

THE USE OF ROADROID APPLICATION AND SMART PHONES FOR ROAD CONDITION MONITORING IN DEVELOPING COUNTRIES

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Abstract

Traffic Safety and Ride Comfort of a road user can be enhanced when the road surfaces are smooth. Similarly, road surface smoothness is important for decreasing vehicular operating and maintenance costs. Road roughness data, which can be an indicator of road condition, can be collected using the in-built accelerometer available in smart phones in a simple and cost-efficient way. The possibility of continuous data collection can also give early warnings of road surface changes and road damage; thus, enabling new ways of road maintenance management. The smart phone-based system equipped with the Roadroid application software is also an alternative to Class 4 – subjective rating of roads where it is impossible to use heavy, complex and expensive equipment, and for bicycle lanes. The technology is objective, highly portable and simple to use. A road section exhibiting different road condition levels in Jabi District of Abuja in Nigeria was identified and the road condition survey was conducted using the Roadroid application. The collected data was wirelessly transferred to the Roadroid web server. When needed, the data was accessible via a web service with an internet mapping server and spatial filtering functions. Currently, Arterial roads within the metropolis of Abuja, Nigeria are being monitored using this application. Developing countries can take advantage of this powerful tool to help in their road inventories, inception reports, tactical planning, program analysis, support maintenance and project evaluation especially in the era of economic challenges and dearth of road funds.

Keywords: *Road Condition Survey, Road Roughness Data, Roadroid, Strategic Asset Management, Pavement Planning.*

1.0 INTRODUCTION

The importance of roads to the socio-economic activities of a country cannot be overemphasized, as it plays an important role in positively shaping the transportation system. A good road transportation system as depicted in Fig. 1 is characterized by effective road pavement development and management, appropriate furniture design and transport operations with proper interconnectivity and timely maintenance done in line with international best practices. Such road networks are known to fast track socio-economic development, enhance seamless mobility of goods and services, promote socio-cultural integration of communities, minimize vehicle operating costs, etc.

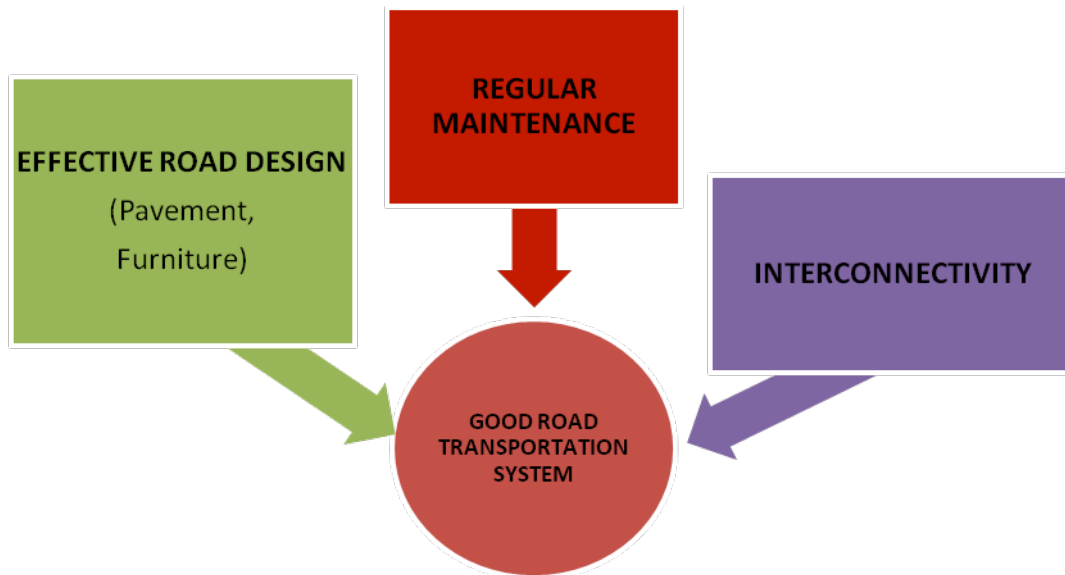


Fig. 1: Elemental Components of a Good Road Transport System

For a sustainable road transportation system, there should be an effective system for road maintenance scheduling based on periodic road condition surveys. This is a critical component of effective road asset management system (Astarita et al, 2012). The road condition is defined by the roughness of the road and is a reflection of the ride quality. This type of assessment requires provision of adequate road funds not only for the equipment and expertise but also for other operational costs.

