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Integration of Road Roughness Measurement Between Specialized Instrumentation and an Android-Based Application

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ABSTRAK

Keadaan permukaan jalan sangat penting untuk menjamin keamanan dan kenyamanan pengguna jalan. Menjaga kondisi jalan agar tetap aman dan nyaman merupakan hal krusial karena jalan adalah infrastruktur vital dalam transportasi orang dan barang. Untuk memperbaiki infrastruktur transportasi, evaluasi kondisi jalan sangat diperlukan. Salah satu pendekatan umum adalah dengan mengukur kekasaran jalan, yang sering dilakukan dengan perangkat seperti Roughometer III dan aplikasi Roadroid berbasis smartphone. Penelitian ini bertujuan membandingkan nilai International Roughness Index (IRI) yang diperoleh dari kedua perangkat tersebut pada perkerasan kaku di jalan tol. Pengujian dilakukan sepanjang 10 kilometer, dengan pengukuran nilai IRI setiap 10 meter. Hasil pengujian menunjukkan bahwa perangkat Roughometer III dan Roadroid dipasang pada kendaraan yang sama. Analisis hubungan antara nilai IRI dari kedua perangkat menggunakan analisis polinomial menghasilkan persamaan IRI (Roughometer) = -0,0022(IRIrd)² + 0,8464(IRIrd) + 1,8894, dengan koefisien determinasi (R^2) sebesar 0,47.

***Kata kunci**: Internasional roughness indeks, Roughometer III, Roadroid, Evaluasi Perkerasan.*

ABSTRACT

The condition of road pavement surfaces is crucial for ensuring the safety and comfort of road users. Proper maintenance of road conditions is essential as roads serve as vital infrastructure for transporting people and goods. Evaluating road conditions is therefore critical for improving transportation infrastructure. Road roughness measurements are the most common method used by road managers to assess pavement surfaces. This study aims to compare the International Roughness Index (IRI) values obtained using the Roughometer III device with those obtained using the smartphone-based Roadroid application. Testing was conducted on a 10-kilometer stretch of rigid pavement on a toll road. IRI values were measured every 10 meters. The Roughometer III and Roadroid devices were tested on the same vehicle. A polynomial analysis was performed to determine the relationship between the IRI values from both devices, resulting in the equation IRI (Roughometer) = -0.0022(IRIrd)² + 0.8464(IRIrd) + 1.8894, with a coefficient of determination (R^2) of 0.4701.

***Keywords**: Internasional Roughness Index, Roughometer III, Roadroid, Pavement Evaluation.*

1. INTRODUCTION

The condition of the road pavement surface is essential to ensure the safety and comfort of road users. Because roads are a critical infrastructure for the transportation of people and goods, maintaining a safe and comfortable condition is a crucial part of ensuring the safety and comfort of road users. A road that is well-maintained not only makes driving easier and safe, but it also lowers the likelihood of accidents. This is evident from the fact that drivers tend to slow down to avoid vehicle damage or the possibility of an accident when the road is facing damage [1]. Good road conditions can be achieved by consistent and effective maintenance.

The evaluation of road conditions is essential for the upkeep of transportation infrastructure. Highway operators can collect information and make educated and effective decisions about priority interventions through the use of a variety of assessment or survey methods.

Road roughness evaluation is one of the best methods for assessing the quality of road pavement without resorting to physical inspections or assessments because of the large and complicated nature of road networks. This is backed by the fact that road roughness parameters mostly depend on road surface type, which is why road roughness measures are used so often by road management to determine the state of road pavement surfaces [2].

Many academics are able to investigate road roughness since roughness measurement techniques are widely used. Because roughness measurement tools are so widely used, many scholars conduct research on road roughness. Some studies compare International Roughness Index (IRI) values to Power Spectral Density (PSD) techniques [3], [4]. In a different project, roughness is measured utilizing a wireless sensor-based system and contrasted with conventional roughness evaluation techniques [5]. Gong conducted a more thorough analysis of the types of damages that significantly affect the degree of road roughness [6]. Additionally, several research employ UAV-based photogrammetry to assess the quality of hardness according to IRI standards [7]. Diaz classified urban pavements automatically using roughness descriptors and mobile LiDAR data [8]. In a number of research findings, computer modeling is used to determine the roughness of roads [9], [10], [11]. Prasad contrasted ocular perceptions with road roughness ratings obtained from bump integrators [12].

Research into more convenient ways to obtain roughness measurements is necessary due to the limitations of road hardness testing methods and the associated high costs. The purpose of this study is to use the smartphone-based Roadroid application to compare the IRI readings acquired with the Roughometer III device to those obtained when moving rigidly on toll roads.

2. LITERATURE REVIEW

2.1 The Internasional Roughness Index

Since 1980, the World Bank has determined that the International Roughness Index (IRI) is a metric for assessing the state of road pavement. A pavement's longitudinal profile that represents road driving comfort is called roughness. The cumulative length up and down the surface per unit length is the quantitative value of this inequality as expressed by the IRI (International Roughness Index), where the IRI unit is measured in meters up and down per kilometer of road length (m/km). The ASTM E 950-94 standard, which was created by ASTM, divides road surface unevenness assessment instruments into four classes according to the method and accuracy used to evaluate IRI. Since then, IRI has gained widespread acceptance as a standard for determining road roughness. IRI has the advantage of being stable throughout time and applicable worldwide [13], [14].

Based on measurement precision, the tools used to gauge the level of roughness in the road surface are separated into several categories. Class 1 denotes extremely accurate measurements, whereas Class 4 denotes less accurate measurements. There are four classifications [15]. To determine the best maintenance plan, the IRI value can also be compared to various pavement condition indexing tools [16].

