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The flatness levels of flexible road based on roadroid software in Perintis Kemerdekaan Street Makassar

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Abstract. This study aims to evaluate working road pavement conditions, the road pavement conditions value based on the International Roughness Index (IRI) method which is used as a basis for knowing the type of road maintenance handling type. For taking IRI, a vehicle that has good performance is used, while IRI value recording uses Roadroid software that has been installed on an Android-based mobile. The data results from this study indicate that the Perintis Kemerdekaan Road produces IRI values of 2.607 and 2.408 for each direction. From this value, it is converted in road stability level which shows that the road is in a steady category so that in general this segment for handling requires regular maintenance periodically to achieve maintaining the service level.

1. Introduction

Road infrastructure that is burdened by high and repeated traffic volumes will cause a decline in road quality. As an indicator, it can be seen from the road surface conditions, both structural and functional conditions that have been damaged. Road damage is caused partly by excessive overloaded traffic, heat/air temperature, water and rain, as well as the initial quality of bad road products. Therefore, in addition to being appropriately planned, the road must be adequately maintained so that it can service traffic growth over the road plan. Routine and periodic road maintenance needs to be done to maintain road safety and comfort for users and maintain durability until the road age planning.

Driver comfort is affected by road surface unevenness level so that it is necessary to check road conditions periodically. Surveys of pavement conditions need to be regularly conducted both structurally and non-structurally to determine the level of road service available. Non-structural (functional) examinations are aimed at checking roughness and slip resistance. The test is intended to define the road surface that is unevenness level value. This measurement is used in maintenance planning or road improvement programs.

One parameter of road conditions that can be used is the IRI (International Roughness Index). The IRI is a road surface flatness which is stated by the number of vertical changes in the road surface for each unit of road length (mm/km). To find out the flatness road surface level can be measured using various methods recommended by Bina Marga and AASHTO [1].

In its implementation, measuring road roughness requires a high cost. Considering the limited allocation of survey funds to public works agencies in the region, as an alternative, an Android-based Road (Roadroid) level measurement application can be used. Applications are a practical choice that has advantages regarding relatively low prices, producing accurate data, and easy to operate. Roadroid is a program developed in Sweden by Lars Forsflof with the prototype that appeared in 2002 and was
developed to date. Therefore, this study tries to compare the value of road surface levelness (IRI) based on the reading range on Roadroid devices which generally use a range of 100 m.

2. Literature review

2.1. Pavement Damage
As a result of repetitive loading, the burden and other factors will decrease the quality of service, which will eventually be damaged. Damage to a road construction can occur due to [2], a) Damage due to poor implementation of initial work, as a result of design errors, inadequate supervision and poor material quality; b) Damage due to usage and time such as surface wear, traffic abrasion, installation of utilities, marking on road surfaces, connection brittle etc.; c) Damage due to particular causes such as accidents, holes and landslides. Road damage can be divided into types of damage, namely structural and functional damage. The second description of the damage is [3], a) Structural Damage is damage to the road structure, in part or in whole, which causes road pavement to no longer be able to support traffic loads. For this reason, it is necessary to strengthen pavement structure by overlaying or repairing existing pavement layer; b) Functional Damage is road surface damage which can disrupt road function. This damage can be related or not with structural damage. In functional damage, road pavement is still able to withstand the workload but does not provide the level of comfort and safety as desired. For this reason, the pavement surface layer must be treated so that the surface returns well. According to the Road Maintenance Manual No: 03/MN/B/1983 issued by the Directorate General of Highways, road damage can be distinguished [4], a) Cracking, namely hair cracking, cracking of alligator cracks, edge cracks, cracks of shoulder joints and edge joint cracks, lane joint cracks, widening cracks, reflection cracks, shrinkage cracks, slippage cracks; b) Distortion, namely grooves (ruts), curly (corrugation), shoving, collapsed (grade depressions), upheaval; c) Disintegration, namely potholes, ravelling, stripping; d) Wearing (polished aggregate); e) Bleeding/flushing; f) Decrease in utility plantations.

