

## Evaluation of Pavement Ride Quality on Road Networks Using Smartphone Application

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**Abstract:** The problems of surface pavement failure on the road are highly affects the road users. It leads increase the travel time, decrease the comfort and safety of passengers, decrease traffic flow of neighbors, expose the vehicle owners for additional maintenance cost, traffic congestion and also affect economic growth and forebode of tourism in the study area. This study aims to evaluate the roughness value of the road surface using the International Roughness Index (IRI) method. Several site location were selected at Jalan Kuala Kedah, Jalan Anak Bukit, Jalan Langgar, Jalan Kangar-Alor Setar, Jalan Pendang-Tanah Merah, Jalan Datuk Kumbar, Jalan Alor Mengkudu, Jalan Titi haji Deris, Jalan Tualang and North-South Expressway Roadbounce application available in the smartphone was employed to measure the level of roughness for the road surface. The results of field measurement recorded that all three of the road networks have the roughness index that falls into the acceptable scale according to standard ASTM E1926 and fulfill the requirement from Public Work Department (PWD). These findings facilitate road surface assessment work to provide a better riding quality, minimum delays at road works and enhance deformation resistance.

**Keywords:** Road Networks, International Roughness Index, Roadbounce, Riding Quality, Deformation Resistance

### 1. Introduction

The leading means of transport in Malaysia are the various modes of transport, including the sea, air, rail and road systems. The concept of the road surface or pavement is that it uses a kind of durable substance laid down in the area to support road or foot traffic, such as a road a walkway. Asphalt pavement has been renowned for its toughness and strength since the 1920s and is made up of stone, sand, additives and liquid asphalt. The composite pavement is the combined product of the Portland cement concrete sublayer with asphalt and is primarily used for the repair of existing roads rather than for new construction.[1]

The roughness or smoothness of the pavement is defined as the deviation of the vertical amount of the road surface and is one of the key technical indicators of the pavement conditions for assessing the

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quality of the ride (RQ) of new and rehabilitated pavements.[2] Road roughness is an important parameter, indicating the level of comfort over a pavement surface, and the vehicle's vibration while in movement, the speed of the vehicle's operation, the wear and tearing of the wheels over the course of time, and consequent vehicle operating costs.[4] A pavement, which is structurally sound to sustain heavy load repetitions, may even be unserviceable functionally if its surface is rough and distressed.[3] Roughness of the pavement is inherently related to the serviceability of the pavement which is a measure of its physical properties. Currently used roughness measurement systems can be combined into profilometric, vehicle response, and subjective assessment. The most precise and best suited to detailed analyses are profilometric methods. Measurements of roughness are calculated by the International Roughness Index (IRI). Usually, the IRI of a roadway is typically determined using inertial profilers. These vehicles are expensive to own and for rent; therefore, many jurisdictions currently have their path studied by expert consultant. Furthermore, these services may be inaccessible to many smaller municipalities who are unable to afford the upfront cost of the data collection vehicle or associated consulting services.[5]

For this study, the roughness index of various types of road network was determined to evaluate the feasibility of collecting comparable roughness data using low-cost sensors embedded in smartphones widely available on the mobile market today. The roughness index is a function of the smoothness of pavement, and its comfort, safety and convenience to the road user. The roughness index depends on the road surface roughness, which in turn depends on the finishing of the road surface. A good road is expected to give an improved riding quality, a reduce surface noise, provide minimum delays at road works, and provides enhance deformation resistance.

## 2. Field Measurement Test

The study involved a field survey and testing using the Roadbounce application on the various bituminous pavement surfaces. The Roadbounce application is an instrument used to produce a series of numbers to represent a profile. The Roadbounce works by combining three parameters mainly, a reference elevation, a height relative to the reference, and a longitudinal distance. The international roughness index (IRI) is calculated from a measured single longitudinal road profile. Firstly, the profile is smoothed with a moving average of base-length 250 mm. Then, response of a quarter car model, in the form of vertical vibration, is accumulated, which on dividing by the profile length yields IRI. The selection of study areas is carried out according to the network of roads, namely federal roads, state roads and highways. Each road network is divided into 5 study areas making the total observation of roughness data is 15 areas and the distance of each observation is 2 km . A pilot test with total of 30 test points were measured to obtain the required roughness statistics. Private vehicle was used along with Huawei Nova 2i smartphones and commercial windshield mount used to mount device at windshield.

## 3. Results and Discussion

Based on observations at the study site, there were some cracks and damage on the road and by the roadside due to the burden of heavy vehicles such as buses and lorries. In addition, the pavement structure received some daily repetition load, the strength of the road will decrease and damage to the road surface will occur. Road surface defects will affect the roughness index. Figure 3.1 shows some of the damage that occurred along the road.