Since the early 1900s, road roughness has been used as an index for expressing road condition and ride quality of road networks (Sayers, Gillespie & Queroz, 1986); and the measurement has been done mostly with sophisticated equipment (Forsslöf & Jones, 2015). However, with technological advancement and the need for standardization, the International Road Roughness Index (IRI), which is obtained from measured longitudinal road profiles was introduced in 1986; and has become widely used worldwide for evaluating and managing road assets (Paterson, 1986).

The typical techniques used for the measurement of road roughness could either be specially built trucks or wagons with laser scanners, bump-wagons or even manually operated rolling straight edges. The specially built equipment for measuring the IRI are therefore very expensive as a result of the complexity in the hardware, low volume of production of accessories and systems, etc. This impacts negatively on the collection of road condition data for proper analysis, and provides draw-back in examining the road condition for most road administrators, especially in developing countries (Chugh, Bansal & Sofat, 2014).

Consequently, for many developing countries, the provision of transportation systems that meet global standards, as explained above, has been an impediment (Chugh, Bansal & Sofat, 2014). The greatest challenge of many road authorities has been the management and maintenance of the available, albeit, inadequate road networks. This may be as a result of inadequate road funds

for the procurement and management of the requisite testing tools and equipment, and/or inherent malpractices in the system.

This paper therefore explores how smart phones can be deployed to conduct road condition surveys, which road authorities or maintenance departments can utilize, for sustainable road maintenance purposes, especially in developing.

2.0 BACKGROUND

2.1 Preview

With the ubiquity of Information and Communication Technology (ICT), and the widespread use of sensors and mobile devices, several new uses have been developed for commonly available devices (Bohn et al, 2005; Tully, 2006). The smart-phone for example, is known to incorporate several sensors capable of capturing road condition related data. These sensors include; accelerometers, Global Positioning System (GPS) chips, microphones, still and video cameras etc. These sensors are included by default in entry level smart phones and can be harnessed for the development of road condition monitoring systems.

Several smart phone-based road condition monitoring systems have been developed in the last decade as experimental projects by individuals, corporations with even fully commercial systems. For example Astarita et al (2012) and Vittorio et al (2014) used the smart phone accelerometer and GPS sensors to detect road anomalies, especially speed bumps and their relative locations using some algorithms.

In a comprehensive review of smart phone use for road condition monitoring, Chugh, Bansal & Sofat (2014) described the transition from dedicated sensors and other associated hardware deployed to capture road condition data, to the use of smart phones which have the required sensors inbuilt and possess operating systems capable of supporting data capture, storage, onboard analysis, transmission to a web server for off-site analysis and/or data storage, as the case might be.

Smart phone-based gathering of roughness data which essentially is a response-type road roughness measuring system (RTRRMS) can be done at a low-cost to monitor changes on a regular basis. The weather elements such as rain, etc. have no effect during data collection; and it can be deployed for performance-based contracts or for research on road deterioration, environmental effects (such as flooding), etc.

2.2 Roadroid™

Roadroid is a road condition monitoring system based on smart phone sensors; especially the accelerometer and GPS (www.roadroid.com). The system is made up of an application (app) and a web service. It samples the vibrations from road surface unevenness at 100 samples per second. The data is also saved with corresponding GPS data to enable the location of the road anomaly. From the accelerometer data, signal analyses allow the generation of the globally recognized IRI. The data and results can be transferred to the web server for further processing and visualization.

According to Forslöf & Jones (2015), there are four generic classes of road roughness measurement methods in common use and they are identified as Class 1 to 4; denoting the decrease in accuracy and sophistication of equipment required (TRL, 1999). These are:

- i. Class 1: These are high precision profiles which require sophisticated equipment and data analysis; implying expertise: and cannot be regularly carried out as general surveys.
- ii. Class 2: Other profile-metric methods less accurate when compared to class 1 methods.
- iii. Class 3: IRI estimates are obtained from correlation equations which provide equivalence from other regional roughness measurement devices which need class 1 and 2 devices for calibration (Paterson, 1986).
- iv. Class 4: Subjective ratings and uncalibrated measures which could include visual inspection reports.

Roadroid system may be placed in between Classes 1 to 4 measurement systems. It is expected that smart phone-based systems like Roadroid would soon challenge subsisting road roughness measurement systems and knowledge with regards to standards and procedures (Forslöf & Jones, 2015).