2.2. Surface Flatness
The level of road flatness (International Roughness Index, IRI) is one of the factors/service functions (functional performance) of a road pavement that is very influential on the driver's comfort (riding quality). The quality of the existing and planned roads must be following applicable standards and provisions. The main condition of a good road is strong, flat, waterproof, durable and economical throughout the planned life. It is necessary to periodically monitor and evaluate so that the correct construction repair method can be determined.

Measuring the road surface flatness level has not been widely conducted in Indonesia given the constraints of limited equipment so that the flatness requirements in monitoring and evaluation of existing road construction cannot be carried out properly according to national standards in the road sector. To find out the road surface flatness level can be measured using various methods that have been recommended by Bina Marga and AASHTO. The road surface is flatness measurement methods, commonly known are NAASRA methods (SNI 03-34261994). Another technique that can be used for measurement and analysis of flatness of pavement is Straight Edge Rolling, Slope Profilometer (AASTHO Road Test), CHLOE Profilometer, and Roughometer [5].

2.3. Road Conditions
Road conditions are something that needs to be considered in determining road maintenance programs. According to the Department of Public Works of the Directorate General of Highways (1992), road conditions can be classified as follows; a) Roads with good conditions are roads with really flat pavement surfaces, no waves and no surface damage; b) Roads with moderate conditions are roads with flat pavement surface, starting with waves but no surface damage; c) The road with a mildly damaged state is a road with a pavement surface that has begun to wave, starting with surface damage and patching (less than 20% of the road are being reviewed); d) Roads with severely damaged conditions are roads with pavement surfaces that have a lot of damage such as wavy, crocodile cracks, and large enough peeling (20-60% of the road being reviewed) accompanied by damage to the foundation layer such as collapsing.

Maintenance is all types of work needed to maintain and repair the road to remain in good condition or work related to both, thus preventing the decline or deterioration of quality at the rate of rapid change
that occurs as soon as construction is conducted. Assessment of road conditions in this study only uses the IRI (International Roughness Index) method.

2.4. Definition of Road Stability

Road Stability is a condition that needs to be considered to see a condition of road pavement construction. The definition of each term road stability is as follows [6], a) Steady Road Construction is a road with construction conditions in a stable corridor which for handling only requires maintenance activities. The solid road of construction is set according to the Minimum Service Standards, the road is in good and medium condition, where the limit of the IRI < 8 m/km is used in this study; b) Unstable roads are roads with conditions outside the stable corridor which for minimum handling are periodic and maximum maintenance of road improvements with the aim of increasing construction structure value. The concept of road stability level used by the Directorate General of Highways is based on data available from the collection system owned, the parameters used are; a) Road flatness parameters or International Roughness Index (IRI); b) Road width parameters and Volume/Capacity Ratio (VCR); c) Parameter of road width and Daily Traffic Volume (LHR).

2.5 International Roughness Index (IRI)

The International Roughness Index is a parameter used to determine road surfaces unevenness level. Roughness parameters are presented on a scale that illustrates the road pavement surface unevenness felt by the rider as a function of longitudinal and transverse sections of the road surface. Besides these factors, Roughness is also affected by operational parameters of the vehicle, which includes suspension wheels, vehicle shape, vehicle flatness and speed.

In general, road roughness can be defined as the deviation of road surface measured from a flat plane, plus other parameters that can affect the following; vehicle dynamic movement, travel quality, construction dynamic load and drainage of water on the surface. The International Roughness Index (IRI) is used to measure road surface roughness, that is measured at each location is assumed to represent all the physical in that location. Road surface roughness is the name given to the unevenness extending on the road surface. It is measured by the effect scale of the surface of the vehicle moving on it. The scale that is widely used in developing countries such as Indonesia is the International Roughness Index [7].

This flatness road level (IRI) is one of the service functions (functional performance) of a road pavement that is very influential in comfort (riding quality). One technical indicator for assessing road surface performance is the IRI (International Roughness Index) value, which is a measure of size that describes surface unevenness value indicated as the cumulative length of the surface rise and fall per unit length. The road surface flatness is considered as a result of the overall road pavement conditions. If it is relatively flat, then the road is considered good starting from the lower to top level of pavement and vice versa [8]. The IRI value is expressed in meters of up and down per kilometre road length (m/km). If the IRI value is 10 m/km, it means that the number of amplitude (up and down) of the road surface is 10 m in each km of road length. The higher the IRI value, the worse the pavement surface is. The IRI is a roughness measurement standard that refers to the Response-Type Road Roughness Measurement System (RTRRMS).

