Similarity Check Comparative Study of Performance between International Roughness Index (IRI), Pavement Condition Index (PCI), and Bina Marga Method on Roadways

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Comparative Study of Performance between International Roughness Index (IRI), Pavement Condition Index (PCI), and Bina Marga Method on Roadways

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Pavement Condition Index (PCI); International Roughness Index(IRI); Bina Marga Method; Flexybel Pavement; Road Damage Assessment

Abstract

In this research, a comparative study is conducted between the International Roughness Index (IRI), Pavement Condition Index (PCI), and Bina Marga method on roadways with a flexible pavement structure. The objective is to compare the results of road damage evaluation using these three methods and formulate appropriate treatment programs. The research findings indicate that overall, the IRI method provides an overview of the road surface roughness level. The majority of the analyzed data falls under the "Moderate" category with a value of 7.2. The PCI method measures the physical condition of the road infrastructure, which is categorized as "Fair" with a value of 41.2. On the other hand, the Bina Marga method assesses the type of road maintenance, which is categorized as "Routine Maintenance" with a value of 6.8. Enhancing road maintenance practices is necessary to address minor damages such as small cracks or surface irregularities that affect road user comfort.

1. INTRODUCTION

Roads are important transportation infrastructure for facilitating economic and social activities, as well as for achieving the goal of connecting one place to another for all traffic passing through them (Maulana et al., 2020; Sanjaya et al., 2017; Zulmi et al., 2017). They play a significant role in the development and progress of a region in terms of economy, tourism, and socio-cultural aspects (Husen et al., 2023; Prasetyo et al., 2021; Ramadhan et al., 2020). According to (Bunga et al., 2019; Kamba & Rachman, 2018; Sukirman, 2007), road networks serve as the lifelines of national economy. Therefore, roads become crucial transportation means for advancing the economy and improving the welfare of society. In order to achieve smooth operation of road networks, good road infrastructure is necessary, as approximately 95% of passenger transport and 92% of freight transport in Indonesia rely on roads (Sangle et al., 2021).

Currently, many roads experience deterioration, although they have not reached their planned lifespan (Yunus, Said, & Alifuddin, 2022). Such conditions can disrupt the comfort and endanger road users (Shtayat et al., 2022). The management of highway infrastructure aims to improve traffic safety (Adeli et al., 2021). Road pavement networks require constant maintenance and repairs due to gradual deterioration caused by factors such as aging of pavements due to climate and increased traffic volume (Kulkarni & Miller, 2003; Patrick & Soliman, 2019). Condition surveys of pavements are essential in the pavement management process (Chin et al., 2019). These surveys provide valuable information needed to analyze pavement performance. Additionally, pavement condition surveys are crucial in predicting pavement performance, anticipating maintenance and rehabilitation needs, determining maintenance priorities, and allocating the necessary funding (McQueen & Timm, 2005). Accurate condition assessment using evolving methods or technologies will impact the effectiveness and efficiency of determining the appropriate maintenance types for a road section (Hermawan et al., 2016). Therefore, studies on methods and supporting instruments to assess the existing and evolving road conditions, particularly in Indonesia, are necessary (Samsuri et al., 2019).

According to (Sihombing et al., 2021), one of the important routine activities in road management is road investigation. This investigation involves measuring the performance of road pavements, both in terms of functional and structural damages. However, in Indonesia, performance measurements based on functional damages have not been adequately conducted. This is due to budget limitations for road construction and maintenance. Therefore, the types of functional damages are still under research. Meanwhile, structural damages are important parameters in assessing road performance and serve as references for handling roads during their planned lifespan.