3.0 CASE STUDY

The road network used as a case study is within the Jabi District of Abuja metropolis as presented in Figs. 1 2 and 3. The smart phone was mounted in the car using a windshield phone holder, while it was ensured that the XYZ coordinates were all on or close to zero for initialization. The application was started by clicking “Start”, and then "Ok" in the display settings box. Data collection can be and was done by one person who was the driver of the available vehicle. There is no need of a specific operator which also contributes to its cost-effectiveness. The possibility of continuous collation of data opens new perspectives for performance monitoring. Roughness changes can be monitored on daily, weekly or monthly basis. The data collected is then uploaded into the web server of Roadroid and then analyzed. A simplified schematic chart of the Methodology adopted for the study is presented in Fig. 4. Charts and other results can be downloaded from the website. Fig. 5 shows the color legend indicating the road condition along the test section studied; and the black spots on the route map indicate the very rough section with potholes. On the asphalt paved section, there were serious undulations when visually inspected. With respect to Class 4 measurement, the Roadroid application elicited the unevenness, which shows the application sensitivity.

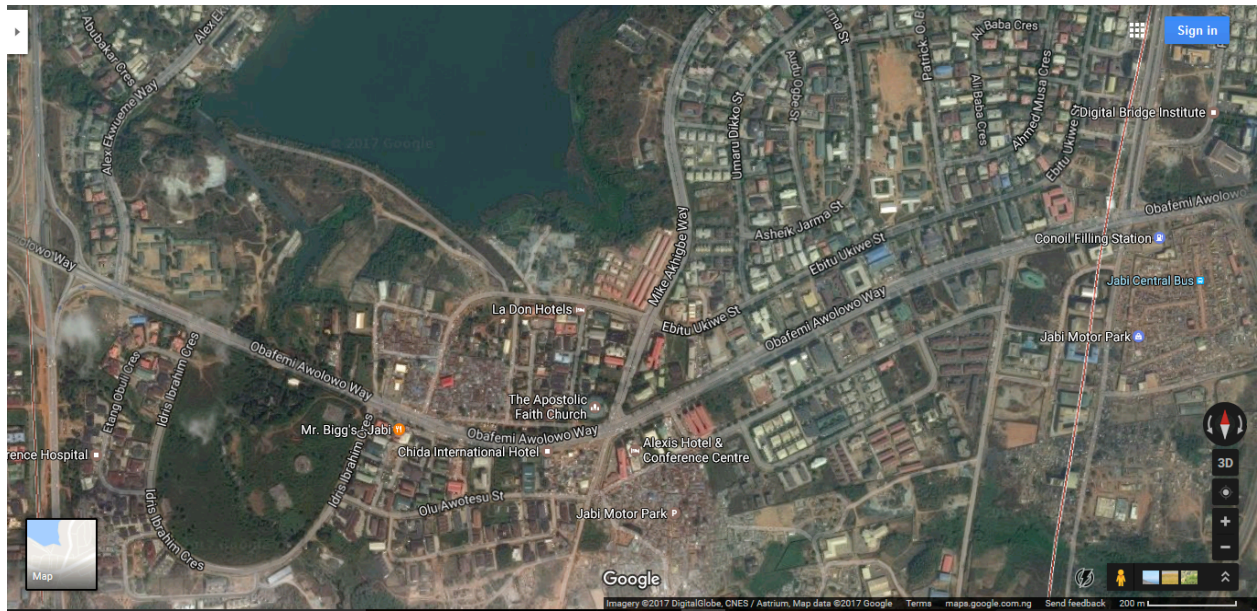


Fig. 2: Aerial View of the Study Area

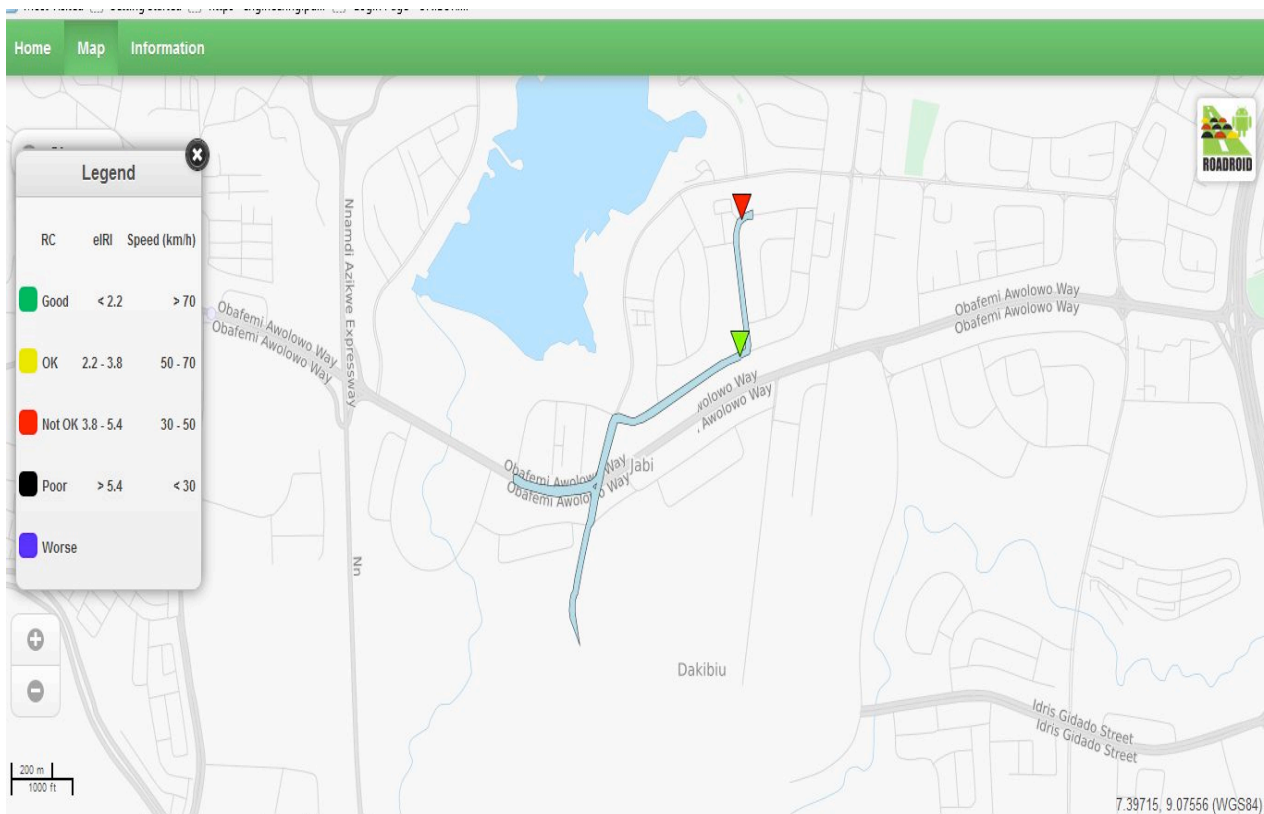


Fig. 3: Study location within Jabu District, Abuja Nigeria

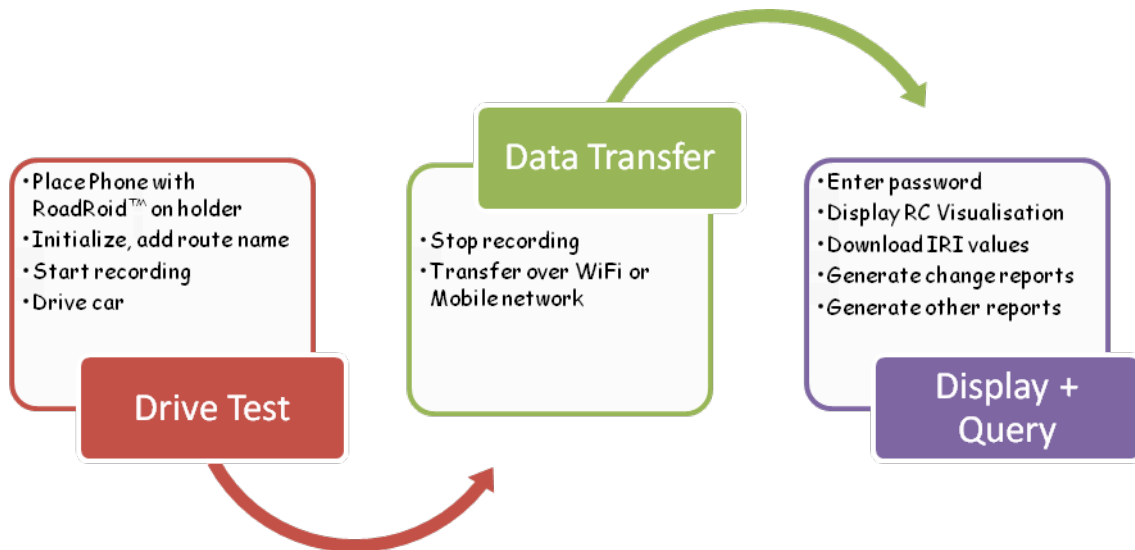


Fig. 4: Simplified Schematic representation of Methodology Adopted

Source: www.roadroid.com

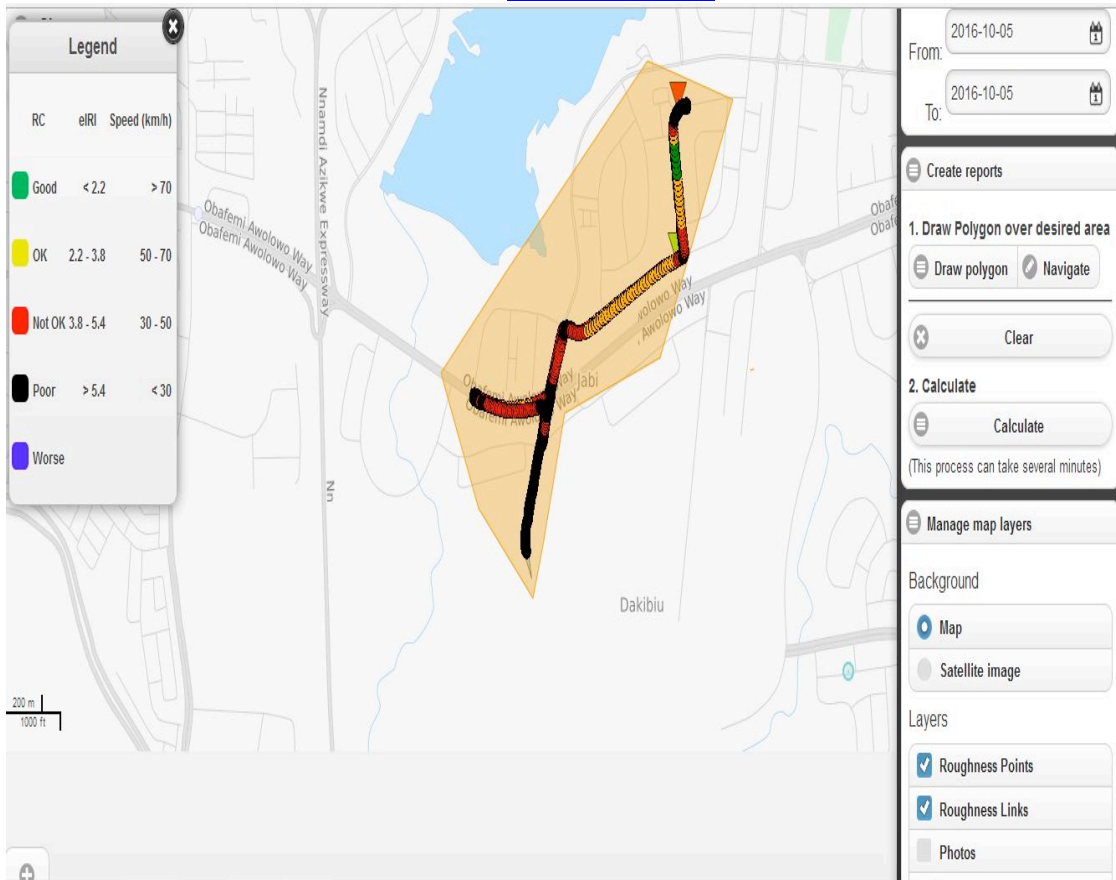


Fig. 5: Colour Coding for Roughness Index and Road Conditioning Levels along the Test Section