The road is the surface flatness measurement method known in general is the NAASRA method (SNI 03-3426-1994). Another method that can be used for measurement and analysis of pavement flatness is Straight Edge Rolling, Slope Profilometer/AASHTO Road Test, CHLOE Profilometer, and Rouge meter [5]. According to Saleh, et al. (2008) the determination of minimum road conditions is medium, in Figure 1 it appears the IRI level between 4.0 m/km to 8 m/km depending on the road function. If the IRI shows below 4.0, it means that the road is still in a routine maintenance phase, while if the IRI is between 4.1 and 8.0 which is categorised as being in moderate condition, it means that the road needs periodic maintenance (overlay). While if IRI ranges from 8 to 12, it means that the road needs to be considered for improvement. Meanwhile, if IRI > 12 means the road cannot be maintained, so the step that must be done is reconstruction [9].

The Directorate General of Highways uses the parameters of the International Roughness Index (IRI) in determining the condition of road construction, which is divided into four groups. As shown in table 1: determination of road conditions and handling requirements.
Table 1. Determination of road condition and handling needs.

<table>
<thead>
<tr>
<th>Road Condition</th>
<th>Average of IRI (m/km)</th>
<th>Handling Needs</th>
<th>Steady Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>≤ 4.0</td>
<td>Routine Maintenance</td>
<td>Regular Road</td>
</tr>
<tr>
<td>Moderate</td>
<td>4.1 ≤ IRI ≤ 8.0</td>
<td>Periodic Maintenance</td>
<td></td>
</tr>
<tr>
<td>Minor Damaged</td>
<td>8.1 ≤ IRI ≤ 12.0</td>
<td>Enhancement</td>
<td>Unsteady Road</td>
</tr>
<tr>
<td>Mayor Damaged</td>
<td>&gt;12</td>
<td>Enhancement</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. Relationship between condition, age and type of road handling.

2.6. Roadroid Applications
Roadroid is a network data collection and road conditions application that is easily accessible at any time and use relatively inexpensive equipment with accurate results, especially for the Roadroid emphasizing more on IRI surveys road surface flatness size/conditions expressed by the number of road surface vertical changes for each unit of road length (mm/km). The IRI is a hardness parameter that is calculated from the cumulative number of rising and surface fall of the longitudinal profile divided by the surface distance/length.

Generally, the main problem in the area to conduct road flatness surveys is the limited allocation of survey funds to public works services. The use of the Roadroid application can be a practical choice that has advantages concerning its relatively low price, produces accurate data, and is easy to operate. Roadroid is a program developed in Sweden by Lars Forsflof with the prototype that appeared in 2002 and was developed to date.

3. Methodology
The purpose of this methodology is to explain the procedures for obtaining necessary data both primary data and other data needed, which will then be used in the processing and analysing data to obtain results that are in line with the expected objectives, namely assessing the pavement conditions for measuring inequality road pavement surface.

3.1 Location of Study
The location of the study was conducted on the national road segment in the Province of South Sulawesi, namely on the Perintis Kemerdekaan Road section of Makassar City. This road is a Primary Arterial Road which extends from south to north with a length of ±15 km as seen in figure 2.
3.2 Roadroid Application Settings

The main thing that needs to be prepared for the Roadroid operation is the media device in the form of an Android Mobile that has a higher specification than the Android Operating system at least version 4.4. Each cellphone only gets one username and password to access the website, based on the mobile IMEI number. Besides, a car holder is needed to put the cellphone on the car dashboard. Cars that are used are still in the best performance (usually the age of the vehicle is a maximum of 5 years). Car performance dramatically affects the accuracy of IRI data obtained. The worse the car's performance, the higher the shock/vibration in the vehicle, causing the IRI data to be read larger than it should be. Other equipment needed is a list of road maps to be surveyed and highlighter to mark the roads that have been surveyed so that they are not surveyed more than once. The next stage is the Calibration devices. Calibration steps are by placing the cellphone on the dashboard in a stable position. Refer to Figure 3; (1) click the Roadroid application icon, (2) click ok, (3) click adjustment fitting, then the value X, Y, Z will appear in yellow. Wait until all the values of X, Y, Z are green after that click OK.