2.2 Road Condition Evaluation Using Roughometer III

The cumulative vertical deviations of the longitudinal profile are divided by the measured distance/length of the surface to get the International Roughness Index (IRI), also referred to as road surface unevenness. The Roughometer III is a measurement tool used to assess how smooth a road surface is. A tiny accelerometer (sensor) mounted on the rear axle of the survey vehicle, a distance measuring device, an interface module, and a controller make up the portable Roughometer. To offer the most accurate and reliable data, this device measures pavement roughness at speeds between 40 and 60 km/h. The International Roughness Index (IRI) units are used to display the output.

A gadget called the Roughometer III is used to measure the roughness value (IRI) of roads, regardless of whether they are unpaved or have stiff or flexible pavement. Due to its easy installation and rapid assembly and disassembly on all four-wheeled vehicle types (portable), this tool is incredibly easy to use and useful, without needing to be calibrated, such as walking profilometers that need at least five different locations with varying IRI values over a period of more than seven days and are outfitted with precise distance sensors and GPS, or devices with bump integrator systems (ROMDAS, NAASRA, etc.), which need to be calibrated using IRI reference values from DIPSTICK devices.
How to operate the gadget in accordance with the Ministry of Public Works Directorate General of Highways' device usage guidelines.

- General Provisions
- Licensing

The first permission that needs to be acquired is the one from the authority at the roughometer survey site and the one for borrowing the equipment from the appropriate division. This is required because the speed utilized in the survey needs to adhere to the equipment standards.

- Equipment Completeness Inspection
  Checking the completeness of survey equipment, including the main unit roughometer, roughometer truck, software, and other supporting equipment, is essential when completing the roughometer survey.
- Survey Preparation
  Things that need to be prepared include:
  a) Roughometer that is already powered (battery).
  b) Suitable vehicle for use.
  c) Permits, such as documents needed for the survey implementation, for example, permits for the Roughometer survey location.
  d) Workforce, which includes the required surveyors for the Roughometer survey. The required workforce consists of recording surveyors, equipment technicians (who also serve as drivers if possible).
- Technical Requirements
  \- Roughometer Equipment Components
  The components of the Roughometer consist of several parts including:

a) Controller, serves as the regulator or control device for the survey.
b) Interface, serves as the connection for cables to all parts of the equipment.
c) 5VDC reg, a cable that connects the interface to GPS and power cables.
d) GPS
e) Inertial Sensor is a sensor connected to the interface.
f) DMI (Distance Measuring Instrument) is a distance measuring device.
g) Power Cable is the cable that connects the power source.

- Software Components
  The software used in the survey is the built-in software of the Roughometer device.

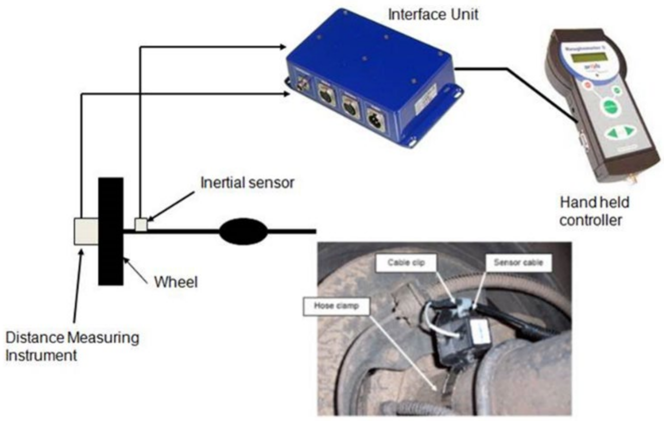

Fig. 1. Roughometer III

- Survey Implementation
  The stages of survey implementation in outline are as follows:
- Preparation and Calibration
- Sensor Distance Calibration Preparation
  Placement of the sensor, as shown in the Fig.2 Sensor distance calibration preparatio :

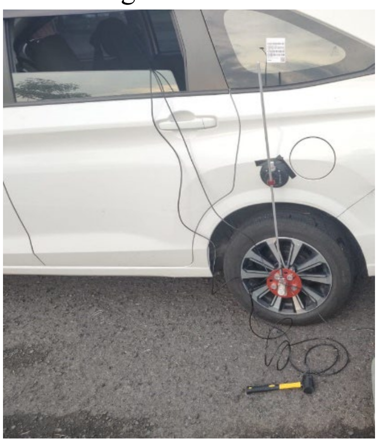

Fig. 2. Sensor distance calibration preparation

- Installation of Inertial Sensor

Fig. 3. Sensor Installation on the Wheel

- Sensor Calibration

  a. Turning on the Roughometer System

  b. Readings in Roughometer Controller, with the following method:

  i. Select the Calibrate sensor menu. Press Yes button

  ii. Sensor at 0 degrees position, press Yes button

  iii. Sensor reading = 2.52V, press Yes button

  iv. Sensor rotated 180 degrees, press Yes button

  v. Sensor reading = 1.68V, press Yes button

  vi. Old 3.11 New 2.44, press Yes button

  vii. Update new calibration value

  To obtain 0 and 180-degree positions, use a water pass tool placed above the sensor or where the sensor is located.

  DMI Calibration

  The method of DMI calibration is as follows:

  i. Turn on the Roughometer System

  ii. Roughometer Controller:

  iii. Select the Distance Cal. menu. Press the Yes button.

  iv. Choose Cal. Distance: 1000 m (use the left/right arrow button to select the calibration distance), press the Yes button.

  v. Position the vehicle at the Start Point, press the Start button.

  vi. The vehicle travels the calibration distance, after which

  vii. it reaches the End Point, stop, then press the Stop button.

  viii. Old 1002 New 1000, press the Yes button.

  ix. Update the new calibration value.