Source: www.roadroid.com

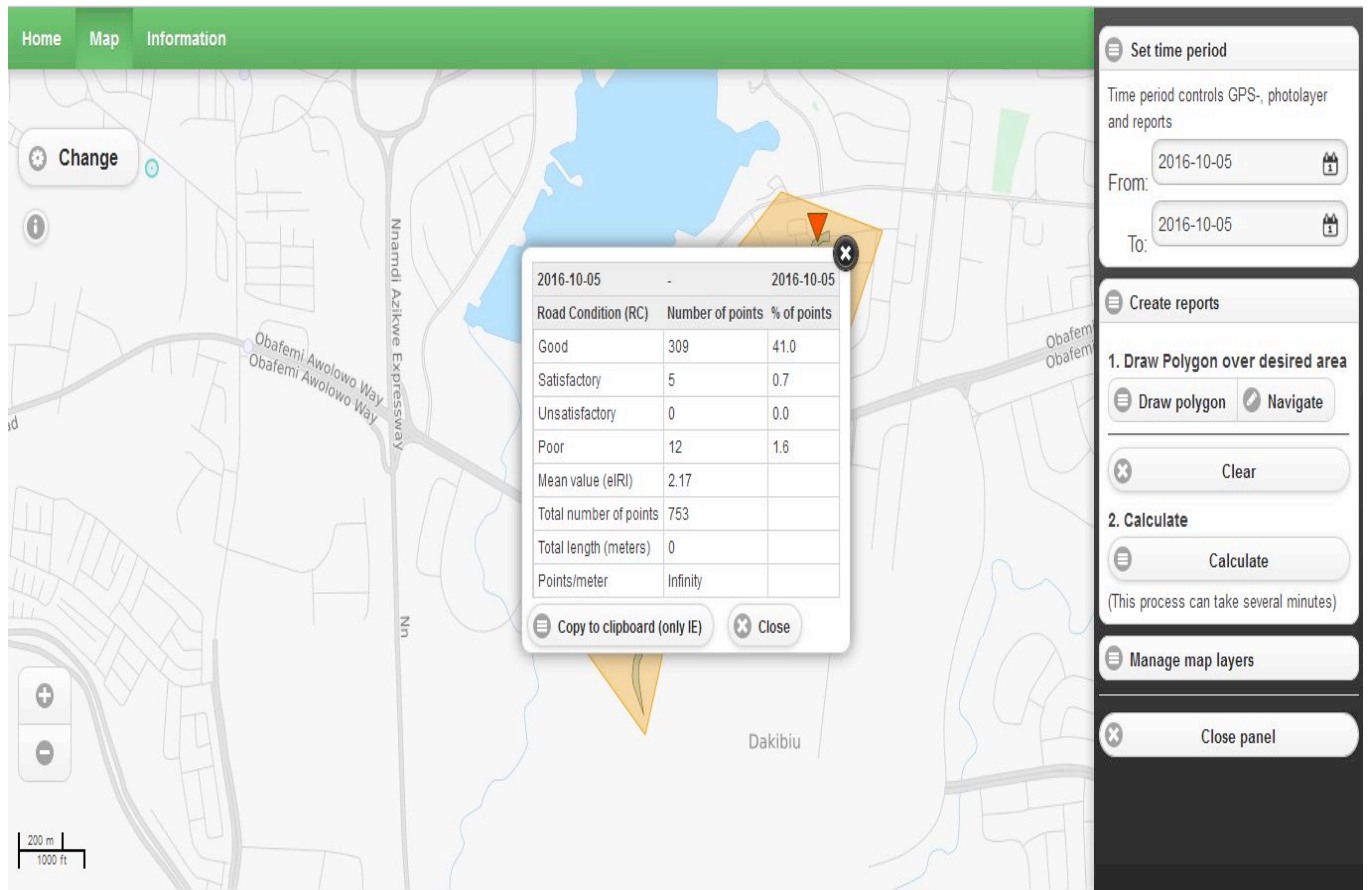


Fig. 6: Road Condition Summary Chart

Source: www.roadroid.com

4.0 RESULTS AND DISCUSSION

The total road length traversed in this study was 4420m. From the road condition summary presented in Fig. 6, it can be observed that the road network is generally good as the mean estimated International Roughness Index (eIRI) is 2.17 while the mean value for the calculated International Roughness Index (cIRI) is 2.04. No complex calibration procedure was required and the application has a setting for three vehicle types. The vehicle speed was between 30-80km/hr along the test route.

The correlation of the estimated IRI (eIRI) towards laser beam measured IRI is about 70-80% depending on road surface type (Forsslöf & Jones, 2015). The accuracy can be increased with some tuning. It should be noted that the global IRI sampling is ongoing and being developed with a calculated IRI (cIRI) to enhance the correlation factor.

From the pictorial views presented in Figs. 7 and 8, the prevailing road conditions of different segments of the test section are depicted in different color bands. For example, the unpaved and poor road sections tested are depicted in black color to indicate that the roads are in poor condition with estimated eIRI greater than 5.4. However, Fig. 7 shows the highest eIRI of 2.93 was achieved at location 1790m from the start point.

