Analysis of Vehicle Type for Roadroid Application

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Abstract. Nowadays, the cheapest and most reliable technology method used to measure IRI (International Roughness Index) value is Roadroid which is an Android application developed from a company in Sweden by using a built-in vibration sensor on a smart phone. This smart phone is placed in the vehicle and the vibration of the vehicle will be recorded and analyze and converted to IRI. In Roadroid application, there are four choices of vehicle types namely motorcycle, small car, medium car, four-wheel drive jeep. Since this is aggregate of many types of vehicles, the accuracy of the result will vary for example different country will have different type of vehicles. This research found that medium car has the highest accuracy rate of 99.7% compare compare to small car and motorcycle

Keyword: international roughness index, roadroid

1. Introduction

Road surface conditions influences the continuity of traffic flow. On bad road condition, drivers tend to slow down the speed and may decrease road capacity of the road and increase the risk of traffic congestion. Traffic congestion also imposes direct economic and health costs on users and non-users in the form of wasted time and money, stress and other illnesses. Transport system also make a significant contribution to global warming through emissions of carbon dioxide (CO$_2$) and other greenhouse gases [1]. It is important to assess the road surface conditions by evaluation the existing road conditions [2].

The International Roughness Index (IRI) is one of the parameters of unevenness which is calculated from the cumulative number of rise and fall of the surface in the direction of the elongated profile divided by the distance or surface length measured. The usual recommended units are meters per kilometer (m/km) or millimeters per meter (mm/m) [3]. The IRI value is obtained based on the roughness characteristics using a roughness measurement tool that is classified by the ASTM E 950-94 standard into four groups based on the level of accuracy and the method used in determining IRI shown in (Table 1) [4].
In Indonesia, mostly the local government still in level Class III and Class IV but only few in level I and II for economic reason. One of the disadvantages of class III is too sensitive the vehicle used. In the overwhelming of smartphone era, using this technology to assess the road condition may lower the capital and maintenance cost of the equipment. For Android based smartphones, the Roadroid is a famous application developed in 2012 from a Swedish company and in 2014 won the 2014 IRF Global Road in Technology, Equipment and Manufacturing [5,9], works by using mobile vibration sensor that is placed on a vehicle to collect road surface condition data [6]. There are four choices of vehicle types namely motorcycle, small car, medium car, four-wheel drive jeep [7].

This research will find out the different of IRI from Roadroid between motorcycle, small car and medium car. For road type and surface variations, the road surface divided into asphalt (flexible pavement) and concrete (rigid pavement) and in good and bad condition, respectively. Besides roadroid, the manual method is used to closely view by visual observation along the road. This visual observation is still used by some of Public Work Agency in local government.

| Level | Method | Tools | Advantages | Disadvantages |
|-------|--------|-------|------------|---------------|
| Class I | Laser Scanner Technology | Hawkeye | Very high precision, Inter-point close intervals, Low operational costs | Expensive, cannot work when it rains, cannot go through narrow roads, Long survey time |
| Class II | Complex Profilometer | MERLIN, CHLOE Profilometer, NAASRA | Dynamic, Medium precision | Relatively expensive, Long survey time |
| Class III | Correlation Method | ROMDAS, Roughometer, Bump Integrator, Roadroid, Roadmaster. | Cheap enough, Medium precision, Portable, can be used on non-paved roads, Low maintenance costs, 100 km / day survey capacity | It needs to be calibrated, Sensitive to the influence of the vehicle and GPS |
| Class IV | Visual Observation | - | Easy, Not expensive | Accuracy depends on subjective surveyors, need to convert to IRI values |

Roadroid only calculate IRI value when driving speed vehicle is 20 km/h or faster, some data were not obtained because of the intersection effect, high traffic volume effect and signal effect [5,9,10]. The usual recommended units are meters per kilometer (m/km) or millimeters per meter (mm/m) [11].

The output of IRI value is refers to the texture of the road, and the output of speed value is refers to the real time speed that occurs in a passing vehicle used shown in (Table 2) [5]. For other than Roadroid applications such as Roughometer, the output of IRI value refers to the International Scale Standard use shown in (Table 2) [6].

| Based on International Standard Scale | Based on Roadroid Application |
|-------------------------------------|--------------------------------|
| **IRI Value (m/km)** | **Road Surface Conditions** | **IRI Value (m/km)** | **Road Surface Conditions** | **Colour Indicator** |
| 0 – 4 | Good | 0 – 2,2 | Good | |
| 4,1 – 8 | Medium | 2,2 – 3,8 | Ok | |
| 8,1 – 12 | Lightly Damaged | 3,8 – 5,4 | Not OK | |
| > 12 | Heavily Damaged | > 5,4 | Poor | |

Table 1. Descriptions of Roughness Measurement Tools In Each Class [9]

Table 2. Determination of IRI Value According to Roadroid Application [5,8]
Table 2 show the result of IRI values refers to roadroid application and International Scale Standard. It shows that the road surface condition are the same but the IRI value has a different not so far. The greater the IRI value, the more damaged the surface of the road [5].

