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# ASSESSMENT OF RIDE QUALITY AND ROAD ROUGHNESS BY MEASURING THE RESPONSE FROM A VEHICLE MOUNTED ANDROIDSMARTPHONE

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## Abstract.

Road surface roughness is considered as one of the most important aspect in functional condition of roads indicating to riding comfort in both transverse and longitudinal direction. For all highway projects maintaining proper surface evenness has been a mandatory requirement from the government of India. In this study, pavement unevenness was estimated using an android-based smartphone and system rely on the movement of a suspension system in response to the unevenness of the road surface travelled by a vehicle. Roughness index (RI) is an indicator to measure the standard road roughness. Conventional way of measuring RI involves usage of bump integrator, profilometer and roughometer. Present study proposes an alternative method to measure roughness using smartphones. The study was carried out in 2 different locations and 3 different smartphones to obtain the magnitude of deflections. Data collected using standard fifth wheel bump integrator is used for validation. Data collected through smartphone i.e., accelerometer sensor details was given as input to Fast Fourier transforms (FFT) to find the magnitude of deflection on the road. The results obtained from smartphones was then correlated with the existing roughness index data collected by standard fifth wheel bump integrator to establish an equation to predict RI using an android mobile.

**Keywords:** *Roughness index, smartphone, accelerometer, Fast Fourier Transforms, surface evenness.*

## 1. Introduction

The mobility of road users is considered as a most important issue in the world. The study presents the aspects of road functional condition like road surface evaluation and inspection, identifying some of the main issues in the field, as each and every state need to introduce a pavement management system (PMS), it is an assessment tool for decision-makers to provide the resources and prioritize the various maintenance and reconstruction projects. Being properly maintained, the roads can constantly serve their main objective, supporting the mobility of users, commercial use, and the economy of the country.

Indication of unevenness present on the road surface, i.e., the road roughness is viewed as the most critical one as it not only affects the pavement's ride quality but also increases fuel consumption, vehicle delays, and maintenance costs. Road roughness is an internationally accepted indicator to measure the



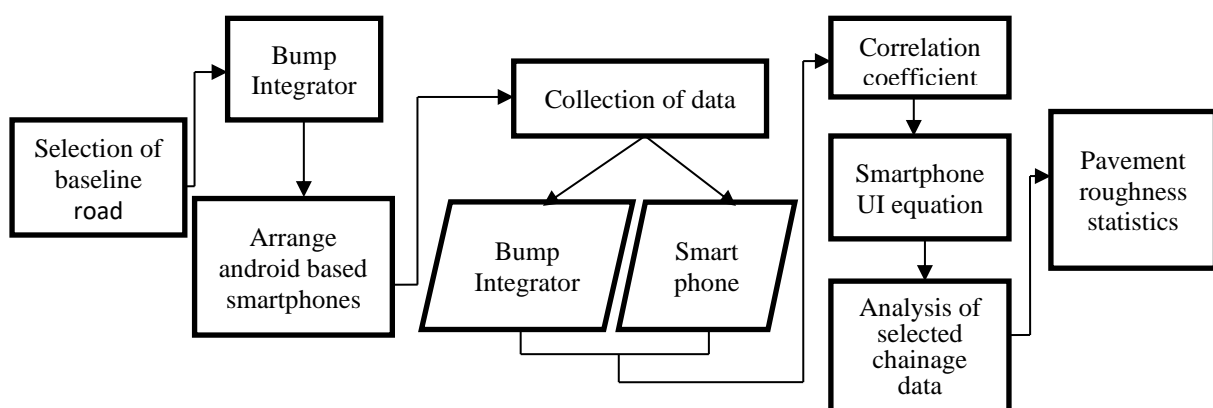
condition of pavement. To know the irregularities of the road surface most commonly used indicator is the Roughness index (RI). RI is the condition index obtained from the measurement of longitudinal road profiles with the measuring unit of slope (m/km, mm/m for instance) [1-4].

