Pavement Condition Assessment Using IRI from Roadroid and Surface Distress Index Method on National Road in Sumenep Regency

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Abstract. The pavement condition will decrease due to the influence of traffic and environment, so that the maintenance effort is needed to maintain the road condition during the service period. In order to carry out road maintenance activities right on target, there needs to be a plan based on accurate pavement condition data. Road roughness is the most commonly used condition parameter in evaluating pavement conditions objectively because road roughness data is relatively easy to obtain, well correlated with vehicle operating costs and the most relevant parameter in road functional performance measurement. The Roadroid is an Android-based application that measures road roughness by using vibration sensors on a smartphone so it is possible to get an International Roughness Index (IRI) value as an indicator of pavement conditions more easily and efficiently. Besides based on road roughness, pavement condition evaluation can also be done visually by using Surface Distress Index (SDI) method that uses the total crack area parameters, average crack width, total number of potholes and the average depth of rutting. This study attempts to assess the condition of Jenderal Sudirman-Kalianget road by combining IRI Roadroid value and SDI value which will be used as the basis to determine the required road maintenance. This road segment is one of the national strategic road connecting the center of Sumenep regency with the Kalianget harbor. Based on IRI measurement and SDI calculation, the pavement condition of Jenderal Sudirman-Kalianget road can be described 4.2 kilometers (37.17%) were good and 2.3 kilometers (20.35%) were fair that need routine maintenance. While 2.1 kilometers (18.58%) were bad and 2.7 kilometers (23.89%) were poor that need periodical maintenance and reconstruction.

1. Introduction

Road is one of the important infrastructure in supporting the economic and social activities of the society. Sumenep regency, located at the eastern end of Madura island East Java, has potential in agriculture, fishery, industry and tourism. Seeing these conditions, it is necessary to properly manage the road network so that it is expected to improve the service and welfare of the society.

The pavement condition will decrease due to the influence of traffic and the environment, so that the maintenance effort is needed to maintain the road condition during its service period. In order to carry out maintenance activities right on target, it is necessary to have a plan based on accurate road
condition data [1]. One of the road condition parameters that can be used to determine pavement conditions is road roughness that expressed in the International Roughness Index (IRI) values. The using of roadroid smartphone applications to obtain IRI value can be an alternative for road operators to monitor road conditions more easily, scalable, effective and efficient. Beside based on road roughness, pavement condition evaluation can also be done visually by using the Surface Distress Index (SDI) method.

This study attempts to assess the condition of the Jenderal Sudirman-Kalianget road by combining the IRI value of the Roadroid application with SDI values that will be used as the basis for determining the required road maintenance recommendations. The road is one of the strategic national roads connecting the center of Sumenep regency with the Kalianget harbor.

1.1. Pavement Condition Assessment based on IRI

Pavement condition evaluation should be done regularly to determine existing pavement performance and predict future pavement performance, whether the pavement has fulfilled its three basic functions, which provide efficient service, safety and has a structural capacity to support the traffic load and resistant to environmental impacts [2].

Road roughness is the most commonly used condition parameter in evaluating pavement conditions objectively. Road roughness data is relatively easy to obtain, well correlated with vehicle operating costs and the most relevant condition parameter in the road functional condition assessment in the long term [8].

The international roughness index was developed in 1986 which was the result of the International Road Roughness Experiment held in Brazil in 1980. Since then, IRI has become the standard for measuring road roughness received worldwide [4]. The IRI is expressed as a ratio of the accumulation of standard vertical vehicle movement (mm or inch) to the distance traveled by the vehicle during the measurement (m, km or miles) [10].

Generally, road roughness measuring method are divided into four classes. IE, direct measurement, indirect measurement, IRI estimation based on correlation equations such as response type road roughness measuring system (RTRRMS) and subjective judgments based on the opinion of the assessment group [9]. Measuring road roughness by using vibration sensors on a smartphone such as Roadroid basically includes the type of RTRRMS. Roadroid is an Android-based smart phone application developed by the Swedish National Road Administration can be an alternative to obtaining road roughness data that becomes an indicator of road conditions to grade 2 and grade 3 with easier and less costly [5].

