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Comparative Study of the Road Roughness Measurement of Roadlab Pro and Roadroid Applicatons for IRI Data Collection in Nigeria

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---***ABSTRACT***---
Modern smartphones are equipped with many useful sensors. These sensors range from gyroscopes to global position systems (GPS) and sensors like magnetometers and three-dimensional accelerometers in-between. These sensors being used by applications installed in the phones can be used to measure the level of serviceability of a road by measuring the international roughness index (IRI). Early researchers have established that the World Bank standard of IRI was the method used in assessing road conditions. It serves as a means of evaluating the conditions and level of serviceability of a road network. This paper evaluates the roughness, surveyed length and vehicle speed measurement using RoadLab Pro (open sourced) and Roadroid (commercial) applications along selected routes. The selected route was carried on four major road networking the Federal Capital Territory (FCT) to neigbouring state capitals. Result show significant proximity in values for total surveyed length and average vehicle speed with error margins within 0.008% - 2% and 0.58% - 3.33% respectively. It was observed that RoadLab Pro smartphone application failed to sense data on sections of road with total/partial pavement deterioration; this may be a failure which smartphone applications reliant on accelerometers as primary roughness sensors may not detect. However, both applications performed consistently on roads with severe rutting. Furthermore, IRI values for certain routes were on different IRI condition category. Lastly, the study reveals that it is possible to get Road Asset Management System (RAMS) data in an inexpensive manner.
KEYWORDS: *Smartphones, International Roughness Index, road asset management system, RoadLab Pro, Roadroid,*

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I. INTRODUCTION

Road condition monitoring is a road quality assessment method which plays a significant role in infrastructure management and aids in allocation of road maintenance resources (Vittorio et al, 2012). Its primary objective is to detect distress on the road surface by measuring surface anomalies (Fendi et al., 2013; Vittorio et al, 2012). Essentially, it provides an indication of the level of serviceability of any road network; an indicator of the comfort expected by commuters, presence of hazards along route, possible wear and tear on vehicles plying the route and so on (Silva et al., 2018). Hence, data collected through road condition assessments forms a major component of any effective Road Asset Management System (RAMS) and basis for road maintenance (Geddes et al., 2016; De Blasiis et al., 2021).

According to ASTM International, E867-06 (2012) standard, pavement roughness is defined as "the deviation of a surface from a true planar surface with characteristic dimensions that affect the vehicle dynamics and ride quality" (ASTM International, 2012). As such, it is a quantitative representation of distress in pavement and major parameter for pavement surface (ASTM International, 2012).

The generally accepted standard for measuring pavement roughness, irrespective of technology employed, is the International Road Roughness Index (IRI). According to Sayers & Karamihas (1996), IRI is described as "a mathematical representation of the accumulated suspension stroke of a vehicle, divided by the distance travelled by the vehicle during a test". The units are millimetre/metre (mm/m) (Sayers & Karamihas, 1996).

In developing countries, challenges exist in the collection of road roughness data for entire road networks (Gamage et al., 2016). The prohibitive cost associated with data collection from the manual approach to the cost of acquiring state of the art systems, the cost of maintaining such equipment, its level of expertise needed and difficulty of regular network scale deployment have rendered most data collection approach unsustainable for developing countries. Alternatively, smartphone-based road condition monitoring systems fill the gap between sophisticated systems and the subjective ratings by experienced crews (Forslöf & Jones., 2015).

Recent advances in computing and sensor technology indicates ubiquitous and pervasive computing applications for intelligent infrastructure systems thereby justifying the use of this technology as it falls within the accuracy limit of an IQL-3/4 device of ± 20% (Schlotjes et al, 2014; Tully, 2006). For instance, roadroid smartphone application collected IRI was correlated with laser measurement system, result shows the possibility to reach greater than 0.85 (Forslöf & Jones., 2015).

In order to evaluate the suitability of using this technology in Nigeria, this paper compares the performance of two smartphones road condition monitoring applications: Roadlab pro the free application and Roadroad that requires an annual licensing fee.

II. METHOD

Two (2) Samsung SM-A720F model android phones running the RoadLab Pro version 2.0.145 and Roadroid version 2.3.8 smartphone applications are both used to measure the roughness index in line with Information Quality Levels (IQL) 3 – IRI by correlation (Response type measurement). These devices are securely mounted on the windshield of a Toyota Hilux Sport Utility Vehicle (SUV) in vertical (RoadLab pro) and horizontal (Roadroid) mode in a well oriented position with the X, Y and Z axes aligned. The applications are allowed to collect data on the selected routes.