**Figure 3.1: The surface defects that occurred along the road networks.**

### 3.1 Analysis of Road Network Roughness With Roughness Index

Table 3.1 to Table 3.3 show the average roughness index at three different types of road. The average roughness index were measured at reference speed of 60km/h. From the result, the roughness index (RI) for the federal road below 60km/h were recorded in the range 0.55 to 1.733 and 0.556 to 1.645 for the speed higher than 60km/hr, respectively. In addition, , the roughness index (RI) value for the state road slightly lower for at thr reference speed compared to the federal road. All in all, it can be conclude that the roughness index (RI) of expressway road provide better riding quality to the traffic users.

**Table 3.1: Average IRI Federal Road**

Road Segment	Length (Meter)	Surface Type	Average RI (m/km) Driving Speed	
			<60km/h	>60km/h
Jalan Kuala Kedah (78)	2000	ACW14	1.104	1.249
Jalan Anak Bukit (North) (1)	2000	ACW14	0.744	1.621
Jalan Anak Bukit (South) (1)	2000	ACW14	1.352	1.115
Jalan Langgar (175)	2000	ACW14	0.550	0.556
Jalan Kangar-Alor Setar (7)	2000	ACW14	1.733	1.645

**Table 3.2: Average IRI State Road**

Road Segment	Length (Meter)	Surface Type	Average RI (m/km) Driving Speed	
			<60km/h	>60km/h
Jalan Pendang-Tanah Merah (K128)	2000	ACW14	0.599	0.675
Jalan Datuk Kumbang (K135)	2000	ACW14	0.479	0.507
Jalan Alor Mengkudu (K138)	2000	ACW14	0.520	0.538
Jalan Titi Haji Deris (K133)	2000	ACW14	0.521	0.645
Jalan Tualang (K359)	2000	ACW14	0.551	0.572

**Table 3.3: Average IRI Expressway Road**

Road Segment	Length (Meter)	Surface Type	Average RI (m/km) Driving Speed	
			<60km/h	>60km/h
North-South Expressway (km49.3- km47.3) (North Bound) (E1)	2000	ACW20	0.515	0.789
North-South Expressway (km46.7- km44.7) (North Bound) (E1)	2000	ACW20	0.483	0.729
North-South Expressway (km44.2- km42.2) (North Bound) (E1)	2000	ACW20	0.593	0.446
North-South Expressway (km32.1- km34.1) (South Bound) (E1)	2000	ACW20	0.642	0.439
North-South Expressway (km37-km39) (South Bound) (E1)	2000	ACW20	0.629	0.433

### 3.2 Analysis of Road Condition Assessment and Level of Comfort Road Network

The level of comfort road network for the five different site location were evaluate by computing the average IRI values. Table 3.4 to Table 3.6 tabulates an average results of IRI for the federal, state and expressway road segment, respectively. For the federal road segment the IRI were recorded at the range 0.556 to 1.621. For the state road segment the IRI were recorded at the range 0.507 to 0.675 and for expressway road segment were recorded at the range 0.593 to 0.789.

**Table 3.4: Funtional Condition IRI per Federal Road Segment**

Road Segment	Average IRI (Higher)	Road Condition
Jalan Kuala Kedah (78)	1.104	Very Good
Jalan Anak Bukit (North) (1)	1.621	Very Good
Jalan Anak Bukit (South) (1)	1.115	Very Good
Jalan Langgar (175)	0.556	Very Good
Jalan Kangar-Alor Setar (7)	1.733	Very Good

**Table 3.5: Funtional Condition IRI per State Road Segment**

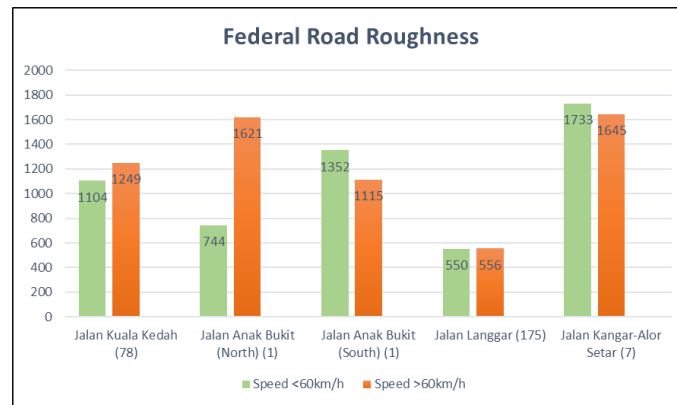
Road Segment	Average IRI (Higher)	Road Condition
Jalan Pendang-Tanah Merah (K128)	0.675	Very Good
Jalan Datuk Kumbar (K135)	0.507	Very Good
Jalan Alor Mengkudu (K138)	0.538	Very Good
Jalan Titi Haji Deris (K133)	0.645	Very Good
Jalan Tualang (K359)	0.572	Very Good