  DMI calibration is shown in the picture below.

Fig. 4.DMI Installation

GPS Installation
Install the GPS on the roof of the right rear wheel (driver's side). Before data collection, perform GPS time synchronization with the following steps:
a. Run the Roughometer Software.
b. Perform GPS Reception Time Synchronization.
c. Connect the GPS to the PC via an RS-232 to USB connector.
d. Select the Setup Survey menu.
e. The GPS must receive a minimum of 3 satellite signals for the synchronization.
f. Upon successful synchronization, old data will be deleted from the GPS memory.
g. Disconnect the GPS from the PC.
GPS installation is shown in the following picture:

Fig. 5.GPS Installation

- Power Cable Installation
  Attach the Power cable to the car's lighter socket. The installation is shown in the following picture:

Fig. 6. Power Cable Installation

- Time Synchronization
  Perform time synchronization for Roughmeter with the following steps:
  a) Turn on the Roughometer System.
  b) Connect the Controller to the PC using an RS 232 to USB connector adapter.
  c) Select the Setup Survey menu.
  d) After the time synchronization is complete, disconnect the Roughometer from the PC.
  e) Data stored in the Roughometer memory is not automatically deleted but is done through the controller.

A portable, inexpensive device that provides objective, repeatable roughness readings is the Roughometer III. The Roughometer III is a World Bank Class 3 roughness measuring device that goes above and beyond the requirements of the category. The Roughometer is a response-type roughness instrument that uses an accurate accelerometer to directly detect axle movement, eliminating vehicle variables like suspension and passenger weight [17].

A tiny accelerometer device (sensor) is mounted on the axle in accordance with the description in Figure 1 to record speed and axle up-and-down movement as a sign of road unevenness. The distance measuring device is fitted on the wheel in order to measure the testing distance. All of the data captured by these sensors is read by the portable device, and the interface unit and handheld unit are connected. The ignition hole provides access to the vehicle's power source, which powers this device. Consequently, the technology effectively assesses road unevenness using energy from the car.

2.3 Road Condition Evaluation Using Roadroid Application

A smartphone app called Roadroid is designed to manage transportation infrastructure. This application uses contemporary sensor technology found in cellphones to collect data on road surface conditions in real time. Road inspectors and maintenance staff may quickly and easily gather data on characteristics including potholes, pavement roughness, and overall road quality thanks to the application's user-friendly interface. It will be simpler to perform thorough analyses of road conditions with Roadroid.

Roadroid uses sensors embedded in smartphones to gather data on road conditions in real time. The application gathers information about the road surface using sensors like GPS and accelerometers. that using smartphones to evaluate roads can provide road organizations with a more effective, scalable, and economical means of transmitting data on road conditions [18]. Accuracy is affected by speed, vehicle type, smartphone features, and mounting style [19], [20].

There are four types of vehicles available: four-wheel drive jeeps, motorcycles, small cars, and medium cars. The accuracy of the result will vary because it is a compilation of numerous automobile types; for instance, different countries will have different car types. With an accuracy score of 99.7%, medium cars outperform motorcycles and tiny cars [21], [22]. Highway officials also receive feedback from the testing results, which helps them decide what kind of maintenance is necessary [23], [24].

A Swedish business created the Roadroid software for Android smartphones with the goal of monitoring road roughness. Only selected phone models with particular specs can use this application. Its operation depends on collecting information on road roughness using smartphones' built-in vibration sensor, which may effectively and efficiently function as an indicator of road conditions up to level 2 or 3. The accompanying image shows the Roadroid gadget being installed.

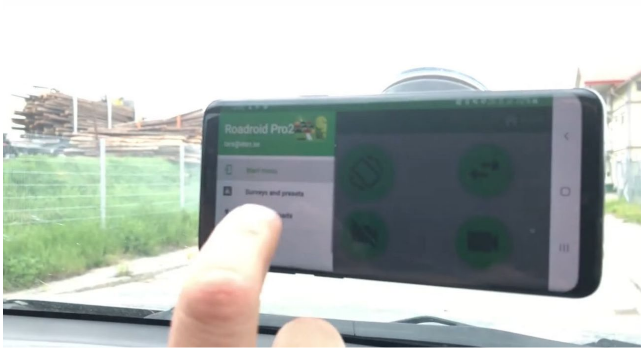

Fig. 7. Shows the installation of Roadroid on a vehicle and the Roadroid logo on an Android smartphone.

Road roughness is measured using both eIRI and cIRI, as explained in the Roadroid program usage instruction. Whereas the Calculated IRI (cIRI) use a quarter car model formula, the Estimated IRI (eIRI) uses a linear conversion formula and records more road texture. For paved roads, eIRI incorporates a speed compensator (20–80 km/h), while cIRI necessitates a constant speed. For paved roads, eIRI has restricted speed compensator settings (specific to vehicle types) and is more sensitive to micro roughness. Working with cIRI is advised for more precise IRI readings.

According to earlier studies by Forslöf & Jones (2015), depending on the kind of road surface, there was a correlation of roughly 70–80% between estimated IRI (eIRI) and laser-measured IRI. Additionally, to improve correlation values, an improved IRI computation (cIRI) was created. Changes must be done with cIRI to obtain more accurate eIRI readings. For certain cars and other circumstances, you should modify the parameters. Figure 8 below shows the cIRI's adjustment or sensitivity setting values. The tool's use is consistent with the Roadroid application guide:

- System
  The survey system consists of:
- Vehicle

1. Use a standard vehicle similar to the types available in the Roadroid application settings menu. The menu provides options such as:
   - Becycle (does not support user-adjusted sensitivity for speed)
   - Small car/business van
   - Medium/big sedan/station wagon (default)
   - 4WD jeep type (Hilux/ King Cab)
2. Avoid poor or specialty suspensions (such as sports suspensions).
   Use standard tire pressure.
3. Ensure all wheels are balanced (such as using similar type wheels).
   Unbalanced wheels will compromise your data.