The criteria of pavement conditions based on IRI values on asphalt road surface types are shown in Table 1 [6].

| IRI Value | Pavement Conditions |
|-----------|---------------------|
| IRI < 4   | Good                |
| 4 ≤ IRI ≤ 8 | Fair               |
| 8 ≤ IRI ≤ 12 | Bad                |
| IRI > 12  | Poor                |

1.2. Pavement Condition Assessment Using SDI Method

The SDI method is developed by the Directorate General of Bina Marga in 2011 in a national road condition survey manual that is intended for road managers within the Balai Besar/Balai Pelaksanaan Jalan Nasional to determine pavement conditions and as a basis for determining the type of road maintenance required [3]. In this method, the road condition evaluation is visually done by using the parameters of total crack area, average crack width, number of potholes and depth of vehicle rutting.
The criteria of road conditions based on the SDI value on the asphalt road surface type are shown in Table 2.

**Table 2. The Criteria of Pavement Conditions based on SDI**

| SDI Value | Pavement Conditions |
|-----------|---------------------|
| SDI < 50  | Good                |
| 50 ≤ SDI ≤ 100 | Fair             |
| 100 ≤ SDI ≤ 150 | Bad              |
| SDI ≥ 150 | Poor                |

1.3. Road Maintenance Based on IRI and SDI

Road maintenance activities can be both preventive and reactive in order to limit or delay further damage and repair damage to the road surface. Road maintenance activities consist of routine maintenance, periodic maintenance that can be followed by reconstruction/improvement [6].

The pavement condition is determined based on a combination of the IRI and SDI values obtained, are shown in Table 3 with the road maintenance recommendations are shown in Table 4 [3].

**Table 3. The Pavement Conditions based on IRI and SDI Value**

| IRI Value (m/Km) | SDI Value |
|------------------|-----------|
| <4               | <50       |
| 4-8              | 50-100    |
| 8-12             | 100-150   |
| >12              | >150      |

| IRI Value (m/Km) | SDI Value |
|------------------|-----------|
| <4               | Good      |
| 4-8              | Fair      |
| 8-12             | Bad       |
| >12              | Poor      |

**Table 4. The Road Maintenance Recommendation Based on Pavement Condition**

| IRI Value (m/Km) | SDI Value |
|------------------|-----------|
| <4               | <50       |
| 4-8              | 50-100    |
| 8-12             | 100-150   |
| >12              | >150      |

| IRI Value (m/Km) | SDI Value |
|------------------|-----------|
| <4               | Routine M.|
| 4-8              | Routine M.|
| 8-12             | Periodical M.|
| >12              | Reconstruction |

2. Experimental

The IRI value is obtained by using the Roadroid application on the smartphone mounted on the windshield of a survey vehicle and running it along the road segment that are observed. Prior to the measurement it is necessary to do Rodroid setting by determining the type of vehicle used, the distance measurement IRI, automatic image capture and minimum speed limits of the vehicle.

The observation of pavement conditions was conducted by using video recording along the observed roads. Further assessment is done based on the type and amount of damage (cracks, holes, rutting) that occur every 100 m of road length using the Bina Marga standard. The research was conducted on Jenderal Sudirman-Kalianget national road segment located in the Sumenep regency of East Java province. This road segment is divided into six segments; Jl. Sudirman (500 m), Jl. A. Yani (400 m), Jl. Urip Sumoharjo (1,600 m), Jl. Slamet Riyadi (1,000 m), Jl. Yos Sudarso (3,200 m) and Bts. Kota Sumenep-Kalianget (4,600 m).
3. Result and Discussion

3.1. Pavement Condition Assessment based on IRI

The results can be obtained from IRI measurements per 100 m using Roadroid applications such as longitude, latitude, distance, altitude, grade and IRI values. The examples of IRI survey results and road conditions based on IRI on the Jenderal Sudirman-Kalianget road at Jl. Slamet Riyadi segment (Sta. 2+500-3+500) is summarized in Table 5 and Figure 1.