Besides roadroid, the manual method is used to closely view by visual observation along the road. This visual observation is still used by some of Public Work Agency in local government. This SDI value is the output of this method and then convert to IRI for the research purposes.

2. Vehicle, Road Type, and IRI Survey

This research will look at the accuracy of 3 of the 4 types of vehicles (as seen in Figure 1), namely motorcycle (Honda Beat 110 cc automatic transmission), small car / business van (Daihatsu Ayla 998 cc manual transmission with ground clearance of 18 cm) and medium car / big sedan (Mitsubishi Xpander Sport 1500 cc automatic transmission with ground clearance 24 cm).

The location of the study was conducted on flexible pavement and rigid pavement. The flexible pavement road was JalanKaliabang Tengah Road, Bekasi City along 1 km with bad and good condition and the rigid pavement was JalanInspeksiKanalTimur Road, North Jakarta City along 1 km with bad and good condition.

It is important to make an interval during the surveys of distances of every 20 m, 50 m, 100 m per length of road 1 km to find out whether the distance interval may affect the IRI value. To determine the SDI value obtained using the RCS (Road Condition System) program. RCS is one part of the IRMS (Integrated Road Management System) application and is one of the parameters used to assess a road condition where the survey is conducted by observation visualization and RCS generates values in SDI units use shown in (Table 3) [8].

| Road Surface Conditions     | SDI Value |
|-----------------------------|-----------|
| Good                        | 0 – 50    |
| Medium                      | 50 – 100  |
| Lightly Damaged             | 100 – 150 |
| Heavily Damaged             | >150      |

To minimize surveyor subjectivity the value from this survey was an aggregate from 3 surveyors, carried out on foot since the length of the road is only 1 km.

3. Results and Discussion

Table 4 to 6 show the one of the result IRI values from roadroid using different types of vehicles with various interval for bad condition of rigid pavement. It shows that the best result is for 50 and 100 m interval due to since this is the poor condition of the road. The other result shown that medium car / big sedan make a good result to show that the road is poor condition.
| Table 4. Comparison of SDI Values and IRI Values Roadroid Based on Interval of Distance 20 m |
|---|
| **Interval Distance of 20 m** |
| Distance (m) | SDI Value Visual Observation | IRI Values Roadroid Application | Medium Car | Small Car | Motorcycle |
|---|---|---|---|---|---|
| 0 – 20 | 75 | 1.4 | 1 | 2.87 |
| 20 – 40 | 115 | 2.5 | 2.22 | 7.32 |
| 40 – 60 | 40 | 2.1 | 3.43 | 6.26 |
| 60 – 80 | 40 | 2.29 | 2.42 | 3.49 |
| 80 – 100 | 80 | 2.41 | 1.51 | 3.03 |
| **Average per 1 km** | **57.60** | **5.39** | **1.77** | **3.81** |
| **Explanation** | Medium | Not Ok | Good | Not Ok |

| Table 5. Comparison of SDI Values and IRI Values Roadroid Based on Interval of Distance 50 m |
|---|
| **Interval Distance of 50 m** |
| Distance (m) | SDI Value Visual Observation | IRI Values Roadroid Application | Medium Car | Small Car | Motorcycle |
|---|---|---|---|---|---|
| 0 – 50 | 115 | 4.53 | 2.19 | 4.62 |
| 50 – 100 | 40 | 4.98 | 2.03 | 3.97 |
| **Average per 1 km** | **68.5** | **6.23** | **1.79** | **3.81** |
| **Explanation** | Medium | Poor | Good | Not Ok |

| Table 6. Comparison of SDI Values and IRI Values Roadroid Based on Interval of Distance 100 m |
|---|
| **Interval Distance of 100 m** |
| Distance (m) | SDI Value Visual Observation | IRI Values Roadroid Application | Medium Car | Small Car | Bi cycle |
|---|---|---|---|---|---|
| 0 – 100 | 115 | 2.19 | 1.93 | 4.12 |
| **Average per 1 km** | **86.5** | **5.42** | **1.75** | **4.84** |
| **Explanation** | Medium | Poor | Good | Not Ok |

**Figure 2. Documentation Per 100 meter**

Each type of vehicle produces an output of IRI values for different each type of road surface damage. That is influenced by the vibration sensitivity setting factor of the roadroid application system during the start calibration of the type of vehicle selection, ground clearance for each type of vehicle, vehicle engine age, vehicle prime condition, driving behaviour.
Table 7. Correlation between IRI Value and SDI Value in Rigid Pavement Bad Condition

| Vehicle    | Regression Type | Interval of Distance |
|------------|-----------------|----------------------|
|            |                 | 20 m | 50 m | 100 m |
|            |                 | $r^2$ | $r^2$ | $r^2$ |
| Medium Car | Linear          | 0.001 | 0.889 | 0.608 |
| Small Car  | Linear          | 0.074 | 0.092 | 0.384 |
| Motorcycle | Linear          | 0.01  | 0.065 | 0.462 |

Table 7 shows that the output interval of 50 meters produces the highest correlation compared to the output interval of 20 meters and 100 meters. This indicates that the author suggests roadroid application users to download data from the rigid pavement bad condition survey at a choice of only 50 meter distance intervals, because the lower the distance interval data, the more wrong data.