- Phone

1. Accelerometer or sensor to measure object acceleration is still good, and capable of capturing population or data set from the application.
2. Using Android system version, and capable of accommodating the application.
3. Phone holder - important with stable mounting, such as Logitech + on Amazon.

- Survey Speed
  1. Speed directly affects survey results - maintain consistent speed.
  2. The best correlation for IQL3/response type methods is around 70-80 km/h.
  3. The system can be set for lower survey speeds down to 30 km/h.
- Installation

  Attach the phone holder on the car dashboard with:
  - horizontal/landscape mode
  - standing vertically from the road
  - Easily reachable for viewing
  - Ensure the camera captures the road surface

  Using a high-quality phone holder in the automobile is crucial. Data corruption may occur if the phone is not firmly secured.

  Press the yellow "start" button after pressing the Roadroid application's program icon.

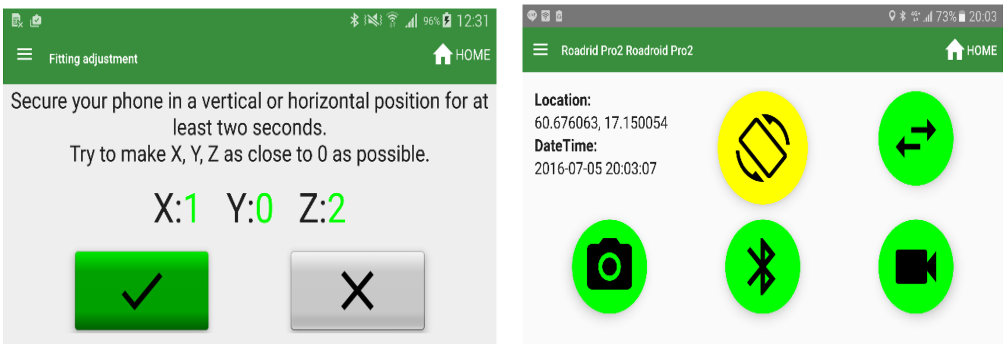

Fig. 8. Adjusting sensor tools on Android and icons that can be used during the survey

Hold your phone vertically or horizontally for at least two seconds while your automobile is on level ground in order to make changes. Set the phone to X, Y, and Z as close to = 0 meters as you can. The OK button may turn green once you are within tolerance. Press the green "OK" button. This procedure ensures that you select vertical addition (Y) that is independent of braking (X) and flipping (Z). This survey is similar to utilizing the camera button (left) for automatic photographs and the video camera (right) for videos. If you do not wish to capture any visual data, press the button with the crossed-out camera. The system only turns on when a GPS signal is present. It may take some time for the GPS to arrive.

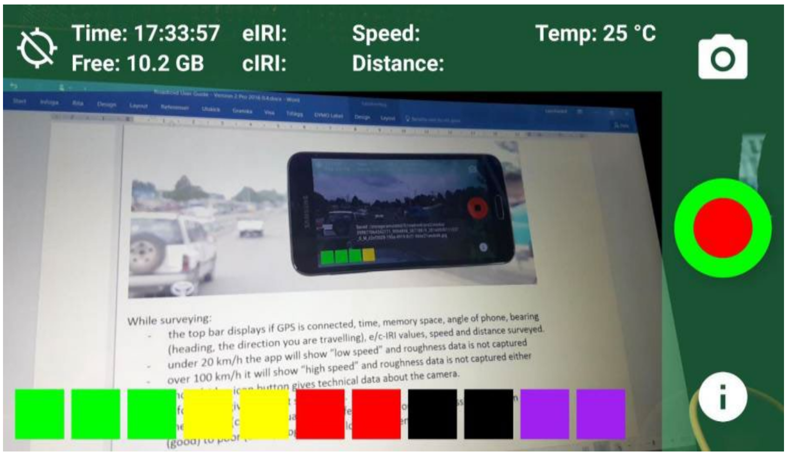

Fig. 9. Display on the Android screen during the survey

During the survey:

a. The top bar displays if GPS is connected, time, memory space, estimated and calculated IRI, speed, and surveyed distance.
b. It also shows the phone battery temperature. Watch out for overheating - in warm/bright conditions - keep your AC on the dashboard to cool the phone.
c. Below 20 km/h, the application will indicate "low speed," and roughness data will not be captured.
d. Speeds over 100 km/h will indicate "high speed," and roughness data will not be captured.
e. The photo/video icon button provides technical data about the camera.
f. The Info button provides current survey information.
g. The bar with colored boxes indicates roughness from green (good) to black (poor).

Starting the survey: To start the survey, press the record button, which is represented by a red circle on a green background. Road IDs and optional remarks can be entered at the beginning of the survey. Since it shows up in the import history list, this provides helpful support in the later Road Data Management system. To end the survey, click the same button, which is now a black box with a red background. You can choose to save or remove the survey after hitting the stop button. Menu -> Presets & Survey: You may find calibrating tools here. Three distinct graphs are available for you to view the results of the most recent survey, which enables you to quickly determine whether you are in a known test area. The Estimated IRI's sensitivity can be changed to better capture the road's macrotexture. For IRI computations, you can additionally change the section's length and sensitivity (using the vehicle formula to concentrate more on its roughness).