Table 5. The IRI Survey Result of Slamet Riyadi Segment

| No. | Latitude   | Longitude   | Distance (m) | Altitude (m) | Grade (%) | IRI (m/Km) | Remarks |
|-----|------------|-------------|--------------|--------------|-----------|------------|---------|
| 1   | -7.02053658 | 113.87677225 | 2,600        | 36.09        | 0.95      | 7.03       | Fair    |
| 2   | -7.02115698 | 113.87748518 | 2,700        | 41.52        | 5.43      | 8.18       | Bad     |
| 3   | -7.02177321 | 113.87806690 | 2,800        | 39.75        | -1.77     | 5.20       | Fair    |
| 4   | -7.02245105 | 113.87868161 | 2,900        | 34.52        | -5.23     | 6.47       | Fair    |
| 5   | -7.02314097 | 113.87916247 | 3,000        | 37.86        | 3.34      | 3.97       | Good    |
| 6   | -7.02390731 | 113.87961248 | 3,100        | 39.46        | 1.6       | 6.34       | Fair    |
| 7   | -7.02466185 | 113.88010418 | 3,200        | 36.94        | -2.51     | 7.41       | Fair    |
| 8   | -7.02544359 | 113.88066806 | 3,300        | 35.12        | -1.82     | 7.83       | Fair    |
| 9   | -7.02617907 | 113.88125786 | 3,400        | 31.98        | -3.14     | 2.50       | Good    |
| 10  | -7.02693132 | 113.88171707 | 3,500        | 31.84        | -0.14     | 5.88       | Fair    |

Figure 1. The IRI Roadroid Value of Slamet Riyadi Segment

Based on the table and figure above, it can be seen that the pavement condition of Jl. Slamet Riyadi segment based on IRI values is generally fair. There are several segments with good conditions such as at a distance of 3,000 and 3,400 meters from the starting point of the survey as well as a bad condition at a distance of 2,700 meters from the starting point of the survey. The lowest IRI value is 2.5 m/Km and the highest is 8.18 m/Km.

3.2. Pavement Condition Assessment Using SDI Method

From the results of pavement conditions observation, can be obtained amount for each type of damage that is cracked, potholes and ruts. Furthermore, the amount of damage data is used to calculate the SDI
value and determine the conditions on a road segment. The example of SDI calculation result on Jenderal Sudirman-Kalianget road at Jl. Slamet Riyadi segment (Sta. 2 + 500-3 + 500) is shown in Table 6 and Figure 2.

Table 6. The SDI Survey Result of Slamet Riyadi Segment

| No. | STA₀ | STA₁ | Percent of Cracks | Crack Width Classification | No. of Pothole /Km | Rutting Calculation | SDI₁ | SDI₂ | SDI₃ | SDI | Remarks |
|-----|------|------|------------------|---------------------------|--------------------|-------------------|------|------|------|-----|---------|
| 1   | 2+500| 2+600| 22.50%           | Wide                      | 110                | 0                 | 20   | 40   | 265  | 265 | Poor    |
| 2   | 2+600| 2+700| 11.67%           | Wide                      | 70                 | 0                 | 20   | 40   | 265  | 265 | Poor    |
| 3   | 2+700| 2+800| 10.00%           | Wide                      | 70                 | 10                | 20   | 40   | 265  | 275 | Poor    |
| 4   | 2+800| 2+900| 30.00%           | Wide                      | 60                 | 0                 | 20   | 40   | 265  | 265 | Poor    |
| 5   | 2+900| 3+000| 14.17%           | Wide                      | 60                 | 10                | 20   | 40   | 265  | 275 | Poor    |
| 6   | 3+000| 3+100| 39.17%           | Wide                      | 100                | 10                | 40   | 80   | 305  | 315 | Poor    |
| 7   | 3+100| 3+200| 17.50%           | Wide                      | 50                 | 0                 | 20   | 40   | 115  | 115 | Bad     |
| 8   | 3+200| 3+300| 10.00%           | Med                       | 40                 | 0                 | 20   | 20   | 95   | 95  | Fair    |
| 9   | 3+300| 3+400| 10.00%           | Med                       | 40                 | 0                 | 20   | 20   | 95   | 95  | Fair    |
| 10  | 3+400| 3+500| 26.67%           | Wide                      | 110                | 0                 | 20   | 40   | 265  | 265 | Poor    |