Structural damage on roads occurs when pavements fail or experience damages in one or more of their components, rendering them unable to withstand traffic loads. According to (Yoder & M.W. Witczak, 1975) as cited by Iskakbayev et al. (2017), structural damages are characterized by damages to pavement materials (Iskakbayev et al., 2017). Paterson (1987) as cited by Alinizzi et al. (2017) categorizes structural damages into 3 modes: cracking, disintegration, and deformation (Alinizzi et al., 2017). Bina Marga (2017) divides road damages into cracking, deformation, surface disintegration, polished aggregate, bleeding, and utility cut depression (pekerjaan umum dan perumahan Rakyat, 2017). Since there are various types of road damages, according to Paterson (1987) as cited by Alinizzi et al. (2017), all types of road damages and their repairs (patching) interact and relate to each other, ultimately resulting in unevenness (roughness). Roughness is the consequence of various types of damages, especially potholes and deformations, and is the outcome of a series of mechanisms of different road damage modes (Alinizzi et al., 2017). Depkimpraswil (2001) as cited by Sihombing (2010) defines roughness as the characteristic profile of a road surface traversed by vehicle wheels, affecting driving comfort. Roughness occurs due to the interaction between the road surface profile and vehicles passing over it (Sihombing et al., 2021).

To qualify the measurement results of roughness, the World Bank funded a research team from several countries known as the International Road Roughness Experiment (IRRE). They conducted research to determine the most satisfactory roughness scale. Eventually, the International Roughness Index (IRI) was adopted as the roughness scale according to Sayers et al. (1986) as cited by Huang (2004) (H.Huang Yang, 2004). Over time, IRI was further developed to be associated with comfort or serviceability levels. Examples include the present serviceability rating (PSR) in HDM III in 1987 by the World Bank (Paterson & Attoh-Okine, 1992), the Road Condition Index (RCI) by Bipran, CDO in 1989, PSR for asphalt and concrete roads by Al-Omari and Darter in 1994 (Al-Omari & Darter, 1994), and the present serviceability index (PSI) AASHTO road test asphalt/concrete sections by Hall and Corea in 1999 (Hall & Muñoz, 1999).

In Indonesia, road damages are generally measured using methods such as the Pavement Condition Index (PCI) (Kiehl & Briegleb, 2011), Surface Distress Index (SDI) (Anonymous, 2011), Road Pavement Condition Index (IKP) - Pd-01-2016-B (PUPR, 2016b), International Roughness Index (IRI) (H.Huang Yang, 2004), and Bina Marga road condition assessment method (Direktorat Jenderal Bina Marga, 1990b), (PUPR, 1987). The IRI method is widely used internationally to measure road roughness levels (Makwana & Kumar, 2018). Comparing road damage assessment methods is important because it can provide more comprehensive and accurate information about road conditions. By comparing several methods, a more comprehensive picture of road damage can be obtained, including the types and levels of damage that occur. In addition, comparing methods can also help determine the most appropriate method to use in certain conditions. For example, the IRI method is more suitable for measuring road roughness, while the PCI method is more suitable for assessing damage to road surfaces. Therefore, the use of several assessment methods can help in making better decisions regarding the necessary repairs and maintenance of roads(Yunusov et al., 2019).

When conducting research on road damage assessment methods, it is important to compare different methods to obtain comprehensive and accurate information about road conditions (Ayu et al., 2022). By comparing the IRI, PCI, and Bina Marga methods, researchers aim to identify the most effective method for making informed decisions regarding road repairs and maintenance in Indonesia (Khurshid et al., 2009). The initial hypothesis indicate although the PCI method is more specific in identifying 19 types of road damage, compared to the Bina Marga method which only identifies 6 types of damage, the Bina Marga method is easier and faster to use. However, both methods have relatively similar accuracy. The IRI method only measures road roughness and does not provide information on the types of damage. There are no relevant search results for references to support the statement. However, the statement highlights the importance of the study in creating a deeper understanding and valuable contribution regarding the comparison of IRI, PCI, and Bina Marga methods for national roads in Indonesia. The study aims to provide updates and breakthroughs in the field of road damage evaluation that can be used as a reference for decision-making and the development of better road infrastructure. Despite several studies on road damage evaluation using IRI, PCI, and Bina Marga methods, the number of studies comparing these three methods is still limited, particularly in the context of national roads.