The RoadLab Pro is a free smartphone-based road condition monitoring and mapping application designed by the World Bank (World Bank, 2017). The application algorithm taps into the smart phones gyroscope, accelerometer and GPS data in order to automatically evaluate pavement roughness. It classifies the IRI values measured into four different categories as described in Table 1 (World Bank, 2017). The application collects GPS coordinates of road section, geo record location of large bumps, pictures and anomalous observation which can be tagged indicating associated road risk. RoadLab Pro equally incorporates a flexible system for managing, editing, and exporting data. Furthermore, data measured can be visualized directly in Google Earth using Keyhole Markup Language (KML) files or directly displayed on smartphones. The operational speed for RoadLab Pro is within 15km/h – 100km/h.

S/No	IRI Range	Condition	Colour Code
1	IRI<2:	Excellent	
2	2<IRI<4:	Good	
3	4<IRI<6:	Fair	
4	IRI>6:	Poor	

Table 1: RoadLab Pro Road Condition Result and Map Interpretation Guide

The Roadroid is a commercial application that employs the use of sensors in smart phones to collect roughness data, photos and video (Jones & Forslof, 2014). The application annual license costs 3,600 USD per unit per year and the set up process is similar to the RoadLab Pro application. Unlike RoadLab Pro, Roadroid has a web interface called the Road Data Management System (RDMS) which facilitates data management and provides a visualisation of the data; roughness index, still images and videos in a Geospatial Information System (GIS) environment (Forslöf & Jones, 2015). The web platform allows data to be exported as Keyhole Markup Language (KML), Comma Separated Variables (CSV) and text files for each route assessed allowing for further analysis. Results are provided as estimated IRI (eIRI) and calculated IRI (cIRI). Besides roughness measurement, the application has other features for measuring traffic volumes; when used in conjunction with other sensors and road surface friction/skidding resistance for slippery conditions. The operational speed for Roadroid is within 20km/h – 100km/h and the Mean IRI are categorized into four (4) different categories as shown in Table 2.

S/No	IRI Range	Condition	Colour Code
1	IRI<2.2:	Good	
2	2.2<IRI<3.8:	Satisfactory	
3	3.8<IRI<5.4:	Unsatisfactory	
4	IRI>5.4:	Poor	

Table 2: Roadroid Road Condition Result and Map Interpretation Guide

For this study; the roughness measurement and other parameters such as time stamp, road ID, Latitude, Longitude, Distance surveyed (m), Speed (km/h), and altitude (m), are collected in both directions along four (4) Federal roads linking some neighbouring state capitals (Minna, Niger State; Lokoja, Kogi State; Kaduna, Kaduna State; and Jos, Plateau State to the Federal Capital Territory (F.C.T). For each road section, the RoadLab Pro and Roadroid are employed simultaneously with pre-set system condition inputted with description of road surface type and vehicle type. The vehicle operational speed is maintained within 70km/h to 90km/h for best correlation for IQL 3/response type method.

III. RESULTS AND DISCUSSION

3.1 Abuja to Minna route

Niger State with Capital in Minna lies to the West of the F.C.T. The road comprises of asphalt paved mostly single carriageway. The route was sub-divided into five (5) road sections for both clockwise and counter clockwise direction for the purpose of evaluation.

From data collected by RoadLab Pro, the total surveyed length is 313.17km with an average speed of 74.38km/h. Roughness measurement from the application showed that 98.35% of total surveyed length was recorded while 1.65% of total survey length was not recorded due to vehicle speed dropping below minimum required speed required to capture data (World Bank, 2017). The average IRI recorded based on the roughness measured is 4.48; classified as fair as indicated in Table 1. Results also show that road sections with fair IRI values were the most prevalent in terms of partial or complete road failure. Visualisation of the IRI measurement for the route from the RoadLab Pro is shown in Figure 1.

From the data collected by Roadroid application, the total surveyed length is 320.84km with average speed recorded at 76.36km/h. The eIRI measured is 3.70; classified as satisfactory.