Figure 2. The SDI Value of Slamet Riyadi Segment

Based on the table and picture above, it can be seen that the condition of Jl. Slamet Riyadi segment based on SDI values is generally poor. This is due to the segment there is a lot of damage in the form of potholes that give a significant influence on the SDI value. There are several segment parts with bad conditions such as in STA. 3+100-3+200 and fair conditions at STA. 3+200-3+400. The lowest SDI value is 95 and the highest is 315.

3.3. Road Maintenance Recommendation Based on IRI and SDI

From the previous calculation results, IRI values and SDI values have been obtained, then combined with the results describing the pavement conditions per 100 m (Table 3.) and the type of road maintenance required (Table 4.). The examples of collaboration IRI values and SDI values to
determine pavement conditions and road maintenance recommendations on Jenderal Sudirman-Kalianget road at Jl. Slamet Riyadi segment (STA. 2+500-3+500) is shown in Table 7.

**Table 7. The Pavement Condition and Maintenance Recommendation of Slamet Riyadi Segment**

| No. | STA. | IRI Value | SDI Value | Pavement Condition | Maintenance Recommendation |
|-----|------|-----------|-----------|--------------------|---------------------------|
| 1   | 2+500–2+600 | 7.03   | 265       | Poor               | Reconstruction            |
| 2   | 2+600–2+700 | 8.18   | 265       | Poor               | Reconstruction            |
| 3   | 2+700–2+800 | 5.20   | 275       | Poor               | Reconstruction            |
| 4   | 2+800–2+900 | 6.47   | 265       | Poor               | Reconstruction            |
| 5   | 2+900–3+000 | 3.97   | 275       | Poor               | Reconstruction            |
| 6   | 3+000–3+100 | 6.34   | 315       | Poor               | Reconstruction            |
| 7   | 3+100–3+200 | 7.41   | 115       | Poor               | Periodical M.             |
| 8   | 3+200–3+300 | 7.83   | 95        | Fair               | Routine M.                |
| 9   | 3+300–3+400 | 2.50   | 95        | Fair               | Routine M.                |
| 10  | 3+400–3+500 | 5.88   | 265       | Poor               | Reconstruction            |

From the table above it can be seen that the pavement condition of the Jl. Slamet Riyadi segment generally is poor, which requires reconstruction/improvement. The segment parts with fair and bad condition only need routine maintenance and periodical maintenance.

The using of SDI method in this research combined with the pavement condition assessment based on IRI as has been done by previous researchers [1], aims to determine the pavement condition and road maintenance recommendation more accurately and appropriately. The IRI value as an indicator of the functional pavement condition based on the driving comfort level, while the SDI value is used to determine the level of pavement damage based on visual observation.

4. Conclusion

Roadroid applications can be used as an alternative to obtain IRI values efficiently that can be collaborated with SDI values to determine appropriate maintenance recommendations. Based on the IRI measurement using Roadroid combined with SDI calculation, the condition of the Jenderal Sudirman-Kalianget national road in Sumenep regency along 11.3 kilometers can be described 4.2 kilometers (37.17%) of roads were in good condition and 2.3 kilometers (20.35%) were in fair condition requiring routine maintenance. While the 2.1 kilometers (18.58%) road segment were bad and 2.7 kilometers (23.89%) were poor, requiring periodic maintenance and road improvements.

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