2. LITERATURE REVIEW

2.1. IRI (International Roughness Index) Method

The International Roughness Index (IRI) is a parameter used by the World Bank in the process of assessing road pavement conditions since 1980. IRI is a quantitative value of the unevenness of the road surface, expressed in units of meters ups and downs per kilometer of road length (m/km). The unevenness of the road surface is a picture of the longitudinal profile of the pavement which is an illustration of the comfort of driving on the highway (Umi et al., 2016; Yunus, Said, & Syarkawi, 2022). Currently there are several tools that can be used in IRI data collection, namely *Roughometer* NAASRA (Potter, 1978); Dipstick (Nasution et al., 1998); Rolling – Straight Edge; Merlin (Machine for Evaluating Roughness using Low-cost Instrumentation) (Jagadeesh Babu & Rahul, 2017); Profilographs (Anonymous, 2015); PARVID (Positioning Accurated Roughness with Video) (Sinurat, 2014); and Rouhgometer III (Mahardika et al., 2021). The IRI method is a widely used approach to assess road roughness. This method measures the roughness of the road surface by calculating the International Roughness Index value. The IRI value represents the vertical displacement of a standard measuring vehicle as it traverses the road. A higher IRI value indicates a rougher road surface (ASTM International, 1998).

Table 1. Criteria of Road Conditions Based on the IRI Values in Paved Surface Type

IRI Value	Category of Road Conditions
$IRI \leq 4$	Good
$4 < IRI \leq 8$	Fair
$8 < IRI \leq 12$	Slightly Damage
$IRI > 12$	Heavily Damaged

Source: (ASTM International, 1998)

2.2. PCI (Pavement Condition Index) Method

Pavement Condition Index (PCI) is a pavement condition assessment method developed by the U.S Army Cops of Engineers, expressed in a pavement condition index (Pavement Condition Index, PCI). The use of PCI for the evaluation of airport pavements, roads and parking lots has been widely used in America and has been published as the ASTM D 6433 standard (ASTM International, 1999). there are 19 (nineteen) types of damage to flexible pavement in the PCI method (Shahin, 1994). The PCI method is a standard method for evaluating pavement conditions. This method involves assessing various types of distress, such as cracks, potholes, and wheel path rutting, and assigning a numerical value that represents the overall condition of the pavement. The PCI value ranges from 0 (failed) to 100 (excellent), with higher values indicating better pavement conditions (ASTM International, 2007).

Table 2. Criteria of Road Conditions Based on the PCI Values in Paved Surface Type

PCI Value	Category of Road Conditions
0 - 10	Failed
10 - 25	Very Poor
25 - 40	Poor
40 - 55	Fair
55 - 70	Good
70 - 85	Very Good
85 - 100	Excellent

Source: (Shahin, 1994)

2.3. Bina Marga Method

In Indonesia, Bina Marga is the institution responsible for road infrastructure development (PUPR, 2016a). Bina Marga has developed a road condition assessment method used to measure the level of damages and wear on roads (Taufikkurrahman, 2021). This method involves visual observation of road surface conditions, such as damages, cracks, potholes, and deformations. Based on these observations, roads are classified according to their conditions, which can be used as references for road maintenance planning (Hapsari et al., 2018). The Bina Marga method is an assessment method developed by the Ministry of Public Works and Housing of Indonesia (Bina Marga) to evaluate road conditions. This method considers several factors, including surface distress, surface condition, and structural condition, to assess the overall road condition. The method provides a qualitative assessment of road conditions, categorizing them into various classes such as good, fair, or poor (Taufikkurrahman, 2021).

Table 3. Criteria of Road Conditions Based on the Bina Marga Values in Maintenance Program Type

Bina Marga Value	Category of Road Conditions
0 - 3	Road Improvement
4 - 6	Periodic Maintenance
7	Routine Maintenance

Source: (Direktorat Jenderal Bina Marga, 1990b)

2.4. Comparison of IRI, PCI and Bina Marga methods From Previous Research

From a theoretical perspective, the IRI, Bina Marga, and PCI methods are used for road condition assessment. The IRI method measures road roughness and is used to evaluate the ride quality of a road surface. However, it does not provide information on the types of road damage. The Bina Marga method is specific to Indonesia and identifies 6 types of road damage, including cracks, subsidence, surface roughness, potholes, ruts, and patches. The PCI method is used to evaluate the surface condition of a road and identifies 19 types of road damage, including cracking, rutting, and roughness (Shahin, 1994). These methods are important for making informed decisions regarding road repairs and maintenance.