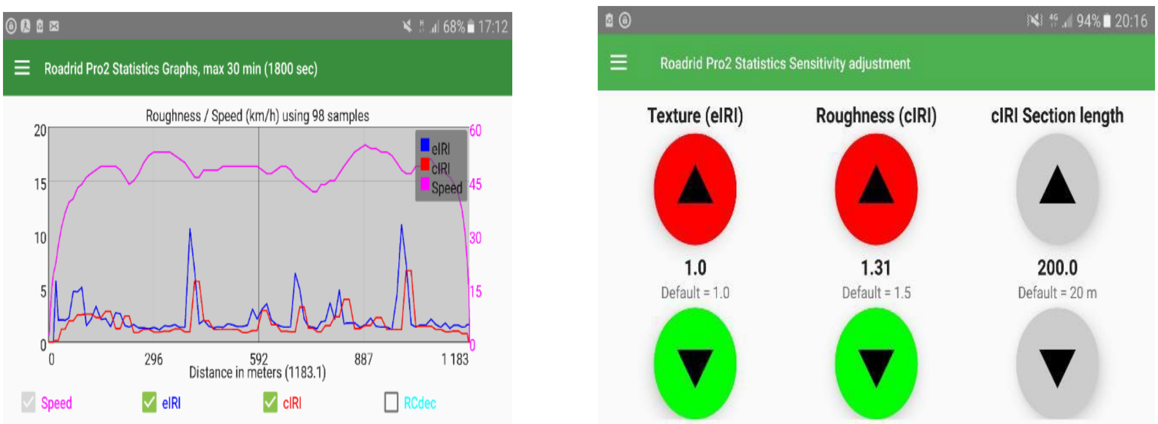

Fig. 10. Example of Graphs after survey and sensitivity adjustment.

You can also use up to 5 different presets - for different system conditions:

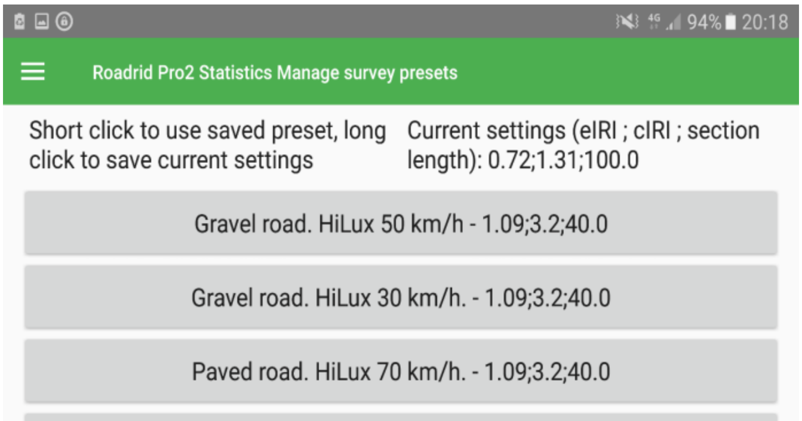

Fig. 11. Example of Storage List During Survey

Determine the proper settings for each of the three conditions—vehicle, phone, and speed—that make up the system, as stated on page 3. Settings: There are a number of sub-settings under Menu -> Settings, including General, Media & Sync Data, Units, Devices & Vehicles. We can start the survey on the desired road once all the options have been changed.

2.4 Previous Research using IRI Comparison

In order to provide a suitable comparison, Surbakti compared the results of the IRI test using the Roughometer III apparatus with the Roadroid application on flexible pavement on national roads [25]. Additionally, Samsuri contrasted the IRI values generated by the Roughometer III program with those derived from Hawkeye, a class 1 IRI measurement equipment [26]. The IRI values produced by the Roadroid application for pavement conditions were visually examined using the SDI technique [27]. Ariyanto combined pavement condition values determined by the SDI method with IRI data from the Roadroid application to create an ideal maintenance strategy [28].

According to this magazine, the values of roads' structural and functional qualities are not precisely determined. Because of this, road maintenance and rehabilitation trends are frequently repetitious, identical, and imprecise. Thus, the purpose of this study was to ascertain the structural and functional state of the roadways. Road functioning is evaluated using the International Roughness Index (IRI), while road structural condition is evaluated using the Structural Number (SN). Roadroid was used to measure the state of the roads. Road condition data may be gathered effectively, quantifiably, and economically with the help of this smartphone app. With an IRI value below 4, the research findings show that the road is in good functional condition. With a 20-year design life, the road segment's structural condition cannot support traffic, as evidenced by the structural pavement state, which shows that the Effective Structural Number (SN) is lower than the Future Structural Number (SN) [29].

This journal explains how non-destructive IRI values can be gathered by smartphone-based techniques for assessing road conditions. In order to determine the correlation between the two tools, the journal also addresses comparing road roughness values (IRI) using Roughometer III and an Android app called AndroSensor. Based on acceleration measurements, AndroSensor uses a Java program with calculating code to identify events on the road. The Roughometer III was used to determine the International Roughness Index values for different road segments. With a coefficient of determination of 0.8906 in the experiment, the two tools showed a very good connection with one another. As a result, it is clarified that while AndroSensor cannot completely replace manual techniques such as the Roughometer III, it does offer a chance to decrease the number of places that need human techniques. Road roughness data that can be used as indications of road conditions up to class levels 2 or 3 can be easily and affordably gathered by using the built-in vibration sensors in smartphones. As a result, data collecting might take place more regularly. The Roadroid software and laser measuring devices are also compared in the publication; the results show an acceptable 81% correlation. This publication concludes that road roughness data collectors may communicate road condition data more effectively, measurably, and economically by using smartphones to measure roads [18].

