Correlation of Vehicle Speed to Road Surface Condition Using Roadroid Application

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Abstract. The road condition should provide a decent level of comfort, safety and efficiency for the road users. One of the pavement performance parameters that can be determined objectively is the International Roughness Index (IRI). This research uses a relatively new technology to measure IRI value named the Roadroid, which is an android application developed from a Sweden company. Roadroid uses a built-in vibration sensor on a smart phone which is placed on the vehicle and produces output value in the form of IRI and speed values. Roadroid application obtained output data based IRI value and speed value with high accurately because used real-time data with each vehicle type which get through each road surface condition. 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 IRI and speed value based on the output of the roadroid application have a high correlation of 87.8% on medium car.

Keyword: international roughness index, roadroid

1. Introduction

Roads are considered one of the critical man-made transportation infrastructures [1]. Poor surface conditions may adversely affect the service ability of a road in relation with their position and vehicle size [2]. The condition of road infrastructure should be able to give users a sense of comfort, safety and efficiency [9].

The external factor can be affecting the free flow speed of traffic that the correlation speed [7]. There is a correlation between speed and road surface damage, the higher the level of road damage, the lower the vehicle speed [10,11]. The higher the volume of the vehicle, the higher the level of road damage that occurs [12,15,16].

There is a correlation between traffic loads and road surface damage [14]. 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 [2,4]. IRI was developed by the World Bank in the 1980s [2,3,4]. The IRI
values have a weak correlation to the observed number of accidents [13]. 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) [9].

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

| 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 |

Each class has its own equipment and functions, but with the limited allocation of funds in the regional government, it is necessary to determine the most optimal method of conducting surveys [9]. Class III measurement method is less accurate and precise compared to Class I and II, but the running costs are relatively low [4]. Another option is to use a newly developed that can be used to assess road surface parameter namely the Roadroid application [1,2,3,4,6,9].

The use of Roadroid application is categorized in Class III and it can be an optimal choice with some advantages including cheaper, more accurate data, and easier to operate than other tools [4]. Roadroid is an Android based smartphone application from Sweden and was developed since 2012 by Lars Forslof and in 2014 won the 2014 IRF Global Road in Technology, Equipment and Manufacturing.

Table 2. Determination of IRI Value According to Roadroid Application [5,8]

| 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 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 [8].
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 Jalan Kaliabang Tengah Road, Bekasi City along 1 km with bad and good condition and the rigid pavement was Jalan Inspeksi Kanal Timur Road, North Jakarta City along 1 km with bad and good condition. The survey was conducted at interval 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 and speed value.

3. Results and Discussion

Table 3 to 5 shows the result of IRI values and speed 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 100 m interval due to since this is the poor condition of the road. The other result shown that small car / business van makes a good result to show that the road is poor condition. 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.

| 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 4.** Comparison of SDI Values and IRI Values Roadroid Based on Interval of Distance 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 5.** Comparison of SDI Values and IRI Values Roadroid Based on Interval of Distance 100 m

| Distance (m) | SDI Value Visual Observation | IRI Values Roadroid Application |
|--------------|------------------------------|---------------------------------|
|              |                              | Medium Car | Small Car | Motorcycle |
| 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

**Table 6.** Correlation between IRI Value and SDI Value in Rigid Pavement Bad Condition

| Vehicle     | Regression Type | Interval of Distance |
|-------------|-----------------|----------------------|
|             |                 | 20 m 50 m 100 m      |
|             |                 | r²                  |
| Medium Car  | Linear          | 0.154 0.051 0.878   |
| Small Car   | Linear          | 0.085 0.67 0.761    |
| Motorcycle  | Linear          | 0.035 0.121 0.131   |

Table 6 shows that in the rigid pavement bad condition, 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 rigid pavement survey for bad conditions at the 100-meter distance interval option, because the lower the distance interval data, the more wrong data. Based on the results of the highest r² value, a recommendation vehicle for surveying the road surface on a rigid pavement bad conditions is using a medium car / big sedan with a correlation of 87.8% with speeds ranging from 30-45 km / hour. It can be concluded that the lower the vehicle speed, the higher the IRI value and the more damaged the road surface conditions.
Table 7 shows that in the rigid pavement good condition, 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 rigid pavement survey for bad conditions at the 100-meter distance interval option, because the lower the distance interval data, the more wrong data.