The results show that the road section traversed is generally in a good condition. As the eIRI increases, the road authority is informed early enough and plans made on when to commence the maintenance of such roads.

A comparison of Figs. 7 and 8 shows the correlation between the eIRI and cIRI results along the test route.

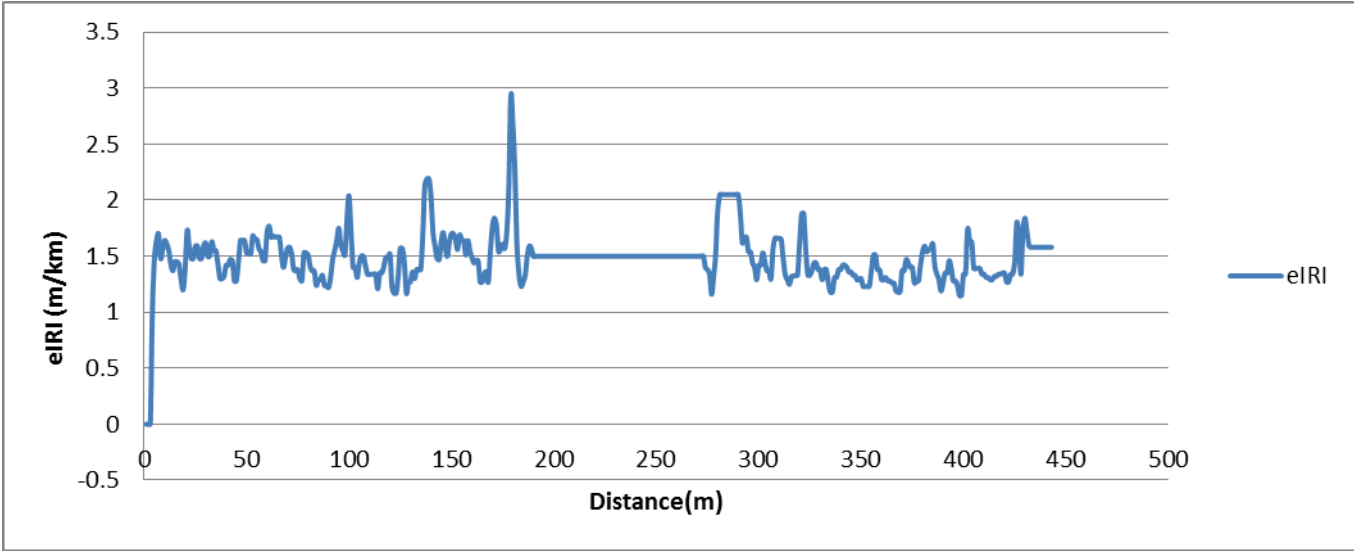


Fig. 7: Relationship between estimated International Roughness Index (eIRI) and Distance travelled (Distance is in tens i.e. x10)