According to this publication, one of the functional performance criteria, the International Roughness Index (IRI), or road smoothness level, is used to measure road conditions. In order to assess the state of national roads' upkeep, this study compares the IRI values derived from the Directorate General of Highways' Roughometer II equipment with the IRI values derived from a smartphone application called Roadroid. The goal is to guarantee enough and economical funding for the upkeep of national roads. The collected data was subjected to regression and correlation analysis, and the findings were then explained through tables, figures, and narratives. According to the study, there are some disparities between road condition assessments based on Roughometer II IRI values and smartphone IRI data (Roadroid), although they are not statistically significant. Positive correlations between measurement findings with different levels of association—from low to moderate to high to extremely strong correlations—are found using correlation analysis. This suggests that actual IRI values can be predicted using the survey findings of IRI values obtained with the smartphone application Roadroid as a guide or preliminary investigation. Future research on smartphone applications (Roadroid) related to vehicle speed should concentrate on the same issue, according to the study [30].

Sectoral movement in the northern part of Wonogiri Regency is greatly facilitated by the existence of the Pokoh-Malangsari road segment. Using the International Roughness Index (IRI), Surface Distress Index (SDI), and Pavement Condition Index (PCI) as the foundation for identifying the type of road maintenance handling, this study attempts to assess the functional condition of the road pavement and compare the pavement condition values. While IRI values were obtained by surveys using a car and the Roaddroid program, visual assessments of road pavement conditions were obtained through field surveys using the SDI and PCI methodologies. One program for Android cellphones that measures road roughness is called Roaddroid, and it was created by a Swedish business. The findings of this study demonstrate variations in the Manjung-Klerong road's state using the three methods: according to the IRI technique, 71% of the road is in good condition, and 29% is in fair condition. There were no signs of minor or serious harm. 78.6% were in good condition, 10.7% were in fair condition, 7.1% had mild damage, and 3.6% had serious damage according to the SDI technique. According to the PCI approach, there was no evidence of minor or serious damage, with 93% in good condition and 7% in fair condition. Road conditions in Wonogiri Regency can be depicted or described utilizing this research's evaluation of road conditions using the IRI, SDI, and PCI techniques [31].

According to this journal, there are roughly 42,000 km of roads in Costa Rica, of which 31,350 km (or 75%) are unpaved and have soil and granular (gravel or crushed stone) surfaces. The Roughometer III gadget, which measures the longitudinal profile of unpaved road surfaces, was recently purchased. This tool makes it possible to measure the road profile objectively in order to determine the International Roughness Index (IRI), which makes it possible to classify functional conditions. If at all feasible, the goal is to use this method in the short-term evaluation of unpaved roads on both the national and regional road networks. According to the study's findings, the Roughometer III tool will improve the assessment of unpaved (granular) road networks [32].

2.5 Flow of Research

A review of relevant road roughness material was the first step in our investigation. Data, including primary and secondary data, was gathered after literature reviews. After an initial evaluation of the testing site, the chosen site was divided into multiple sections. The Roughometer III device was installed on the same vehicle to start the testing phase, and then the Roadroid device was installed. A 10-kilometer stretch of toll road was then used for testing. The IRI computations made using the Roadroid and Roughometer III devices were then examined as a point of reference for upcoming talks.

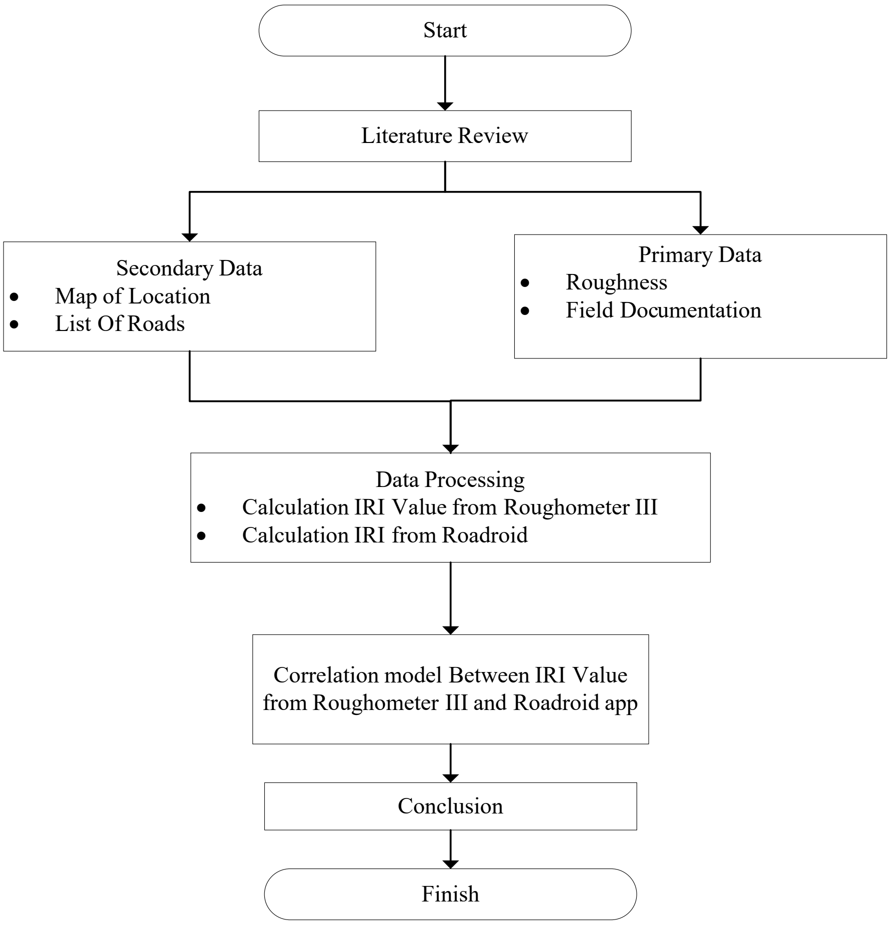

Fig. 12. Research flow chart

III. ANALYSIS AND DISCUSSION

The firm pavement of a 10-kilometer section of a toll road was used for the tests. The International Roughness Index over a 10-meter span is represented by the IRI values that were obtained. The test results for the IRI values derived from the two instruments utilized are as follows. The identical vehicle was used to install and test the Roadroid and Roughometer III equipment. The pavement in question has an overall hardness state that is very recent.