A recommendation vehicle for surveying the road surface on a rigid pavement bad condition is using a medium car / big sedan with a correlation of 88.9%.

Table 8. Correlation between IRI Value and SDI Value in Rigid Pavement Good Condition

| Vehicle    | Regression Type | Interval of Distance |
|------------|-----------------|----------------------|
|            |                 | 20 m | 50 m | 100 m |
|            |                 | $r^2$ | $r^2$ | $r^2$ |
| Medium Car | Linear          | 0    | 0.721 | 0.436 |
| Small Car  | Linear          | 0.095 | 0 | 0.001 |
| Motorcycle | Linear          | 0.006 | 0.148 | 0.114 |

Table 8 shows that the output interval of 50 meters produces the highest correlation compared to the output interval of 20 meters and 100 meters. This indicates that the author suggests roadroid application users to download data from the rigid pavement bad condition survey at a choice of only 50 meter distance intervals.

A recommendation vehicle for surveying the road surface on a rigid pavement good condition is using a medium car / big sedan with a correlation of 72.1%.

Table 9. Correlation between IRI Value and SDI Value in Flexible Pavement Bad Condition

| Vehicle    | Regression Type | Interval of Distance |
|------------|-----------------|----------------------|
|            |                 | 20 m | 50 m | 100 m |
|            |                 | $r^2$ | $r^2$ | $r^2$ |
| Medium Car | Linear          | 0.683 | 0.588 | 0.997 |
| Small Car  | Linear          | 0.715 | 0.734 | 0.605 |
| Motorcycle | Linear          | 0.491 | 0.586 | 0.225 |

Table 9 shows that the output interval of 100 meters produces the highest correlation compared to the output interval of 20 meters and 50 meters. This indicates that the author suggests roadroid application users to download data from the flexible pavement bad condition survey at a choice of only 100 meter distance intervals, because the lower the distance interval data, the more wrong data.

A recommendation vehicle for surveying the road surface on a flexible pavement bad condition is using a medium car / big sedan with a correlation of 99.7%.

Table 10. Correlation between IRI Value and SDI Value in Flexible Pavement Good Condition

| Vehicle    | Regression Type | Interval of Distance |
|------------|-----------------|----------------------|
|            |                 | 20 m | 50 m | 100 m |
|            |                 | $r^2$ | $r^2$ | $r^2$ |
| Medium Car | Linear          | 0.001 | 0.009 | 0.995 |
| Small Car  | Linear          | 0    | 0.088 | 0.803 |
| Motorcycle | Linear          | 0.306 | 0.153 | 0.97 |
Table 10 shows that the output interval of 100 meters produces the highest correlation compared to the output interval of 20 meters and 50 meters. This indicates that the author suggests roadroid application users to download data from the flexible pavement good condition survey at a choice of only 100 meter distance intervals, because the lower the distance interval data, the more wrong data. A recommendation vehicle for surveying the road surface on a flexible pavement good condition is using a medium car / big sedan with a correlation of 99.5%.

Based on the results in Tables 7 to 10, medium car / big sedan has the highest accuracy of 99.7% for conducting survey assessments of road surface conditions. Then the authors make a graph in accordance with the regression equation with the highest $r^2$ value for each type of road surface where one of the highest results can be seen in Figure 3 below:

![Figure 3. The Highest Relationship between IRI Value and SDI in Medium Car / Big Sedan](image)

Based on the graph in Figure 3, it produces a positive linear graph, where the higher the IRI value, the higher the SDI value and the more damaged road surface conditions, and vice versa. This study also produces a regression equation that will make it easier for surveyors to no longer need to walk to find SDI values. Only based on the IRI value of the roadroid application output that is placed on the medium car / big sedan (based on the highest $r^2$ value) belonging to the surveyor, then the IRI value is entered into the equation to produce the SDI value. So that finding the SDI value in the future is faster, easier and more efficient.

The best results on each type of road surface for damaged condition is using a medium car / big sedan, because all parts of this car can pass through the damaged condition compared to small car / business van and motorcycle.

In accordance with the RCS method, that SDI assessment is more suitable for flexible pavement. In rigid pavement, SDI and IRI values are strongly influenced by the crack area and crack width. In flexible pavement, SDI and IRI values are strongly influenced by the number of holes and wheel depth.

4. Conclusion and Suggestion

Road surface conditions influences the IRI value and SDI value, these values have a high correlation and statistically significant. The road condition can be affected the continuity of sustainable transportation such as congestion or road safety.

Each type of vehicle produces an output of IRI values on different roadroid applications for each type of road surface damage which is influenced by various factors, one of which is the vibration sensitivity setting factor of the roadroid application system during the start calibration of the type of vehicle selection. The recommended vehicles to survey road surface conditions using the roadroid
application are medium car / big sedan with the highest accuracy rate of 99.7% compared to small car / business van and motorcycles. For further research purposes, it is expected to be carried out on local roads which often have heavy damage on the road surface due to poor maintenance.

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