**Table 3.6: Funtional Condition IRI per Expressway Road Segment**

Road Segment	Average IRI (Higher value)	Road Condition
North-South Expressway (km49.3-km47.3) (North Bound) (E1)	0.789	Very Good
North-South Expressway (km46.7-km44.7) (North Bound) (E1)	0.729	Very Good
North-South Expressway (km44.2-km42.2) (North Bound) (E1)	0.593	Very Good
North-South Expressway (km32.1-km34.1) (South Bound) (E1)	0.642	Very Good
North-South Expressway (km37-km39) (South Bound) (E1)	0.629	Very Good

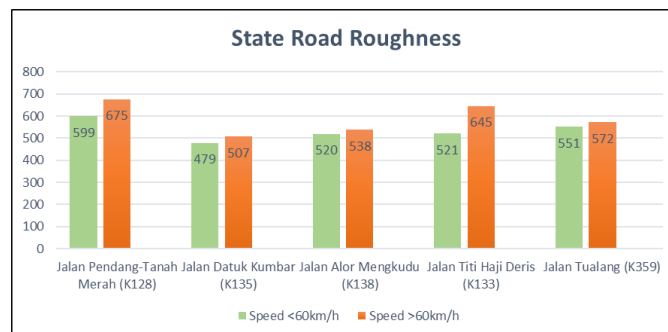
### 3.3 Analysis of Road Network with JKR Specification

The futher analysis of selected road network were carried out in order to evaluate the roughness parameter. Comparative analysis at desired speed 60km/hr were presented in Figure 3.2 to Figure 3.4 strictly followed JKR specification.

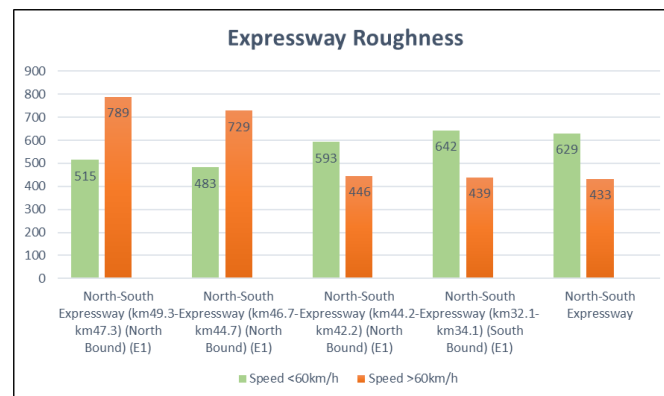


**Figure 3.2: Roughness index result of federal road**

Figure 3.2 shows the roughness index result for federal road with different speed of testing. Based on the result for both speeds at all the road networks, it can be seen that the results obtained show federal roads which uses ACW 14 for surface pavement conforms with JKR specification, which is for federal roads maximum requirement for roughness index is 2.5 m/km for two lane roads.



**Figure 3.3: Roughness index result of state road**



**Figure 3.4: Roughness index result of expresswayroad**

By referring to Figure 3.3 and Figure 3.4, it is shown that state road and expressway which uses ACW14 and ACW20 also conforms with JKR specification, which is maximum requirement for roughness index is 8 m/km for minor roads and 1.6 m/km for four lane roads.

#### 4. Conclusion

The roughness index is therefore important information both for transport agencies, maintenance and rehabilitation planning, and for users and navigation systems, in order to maximize safety and minimize user costs. International roughness index (IRI) is a parameter for evaluating and managing road systems. To achieve the first major objective, tests were performed using the Roadbounce application, with a smartphone Huawei Nova 2i as a device. Tests perform using vehicles, which is Perodua Myvi with commercial windshield mount as a mounting arrangement.

After performing the analysis, it was determined that average roughness index statically similar at both high and lows speed of greater that 60 km/h and lower than 60 km/h for two types of road network, which is state road and expressway. The average roughness index for federal road slightly higher that state road and expressway. In addition, the second objective has been achieved with ASTM E 1926 standard where all the road networks at research location was determined that very good pavement condition and fulfill all the JKR specification. This study has presented an analysis of the performance of the Roadbounce application as a low-cost solution for the road condition surveys. With this low cost and reliable to use any unskilled person to collect the data. Roadbounce appears to be a viable option for measuring the roughness of the pavement. With this application, it would be possible to obtain the most up-to-date roughness values for the road network for maintenance and rehabilitation planning purposes.

There are several recommendations based on the conclusion drawn in this research that would be appropriate for the application Roadbounce. Roadbounce can provide local council-controlled authorities with roughness measurements. The roughness data obtained by Roadbounce can also be used to gage the understanding of vehicle operating costs such as fuel consumption, maintenance costs and tire wear resulting from rough roads. This will show the cost to citizens of road users and help set standards for using road networks. For more accurate data, further research needs to be carried out to make comparison roughness index result using Roadbound and industry standard inertial profiler.

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