3.1 IRI Value From Rouhometer III Analysis And Discuccion

With values ranging from 0 to 30 m/km, the IRI value computations in Fig. 3 generated by the Roughometer III tool reveal significant variations. In this range, some IRI measurements get comparatively high. The existence of several bridges along the route is the cause of the increased IRI values, according to additional research.

The rise in IRI values has been mostly attributed to expansion joints, namely in bridge structures. The features of expansion joints, which are a natural part of bridge construction, may make the road surface more uneven. Therefore, even though bridges are crucial parts of the transportation system, it's important to understand how expansion joints affect IRI values.

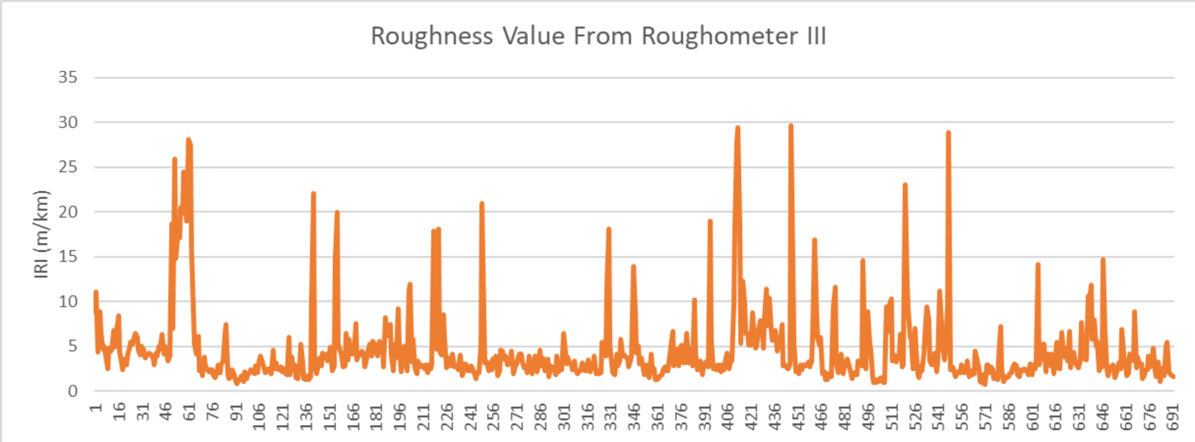

Fig. 13. Roughness value from roughometer III

3.2 IRI Value From Roadroid Analysis And Discuccion

The following results were obtained from the IRI calculations made using the Roadroid tool in Fig. 4. There is a large range and significant volatility in the stated IRI values. The number of bridges on the route is associated with the occurrence of high IRI values. The expansion joints on these bridges help explain their comparatively high IRI ratings.

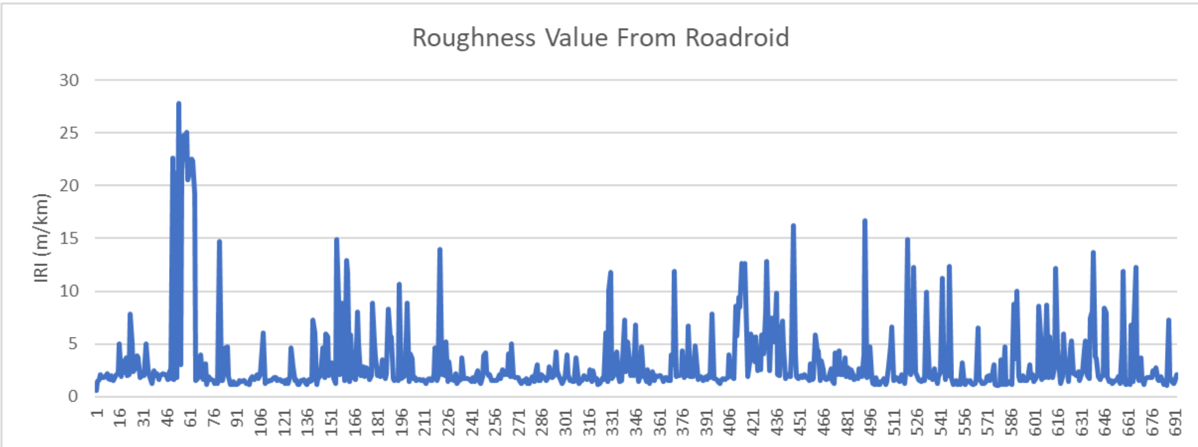

Fig. 14. Roughness value from Roadroid

To specifically evaluate the effect of expansion joints on IRI values and to find technical fixes or upkeep techniques that can counteract their negative effects, more research could be needed. To lessen the effect on the quality of the road surface, this can entail optimizing bridge designs or utilizing innovative material technologies.