To identify the road roughness, two main appraisals are available in practice. The first is a manual or subjective rating survey and the second is with the use of very advanced profilers. The first approach uses man-power and cumbersome because, the evaluation of road surface is judged by inspectors from a visual inspection or the use of uncalibrated roughness meters. The automated (second approach) relies on the use of one or many types of advanced road profilers, which are more expensive to obtain, operate and maintain. The operator for this type of profiler should have more experience in handling the equipment. Moreover, to use such profilers, a maximum of those requires physical calibration before initiating [6,7]. Sensors are used in various fields of transportation such as road maintenance and traffic management. Janani et al., (2020) [5] explored about smartphone-accelerometer-based road roughness estimation method and a model was developed between international roughness index (IRI) and power spectral density (PSD) of acceleration data.

Nguyen et al., (2019) [8] developed a response-based method to measure road surface distresses by utilizing smart technologies, internet of things and inexpensive onboard sensors. Aleadelat et al., (2018) [9] used smartphone 3D accelerometers for collecting a vehicles vertical acceleration data and analysis signal processing pattern recognition techniques, such as correlation, welch periodogram and variance analysis to predict IRI values. Lei et al., (2018) [10] developed an IMU-based monitoring system for assessment of pavement surface irregularities by using wireless platform designed for real-time traffic estimation and road surface monitoring. Zang et al., (2018) [11] measured surface roughness of un-motorable roads, such as pedestrians and bicycle lanes based on GPS and accelerometer sensors on bicycle-mounted smartphones. Du et al., (2016) [12] proposed a process which help us in knowing the vehicles status and location data via wireless acceleration sensors and GPS for evaluating the international roughness index (IRI) by power spectral density analysis. Joel et al., (2014) [13] developed a low-cost road roughness assessment using smartphone and geographic information system (GIS) a significant relationship between vehicle intelligent monitoring system (VIMS) and smartphone method were achieved for certain roads satisfying the conditions required to know the accurate IRI survey using smartphone.

For economically developing countries, economic constraints, time-consuming and man- power are constraints for road surface data collection. Hence, this study focuses on use of android based smartphones to evaluate the road surface condition.

## 2. Methodology



**Figure 1.** Methodology adopted for the study

Methodology adopted for the study is shown in Figure 1. Two different road stretches with a span of 4 km, i.e., Nagpur-Aurangabad (2 lane Bitumen surfacing) and Nagpur to Mumbai (6 lane concrete surfacing) were considered for this study and is shown in figure 2. Data collection involves two steps. First step involves smartphones and second step involves measuring road roughness using fifth wheel bump integrator.

Three different android-based smartphones oneplus7T, pocoX2, samsungM31 were used because the smartphones will be equipped with different kind of accelerometer sensor to know the accuracy of the data using different types of smartphones to predict the RI and are placed at different locations inside a car (Figure 3).

1. Samsung M31 was placed at front side near to the gear rod.
2. Poco X2 was fixed in the middle i.e., on the hand rest.
3. One plus 7T was placed at backseat of the vehicle.



**Figure 2.** (a) Nagpur-Aurangabad



**Figure 2.** (b) Nagpur-Mumbai

A mobile application called “Androsensor” on each smartphone is installed to record the accelerometer data and arrange the phone’s respective locations inside the car (near gear rod, on hand rest, and backseat of the vehicle). The data recorded after processing is listed in Table 1. The standard equipment fifth wheel Bump integrator was used to estimate the actual condition (RI) of selected roads.

Infield survey data collected for 2 different road sections at constant speed of 32kmph for both bump integrator and smartphone accelerometer data.



**Figure 3.** Smartphone arrangement inside the vehicle

**Table 1:** Processing of accelerometer sensor data collected using smartphone

Accelerometer per 1km(m/s <sup>2</sup> )	Magnitude	BI per 1km (cm)	Corrected Values(cm)
9.8450925	1.731934	13	13.10271
9.79397208	0.084621	12.1	12.34017
9.861486385	0.682379	12.9	12.61687
9.790543225	0.084621	12.4	12.34017

The first one is mounted near the gear rod and second one on the hand rest of the vehicle and the third one at the backside of theseat. The vehicle that we used for the survey was the Hyundai Venue.