Table 7. Correlation between IRI Value and Speed Value in Rigid Pavement Good Condition

| Vehicle   | Regression Type | Interval of Distance |          |          |          |
|-----------|-----------------|----------------------|----------|----------|----------|
|           |                 | 20 m  | 50 m  | 100 m  |          |          |
|           |                 | r²    | r²    | r²     |          |          |
| Medium Car| Linear          | 0.079 | 0.03  | 0.088  |          |          |
| Small Car | Linear          | 0.771 | 0.821 | 0.846  |          |          |
| Motorcycle| Linear          | 0.012 | 0.022 | 0.088  |          |          |

Based on the results of the highest r² value, a recommendation vehicle for surveying the road surface on a rigid pavement good condition is using a small car/business van with a correlation of 84.6% with speeds ranging from 50 - 65 km/hour. It can be concluded that the higher the vehicle speed, the lower the IRI value and the more damaged the road surface conditions.

Table 8. Correlation between IRI Value and Speed Value in Flexible Pavement Bad Condition

| Vehicle   | Regression Type | Interval of Distance |          |          |          |
|-----------|-----------------|----------------------|----------|----------|----------|
|           |                 | 20 m  | 50 m  | 100 m  |          |          |
|           |                 | r²    | r²    | r²     |          |          |
| Medium Car| Linear          | 0.153 | 0.443 | 0.684  |          |          |
| Small Car | Linear          | 0.286 | 0.395 | 0.564  |          |          |
| Motorcycle| Linear          | 0.01  | 0.07  | 0.37   |          |          |

Table 8 shows that in the flexible pavement bad condition, 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 rigid pavement survey for bad conditions at the 100-meter distance interval option, because the lower the distance interval data, the more wrong data. Based on the results of the highest r² value, 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 68.4% with speeds ranging from 20-30 km/hour. It can be concluded that the lower the vehicle speed, the higher the IRI value and the more damaged the road surface conditions.

Table 9. Correlation between IRI Value and Speed Value in Flexible Pavement Good Condition

| Vehicle   | Regression Type | Interval of Distance |          |          |          |
|-----------|-----------------|----------------------|----------|----------|----------|
|           |                 | 20 m  | 50 m  | 100 m  |          |          |
|           |                 | r²    | r²    | r²     |          |          |
| Medium Car| Linear          | 0.136 | 0.046 | 0.198  |          |          |
| Small Car | Linear          | 0.015 | 0.063 | 0.839  |          |          |
| Motorcycle| Linear          | 0.059 | 0.006 | 0.568  |          |          |

Table 9 shows that in the flexible pavement bad condition, 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 rigid pavement survey for bad conditions at the 100-meter distance interval option, because the lower the distance interval data, the more wrong data.
Based on the results of the highest $r^2$ value, a recommendation vehicle for surveying the road surface on a flexible pavement good condition is to use a small car / business van with a correlation of 83.9% with a speed ranging from 40 - 65 km / hour. It can be concluded that the higher the vehicle speed, the lower the IRI value and the better the road surface conditions. Based on the results in Tables 6 to 9, medium car / big sedan have the highest accuracy of 87.8% for conducting survey assessments of road surface conditions. Then the authors make a graph in accordance with the regression equation with the highest r2 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, the results of the study produce a negative linear graph (in blue) and in accordance with the provisions of the roadroid's negative linear graph (in black). It can be concluded that all types of vehicles are suitable for crossing all types of road surfaces, where the higher the speed of the vehicle, the lower the IRI value and the better the road surface conditions.

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 flexible pavement, the IRI and speed value have strongly influenced by the number of holes and wheel depth. In the rigid pavement, the IRI and speed value have strongly influenced by the crack area and crack width. It can be concluded that the weight value of road surface damage in flexible pavement is greater than rigid pavement.

4. Conclusion and Suggestion

Road surface conditions influences the IRI value and speed value. These values can be obtained used to roadroid application with high accurately because used real-time data with each vehicle type which get through each road surface condition.

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 IRI value and speed based on the output of the roadroid application have a high
correlation of 87.8% on medium car / big sedan. For further research purposes, do a survey in quiet hours to get a vehicle speed > 20 km / hour.

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