavement management systems.

6.2 Recommendation

Panel-based Riding Quality Index (Panel RQI) is recommended as a rapid and cost-effective tool for preliminary pavement condition assessment, particularly for large-scale and resource-constrained road networks. It provides reliable insights into ride quality and is suitable for routine monitoring and initial screening. To ensure consistency, standardized survey protocols, proper panel selection, and adequate training and calibration of panelists are essential.

Panel RQI should be integrated with conventional methods such as PCI to achieve a comprehensive evaluation of both functional and structural pavement performance. This combined approach can enhance the effectiveness of pavement management systems. Transportation agencies are encouraged to incorporate Panel RQI into regular assessment practices due to its simplicity and low cost. Further studies are recommended across diverse road conditions to improve its applicability. Integration with objective measurement technologies, such as smartphone-based methods, is suggested for developing more accurate hybrid evaluation models.

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Gratitude is further extended to all field personnel involved in data collection, particularly during the Pavement Condition Index (PCI) survey, for their dedication and accuracy in recording distress data. The support provided during field-work was instrumental in ensuring the quality of the dataset.

Finally, the author acknowledges the support of colleagues and well-wishers who directly or indirectly contributed to this research work.

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