### 3. Analysis phase

Line graphs of smartphone data and bump integrator data is shown in Figure 4(a) and 4(b). To find the correlation between RI obtained using fifth wheel bump integrator and smartphone RI, regression analysis was done. Unevenness data from the smartphone is given as input to fast fourier transforms (FFT) to estimate the magnitude of unevenness. FFT is a filtering technic widely used in processing signals. Magnitude has been calculated from FFT to know the strength or amplitude of the signal component.

Simple linear Regression analysis was done by considering the dependent variable as unevenness index obtained using BI and the independent variable as magnitude data collected using smartphone (Figure 5). The equation generated to estimate RI for flexible pavement is shown in equation 1.

$$y = 0.0621x + 13.362$$

(1)

Similarly, the equation generated by using derived coefficients from the regression analysis of BI and smartphone results for concrete pavement as shown in figure 6 is shown in equation 2.

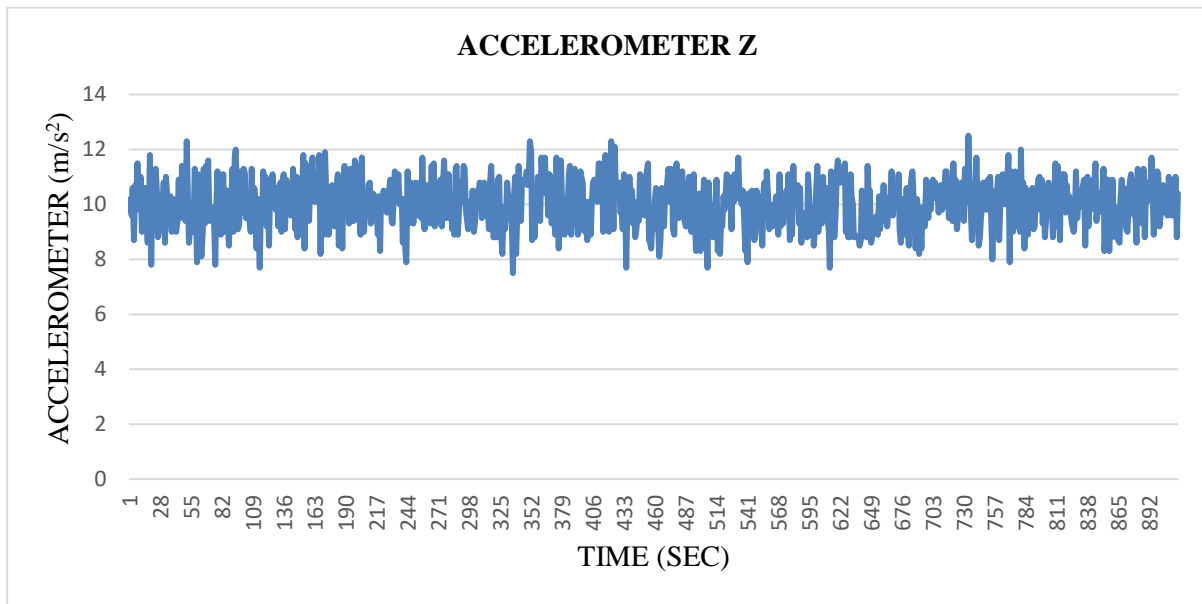
$$y = 0.0859x + 13.359 \quad (2)$$

Table 2 shows the R-squared values from smartphones placed at different locations.