The outcomes of the IRI value computations offer important preliminary information about road conditions and emphasize how important it is to include stakeholders in the decision-making process for road maintenance and improvement plans. The technical characteristics of bridge structures can therefore be taken into consideration when implementing strategic measures to enhance road quality and safety.

3.3 Comparation Between IRI Value based on Roughometer III and IRI Value Based on Roadroid

The IRI values generated using Roadroid and the Roughometer III tool are contrasted in the accompanying figure. The average IRI value from the Roughometer III was 4.6 m/km, while the average IRI value from the Roadroid application was 3.2 m/km.

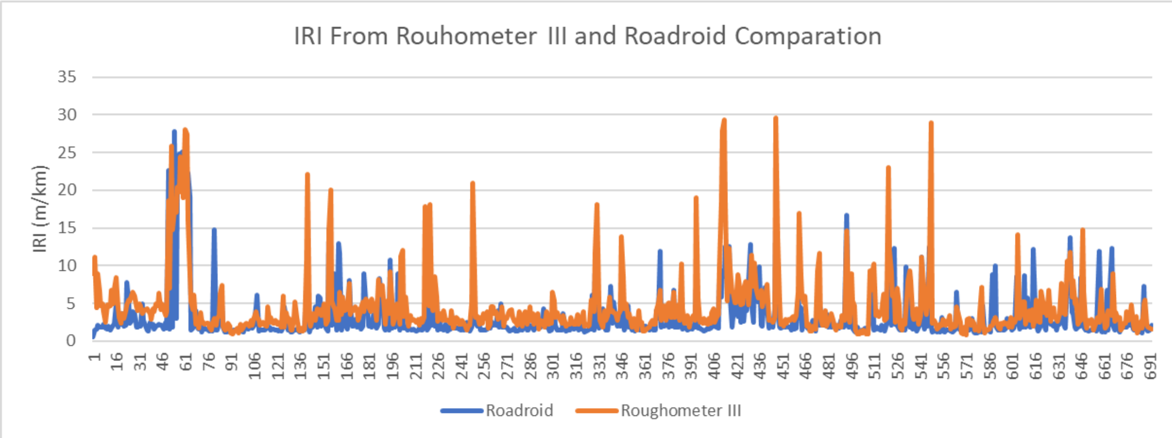

Fig. 15. IRI from Rouhometer III and Roadroid comparation

3.4 Determining Correlation Between IRI Value based on Roughometer III and IRI Value Based on Roadroid

The polynomial model correlation analysis yielded an R-squared value of 0.4701 (Fig. 6), indicating a positive correlation between the IRI values generated by the Roadroid application and the Roughometer III tool. One aspect is the differing sensor positions, even though the correlation between the two instruments is not very substantial. Compared to IRI values acquired with the Roadroid application, which places the sensor on the vehicle's front windshield, IRI values measured with the Roughometer III, which places the sensor close to the wheel axis, provide values that are more accurate depictions of the actual road conditions.

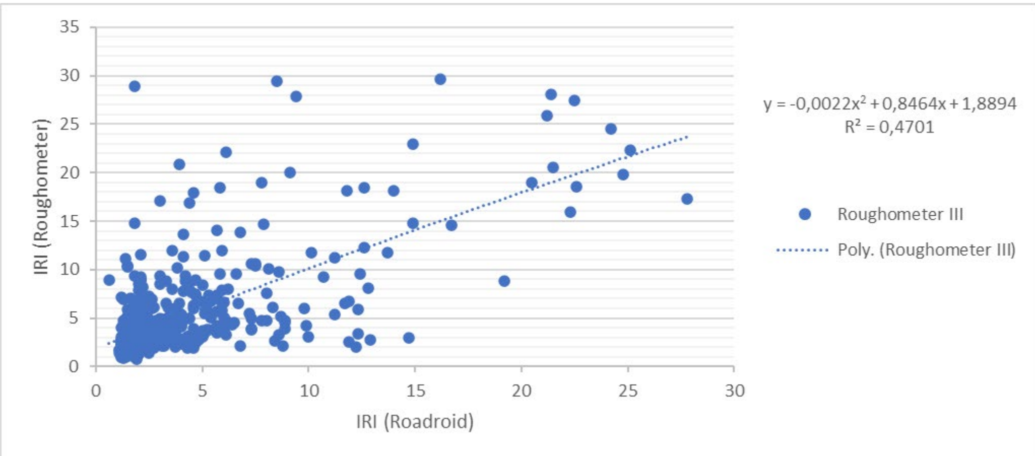

Fig. 16. Correlation Between IRI Value based on Roughometer III and IRI Value Based on Roadroid

IV. CONCLUSION

A polynomial analysis was used to examine the link between the IRI values from Roadroid and Roughometer III. With a coefficient of determination (R2) of 0,4701, the equation IRI (Roughometer) = -0,0022(IRIrd)2+0,8464(IRIrd)+1,8894 was the outcome. While 52.99% of the IRI value has no effect on any of the tools, the R2 value shows that the equation may explain the influence of the Roadroid IRI value on the Roughometer III IRI value to the extent of 47.01%.

To specifically evaluate the effect of expansion joints on IRI values and to find technical fixes or upkeep techniques that can counteract their negative effects, more research could be needed. To lessen the effect on the quality of the road surface, this can entail optimizing bridge designs or utilizing innovative material technologies. Additionally, the application can be further explored by observing the sensitivity of the sensor settings, the cellphone's position, and the stability of the cellphone holder in addition to differences in different pavement construction kinds.

The IRI value comparison's findings offer important preliminary information about road conditions and emphasize how important it is to include stakeholders in the decision-making process for road maintenance and improvement plans. The technical characteristics of bridge structures can therefore be taken into consideration when implementing strategic measures to enhance road quality and safety.

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