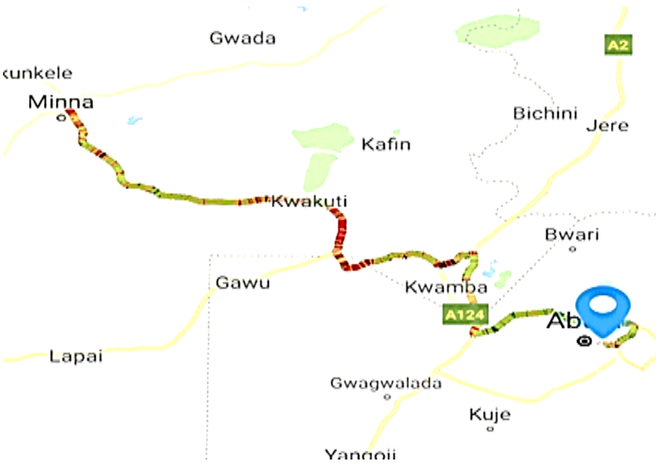

Figure 1: Screenshot of IRI measurement for road link (RoadLab Pro)

From data analysed, there is a 2% and 2.6% error margin of the total surveyed length and average speed for the road link. It is also observed that each road section surveyed in clockwise and counter clockwise direction falls within, 0.02% to 0.48% error margin except for the section of road with severe pavement deterioration (Lambata to Minna) in clockwise and counter clockwise direction with error margin of 4.80% (3.32km) and 4.91% (4.14km) error margin. This section has the longest length without roughness or road length recorded by RoadLab Pro; implying that the reliant on accelerometers as primary roughness sensors may not detect roughness index on certain road failure conditions. Also, the IRI values for both applications are classified in different IRI condition category seen in the road condition result and map interpretation guide in Table 1 and Table 2.

3.2 Abuja to Lokoja route

Kogi State with Capital in Lokoja lies to the South of the F.C.T. The road comprises of asphalt paved, dual carriageways with sections under construction at the time of survey. The route was broken into eight (8) road sections in both clockwise and counter clockwise direction starting and terminating at the Unity Gate, Abuja It is worth mentioning that significant sections of this route are within the F.C.T.

From data collected by RoadLab Pro, total surveyed length is 392.25km with average speed of 87.91km/h. 99.74% of the total survey length recorded an average IRI of 3.13; classified as good. Most section of the road link recorded IRI values classified as good as seen in Figure 2 where significant section of the route link is within the green colour range.

Figure 2: Screenshot of IRI measurement for road link (RoadLab Pro)

From the data collected by Roadroid, total surveyed length is 392.28km with an average speed of 88.42km/h. The estimated IRI (eIRI) 2.47; classified as satisfactory.

From both data collected, there is a 0.008% and 0.58% error margin of the total surveyed length and average speed of road link in clockwise and counter clockwise direction. From visual observation, this route has the longest road link with severe rutting with total surveyed length of about 0.03km. This may mean that the sensors can detect roughness on pavement surface with rut. Also, IRI values for both applications are captured within similar condition category as seen in Table 1 and Table 2.

3.3 Abuja to Kaduna route

Kaduna State with Capital in Kaduna lies to the North – West of the F.C.T. The road section comprises of asphalt paved dual carriageway which was undergoing rehabilitated at time of survey. The total surveyed length is broken into six (6) road sections in both clockwise and counter clockwise direction.

From data collected by RoadLab Pro, total surveyed length is 436.89km with average speed recorded at 84.02km/h. 99.61% of the total surveyed length measured the roughness index of the road link with average IRI value of 5.19 classified as fair. Visualisation of the IRI data for the route link is shown in Figure 3.

From data collected by Roadroid, total surveyed length is 436.80km with average 84.68km/h. The eIRI value measured is 9.06; classified as poor. Results also show that road sections with poor IRI values were the most prevalent.

From data analysed, there is a 0.02% and 0.78% error margin of the total surveyed length and average speed of road link in clockwise and counter clockwise direction when applications were compared. Also, the IRI values are classified in different IRI condition category.

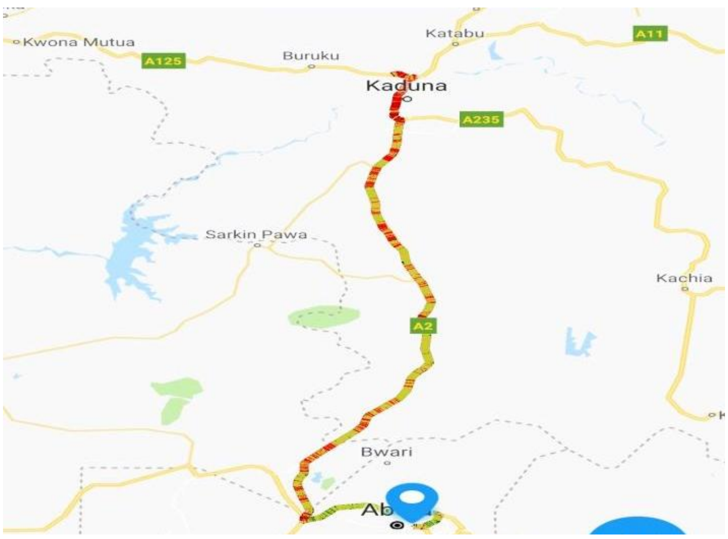

Figure 3: Screenshot of IRI measurement for road link (RoadLab Pro)