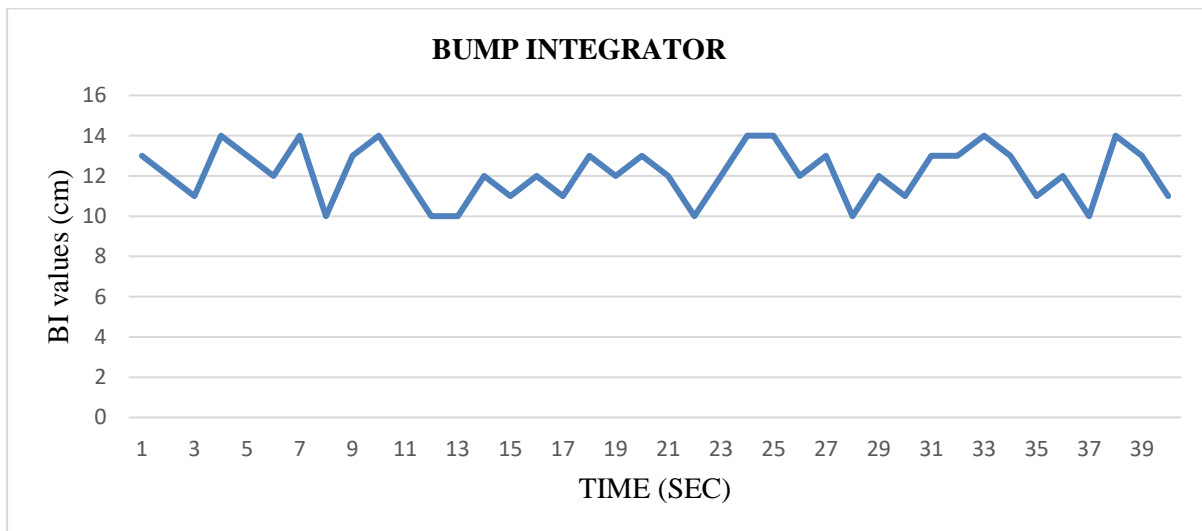
**Table 2:** R-squared values from smartphones placed at different locations.

S.NO	Concrete road						Bitumen road		Bump Integrator			
	Lane1		Lane2		Lane3		Lane1	Lane2	Concrete		Bitumen	
	Trail1	Trail2	Trail1	Trail2	Trail1	Trail2			Trail1	Trail2	Lane1	Lane2
Samsung M31	0.46	0.39	0.66	0.28	0.58	0.85	0.87	0.86	0.68	0.29	0.85	0.79
Oneplus 7T	0.46	0.35	0.68	0.30	0.59	0.86	0.86	0.87	0.68	0.86	0.85	0.85
Poco X2	0.45	0.72	0.68	0.17	0.72	0.18	0.64	0.78	0.67	0.27	0.73	0.86

The magnitude values obtained using poco x2 were having more variations for each trail on the same segment of road. So, it was observed to avoid the data collected using poco x2.

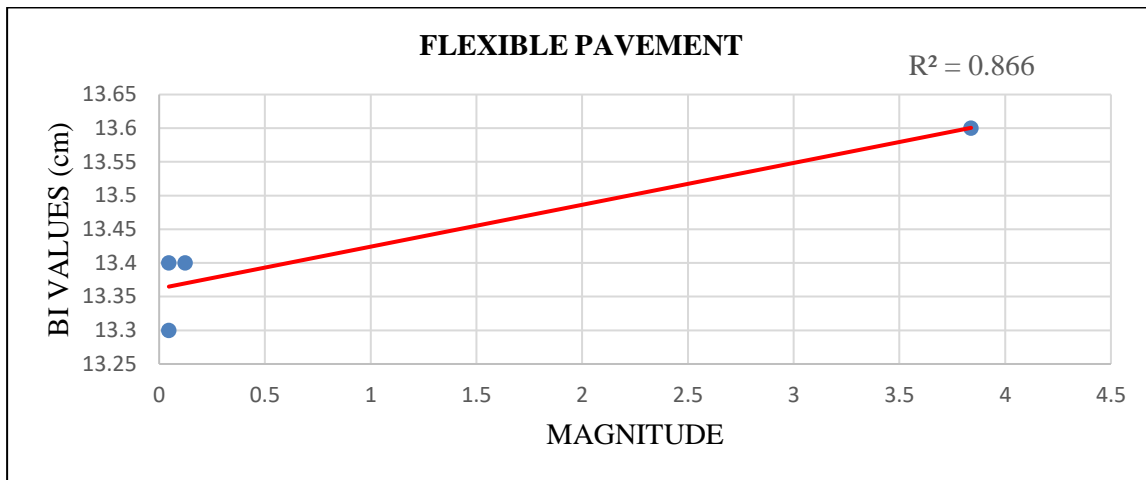


(a)