The Roadroid application in cellphone needs adjusting the terrain conditions, and vehicle type of vehicle will be used in the survey. Some monitored parameters are; personal e-mail, cellphone type, vehicle type, CIRI sensitivity, length of each CIRI segment, automatic photo taking, the minimum speed of vehicle speed, sleep police button, and mobile orientation, etc. To retrieve data from a road section, the survey starts from the base section and taking data by clicking (Start/stop sampling), then giving the name of the road with an easy and integrated code with other roads. After that, let Roadroid work to end segment. When it reaches the end segment, the data collection is stopped by clicking (Start/Stop Sampling) again. Conditions and documentation of the road segment data have been recorded on devices, and surveyors can start surveys for other sections and so on. When there is an internet signal, this data should be uploaded to the internet immediately given the limited cell phone memory. This
Survey data will then be stored on the Internet and can be checked by going to the address roadroid.com. Moreover, log in with the user and password devices for data retrieval. Data obtained from this survey are: KML File and Shape File that can be generated in map applications such as Google Earth, Google Map etc. Data in the form of files (*.txt) generated for each segment of the road with a segment at least every 20m, 50m, etc. The data contains: (i) time and date of survey; (ii) segment name; (iii) GPS position; (iv) KM/distance; (v) speed; (vi) changes in road vertical alignment; (vii) IRI; and (viii) CIRI. Based on the experience and results of the analysis, it is recommended that e) IRI is used as a reference [10].

4. Results and discussions

The value of road unevenness reviewed is affected by the amount of Roadroid value obtained during the survey, where the greater Roadroid value generated, the higher of road unevenness value (IRI) which will result in more extended and more severely damaged conditions. The factor causes the Roadroid value to increase is the quantity and location of the widespread type of asphalt damage, wherein the absence of serious handling the level of road quality will decrease dramatically due to daily traffic which burdened the national road, which tends to be passed by heavy vehicles, considering Perintis Kemerdekaan road is one of the national highways in Makassar and is a connecting road between provincial capitals that functions in fulfilling the need for goods and services for each region.

4.1 Assessment of Road Conditions

Based on the survey results, the latest conditional value of the Perintis Kemerdekaan Road segment is obtained. Condition values based on the IRI method are set out in the following graphs in Figures 4 (a) and 4 (b).

![Figure 4. The IRI value chart of Perintis Kemerdekaan road.](image)

Based on Figure 4 (a) and 4 (b) it is known that the IRI value of Perintis Kemerdekaan road toward Makassar-Maros has lowest IRI value is 1.52 in STA 1 + 300, and the highest IRI value is 11.56 in STA 4 + 400. The average IRI was obtained at 2.607. While on the same section but in the opposite direction, namely in the direction of Maros-Makassar, it is known that the highest IRI value occurs in STA 7 + 600 with a value of 7.39 and the lowest value occurs in STA 7 + 800 with an IRI value of 1.60. The
The average IRI for this section is 2,408. The percentage of Perintis Kemerdekaan road segment condition can be presented in figure 5.

Meanwhile, Figure 5 shows that the average surface flatness conditions of the Perintis Kemerdekaan road are in good condition. It can be seen from the percentage of road alignment, namely the direction of Makassar-Maros road grade conditions in the good category reaches 90.65% or equivalent to 9.7 km while in the direction of Maros-Makassar the good category reaches 92.52% or equal to 9.9 km. For the road surface conditions in the medium category in the direction of Makassar-Maros, only 8.41% is higher than in the opposite direction, which is 7.48%. Complete results related to road conditions and road length can be seen in the following Table 2.