3.4 Abuja to Jos route

Plateau State with Capital in Jos lies to the North- East of the F.C.T. The road comprises of asphalt paved dual carriageway from Abuja, F.C.T to Keffi in Nasarawa State and paved single carriageway from Keffi to Jos, Plateau State. The road link was broken into ten (10) sections in both clockwise and counter clockwise direction.

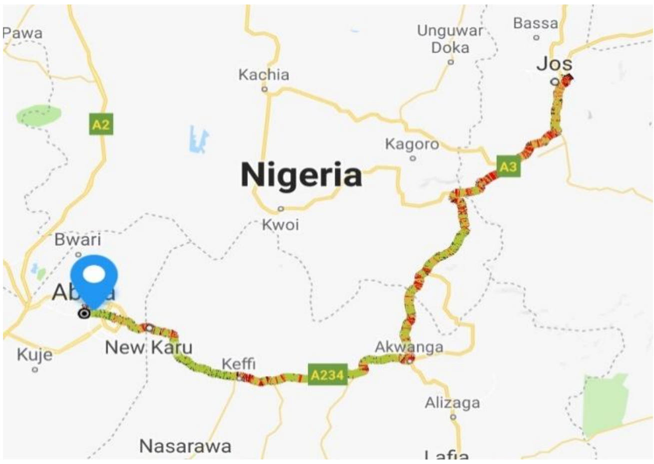

Figure 4: Screenshot of IRI measurement for road link (RoadLab Pro)

From data collected by RoadLab Pro, total surveyed length is 556. 86km with an average speed of 75.98km/h. Roughness measurement from the application showed that 98.67% of the total surveyed length was measured with an average IRI of 5.00, classified as fair. Predominantly, the road section recorded IRI values that are categorized as fair with the remaining section, partly good and poor. The visualization of the IRI data retrieved from RoadLab Pro shows that significant part of the road link from Akwanga to Jos as seen in Figure 4 have IRI greater than 6; implying poor condition level.

From data collected by Roadroid, total surveyed length is 554.99km with an average speed of 78.60km/h. The eIRI value is 13.47 classified as poor.

Result also shows a 0.34% and 3.33% error margin of total surveyed length and average speed between applications. Also, the IRI values are classified in different IRI condition category.

Route	Applications	Length (km)	Speed (km/h)	eIRI	Cond Cat
Abuja to Minna	RoadLab Pro	313.17	74.38	4.48	Fair
	Roadroid	320.84	76.36	3.7	Sat
Abuja to Lokoja	RoadLab Pro	392.25	87.91	3.13	Good
	Roadroid	392.28	88.42	2.47	Sat
Abuja to Kaduna	RoadLab Pro	436.8	84.02	5.19	Fair
	Roadroid	436.8	84.68	9.06	Poor
Abuja to Jos	RoadLab Pro	556.86	75.98	5	Fair
	Roadroid	554.99	78.6	13.5	Poor

Table 3: Summary of data collected via smartphone applications
Cond Cat: Condition Category;
Sat: Satisfactory

IV. CONCLUSION

In this study, the roughness, surveyed length and vehicle speed measurement using RoadLab Pro and Roadroid applications along selected routes were evaluated. Result show significant proximity in measured data for total surveyed length and average speed. It was observed that total pavement deterioration on some sections of the road was not sensed by the RoadLab Pro application; this may be a failure which smart phone applications reliant on accelerometers as primary roughness sensors may not detect. However, both applications were consistent on sections of roads with severe rutting. Also,

Abuja to Minna, Abuja to Lokoja and Abuja to Jos route IRI values were on different IRI condition category. This may be as result of the fact that mean IRI is calculated based on recorded points. A difference in the number of points recorded affects the mean value of IRI. It is possible that combination of road monitoring application and road damage sensing techniques will help to mitigate such system failures. However, further work needs to be done to evaluate the high IRI values realized in Roadroid application in comparison with RoadLab Pro. In addition, statistical analysis should provide significant level of correlation between both applications.

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