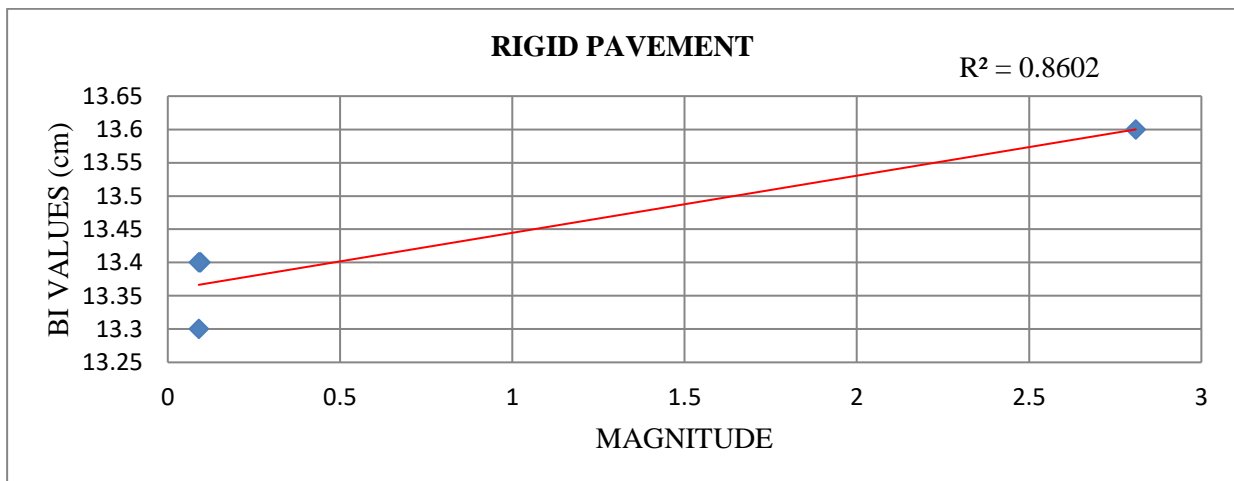


(b)

**Figure 4.** Line graphs of smartphone data and bump integrator data.



**Figure 5.** Correlation between Smartphone values and Bump integrator Values of flexible pavement.



**Figure 6.** Correlation between Smartphone values and Bump integrator Values of rigid pavement.

The surface evenness recommended standard for expressways, national highways and state highways to exercise control over the quality of construction. The recommended values for surface unevenness items of roughness index in mm/km are given in table 3 for different types of roads. It is mandatory to newly going projects need to meet the criteria of roughness values as per good surface condition. The unevenness values between fair and poor in condition, considered for the purposes of timely maintenance.

**Table 3:** Maximum permitted values of roughness for expressways, national highways and state highways. (Source: IRC:SP:16-2019)

S. No	Type of surfaces	condition of road surface		
		Good	Fair	Poor
1	Bituminous (or) flexible	<1800	1800-2400	>2400
2	Concrete (or) rigid	<2000	2000-2400	>2400

#### 4. Conclusions

This present research demonstrated the feasibility of using smartphones, which are embedded with most efficient sensors such as accelerometer, for assessment of pavement condition. To know the roughness of the road a wide range analysis has been done and established a relationship between android based smartphone data and road roughness condition (RI). By using signal processing techniques to measure the different signal data collected using smartphone. That signal data was compared with the unevenness index values that were measured using conventional way by using Bump integrator. Mathematical models were developed with high correlation to directly estimate the RI through android-based smartphone. The developed model is the corrected equation for the targeted roads which have been considered for the survey. The estimated values also show similar tendency in the classification of magnitudes by road condition indexes. Therefore, these mobile application based assessments can be used to estimate the road unevenness which can further be helpful for better monitoring and maintenance of roads.

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