<table>
<thead>
<tr>
<th>Direction</th>
<th>Road Length (m)</th>
<th>Kondisi Jalan</th>
<th>Good (m)</th>
<th>Good (%)</th>
<th>Moderate (m)</th>
<th>Moderate (%)</th>
<th>Minor Damaged (m)</th>
<th>Minor Damaged (%)</th>
<th>Major Damaged (m)</th>
<th>Major Damaged (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makassar - Maros</td>
<td>10,700</td>
<td></td>
<td>9,700</td>
<td>90.65</td>
<td>900</td>
<td>8.41</td>
<td>100</td>
<td>0.93</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Maros - Makassar</td>
<td>10,900</td>
<td></td>
<td>9,900</td>
<td>99.00</td>
<td>800</td>
<td>8.00</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

4.2 Assessment of Road Stability

In road stability aspect on Perintis Kemerdekaan road segment is included in the stable category with stability value, reaching 99.07% for Makassar-Maros direction, even for the direction of Maros-Makassar reaching 100%. It means that road works as expected in serving the movement of vehicles both from Makassar City and to Makassar City direction. The description of road stability on Perintis Kemerdekaan road section as shown in Figure 6 and Table 3.

Figure 6. The percentage of road stability condition.
### Table 3. Road stability value

<table>
<thead>
<tr>
<th>DIRECTION</th>
<th>ROAD LENGTH (m)</th>
<th>ROAD STABILITY VALUE</th>
<th>Stability Level</th>
<th>Required Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makassar – Maros</td>
<td>10.700</td>
<td>10.600 90.65</td>
<td>Stable</td>
<td>Routine</td>
</tr>
<tr>
<td>Maros - Makassar</td>
<td>10.700</td>
<td>10.700 100</td>
<td>Stable</td>
<td>Routine</td>
</tr>
</tbody>
</table>

#### 4.3 Required Road Maintenance

The purpose of road maintenance is to maintain a steady road condition following the level of service and its ability when the road is completed and operated until planning age is determined. Starting from this steady-state, road maintenance needs to be conducted routinely and continuously, especially in road construction type that uses flexible pavement systems.

Routine road maintenance is carried out continuously throughout the year and carried out as soon as possible when the damage has not yet spread. Maintenance and repairs are carried out at the mild and local damage stage. It is done in connection with relatively low repair costs, and how to repair them is relatively easy/light. Periodic road maintenance is carried out regularly by also rejuvenating pavement materials and other materials. Besides that, re-leveling of the road surface was carried out. Both routine maintenance and periodic maintenance are not intended to improve the necessary capabilities.

Before deciding on actions related to road maintenance, and assessment of road conditions is needed. One assessment of road conditions is to visually assess road pavement conditions obtained by conducting a field survey using the IRI method obtained by survey using a car and using the Roadroid application. In determining the road handling needs, it is closely related to the IRI value generated from a survey. From the results of surveys and references from the Directorate General of Highways, as illustrated in Table 1, the model of handling needs for the Perintis Kemerdekaan road as shown in table 4.

#### Table 4. Required road maintenance

<table>
<thead>
<tr>
<th>ROAD SEGMENT</th>
<th>AVERAGE OF IRI VALUE</th>
<th>STABILITY LEVEL</th>
<th>REQUIRED MAINTENANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mksr - Maros</td>
<td>2.607</td>
<td>Stable</td>
<td>Routine</td>
</tr>
<tr>
<td>Maros - Mksr</td>
<td>2.408</td>
<td>Stable</td>
<td>Routine</td>
</tr>
</tbody>
</table>

Based on Table 4, it can be seen that using the IRI method and using the Roadroid software gives an average IRI value of 2.607 for the Makassar-Maros road section and for the Maros-Makassar road section the resulting IRI value is 2.408. The results illustrate the level of stability of the road that is included in the stable category. Thus on this road only requires routine maintenance which can be done periodically.

### 5. Conclusion

Based on the results of the data from this study, the following conclusions can be taken; that the *Perintis Kemerdekaan* road produces an IRI value of 2.607 and 2.408 for each direction. From this value, it is converted into the level of road stability, including the road in the stable category, so that in general this segment for handling needs only requires regular maintenance regularly to achieve maintaining the service level.

We want to thank especially to Abrorhanif Paisal and M.Syuiaib who have helped the data collection process and Roadroid data input.

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