Source: www.roadroid.com

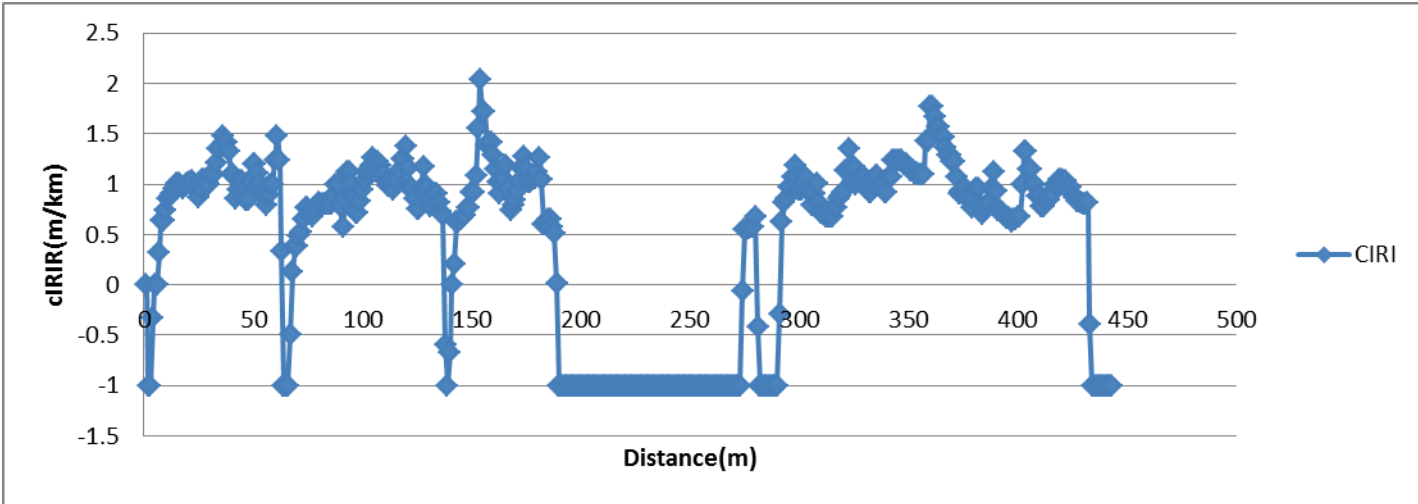


Fig. 8: Relationship between Computed International Roughness Index (cIRI) and Distance travelled (Distance is in tens i.e. x10)

Source: www.roadroid.com

5.0 CONCLUSION

With Roadroid and similar applications, road administrators and relevant organizations can deploy smart phones for road condition surveys which are affordable, efficient and require little expertise. This paper shows that Roadroid application which does not require internet connection when collecting data can easily geo-locate data on a global level with sufficient accuracy down to object levels. The eIRI reached 2.93 at 30-80km/hr and the mean value was 2.04, which depicted a generally good road.

The benefits of such smart phone-based system are more appropriate on a global level where data needs to be collected for a large road network. There is however great ease collecting large volumes of data using the Roadroid index to search and filter by geographic areas and special queries. It also enables measuring and establishing the relationship between roughness index results from Roadroid and other conventional methods in use.

6.0 RECOMMENDATION

The use of this system for measuring IRI for the management of road assets is highly recommended for developing countries where accessibility to sophisticated equipment and expertise for road monitoring is limited. Roadroid is efficient, cheap to use and affordable, especially in poorly funded road maintenance agencies which are common in the developing world.

This study further recommends that large scale Road Roughness data collection be done for the Nigerian road network and the actual correlation between the conventional methods of IRI data collection examined. It is also recommended that further research be extended to study the impact of road roughness on travel safety, vehicle operating and maintenance cost for the Nigerian Federal highway network using this application.

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REFERENCES

- Astarita, V., Caruso, M. V., Danieli, G., Festa, D. C., Giofrè, V. P., Iuele, T., & Vaiana, R. (2012). A mobile application for road surface quality control: UNIquALroad. *Procedia-Social and Behavioral Sciences*, 54, 1135-1144.
- Bohn, J., Coroamă, V., Langheinrich, M., Mattern, F., & Rohs, M. (2005). Social, economic, and ethical implications of ambient intelligence and ubiquitous computing. In *Ambient intelligence* (pp. 5-29). Springer Berlin Heidelberg.
- Chugh, G., Bansal, D., & Sofat, S. (2014). Road condition detection using smartphone sensors: A survey. *International Journal of Electronic and Electrical Engineering*, 7(6), 595-602.
- Forslöf, L & Jones, H. (2015). Roadroid: Continuous Road Condition Monitoring With Smart Phones. *Journal of Civil Engineering and Architecture* 9 (2015) 485-496 Doi: 10.17265/1934-7359/2015.04.012.

- Paterson, W. (1986). International roughness index: Relationship to other measures of roughness and riding quality. *Transportation Research Record*, (1084).
- Sayers, M. W., Gillespie T. D. & Queroz, C. A. V. (1986). The International Road Roughness Experiment: Establishing Correlation and a Calibration Standard for Measurements. Technical Paper No. 45. World Bank, Washington D.C.
- TRL (1999). Overseas Road Note 18 - A Guide to the Pavement Evaluation and Maintenance of Bitumen-Surfaced Roads in Tropical and Sub-Tropical Countries.
- Tully, A. (2006). Pervasive tagging, sensors and data collection: a science and technology review for the foresight project on intelligent infrastructure systems. In *IEE Proceedings-Intelligent Transport Systems* (Vol. 153, No. 2, pp. 129-146). IET Digital Library.
- Vittorio, Astarita, Vaiana Rosolino, Iuele Teresa, Caruso Maria Vittoria, and P. Giofrè Vincenzo. (2014) Automated sensing system for monitoring of road surface quality by mobile devices. *Procedia-Social and Behavioral Sciences* 111 (2014): 242-251.