From a practical perspective, the Bina Marga and PCI methods are used in Indonesia for road condition assessment and are subject to maintenance and procurement of road equipment. The Bina Marga method is easier and faster to use than the PCI method, but identifies fewer types of road damage. The PCI method is more specific in identifying types of road damage, but is more time-consuming to use. These methods are important for identifying road damage and making informed decisions regarding road repairs and maintenance.

Table 4. Comparison Result of IRI, PCI and Bina Marga Methods

Num	Road Damage Identification Methods	Type Survey	Comparison Result			Recommendation
			Bina Marga	PCI	IRI	
1	Bina Marga	Manuals	The Same	It's the same, but Bina Marga is easier and faster to use, while the PCI method is more detailed to use.	Relatively the same	PCI
2	PCI	Manuals	It's the same, but Bina Marga is easier and faster to use, while the PCI method is more detailed to use.	The Same	different	PCI
3	IRI	automatic	Relatively the same	different	The Same	PCI

Interpretation

PCI - IRI : the results of the comparison between the IRI and PCI methods depend on the specific context and purpose of the assessment (Melyar et al., 2021; Pratiwi, 2019). In general, the IRI method focuses more on measuring road surface roughness (Alinizzi et al., 2017; Hermawan et al., 2016; Yunusov et al., 2019), while the PCI method provides a more comprehensive assessment of overall road conditions (Yunus, Said, & Alifuddin, 2022). The IRI inspection is not sufficient to represent the actual field conditions; it is necessary to carry out a subjective functional examination by assessing the road, one of which is the Pavement Condition Index ASTM-D6433-99.001 (ASTM International, 1999). Therefore, the choice of method depends on the specific needs of the road management agency or other stakeholders involved in road maintenance and planning. In addition to differences in the rating scale, the IRI values obtained tend to be less close to field conditions. This is because the IRI value is derived from the magnitude of the ups and downs of the roughness sensor mounted on the axle of the survey vehicle, causing the sensor to only read the road surface through the car wheels (Hasibuan, 2019; Suwandi, 2016) besides that the PCI method is very dependent on the skills and subjectivity of the surveyor (Prasetyo et al., 2021). although the PCI method has been widely applied in several countries because it has many advantages. However, to carry out this examination requires a lot of money (Psalmen Hasibuan & Sejahtera Surbakti, 2019). there are differences in functional conditions between PCI and IRI but each shows a good correlation (Adeli et al., 2021).

PCI - Bina Marga : the results of a comparison between the PCI and Bina Marga methods turned out to produce relatively similar ratings (Faisal, 2020; Isradi et al., 2020; Salsabilla et al., 2020) but the Bina Marga method is easier and used quickly (Maulana et al., 2020), while the PCI method is more detailed and objective regarding all aspects of the damage (Faisal et al., 2021; Ramadhan et al., 2020). So it is recommended to use a maintenance program based on the results of the PCI method (Ayu et al., 2022).

IRI - Bina Marga : the results of a comparison between the IRI and Bina Marga methods yield relatively the same assessment (Zulmi et al., 2017).

2.5. Types Of Damage To Asphalt Roads Along With Their Causes

Types of damage to asphalt roads can be distinguished based on the type of pavement, namely flexible and rigid. The following are the types of damage to asphalt roads along with their causes:

1. Cracks, such as alligator cracks, edge cracks, shoulder joint cracks, reflection cracks, and shrinkage cracks. The causes include heavy vehicle traffic, differences in settlement between the shoulder and pavement structure, and vertical/horizontal movement under an additional layer.(Anonymous, 2023)
2. Distortion, such as shoving and transverse/vertical waves due to plastic deformation. The causes are heavy vehicle loads and an unstable pavement or foundation layer.(Anonymous, n.d.)
3. Surface defects (disintegration), such as polished aggregate and corrugation. The causes include heavy traffic, too fine asphalt, and too much fine aggregate.(Anonymous, 2017)
4. Bleeding, which is damage that occurs when high temperatures cause the asphalt to become soft and form a hump due to passing vehicles.(Anonymous, 2017)
5. Potholes, which are bowl-shaped road damage that vary in size from small to large. The causes include a non-functioning water absorption system or lack of drainage on the road, poor quality hotmix asphalt, and excess vehicle load.(Anonymous, n.d.)
6. Stripping, which is road damage that occurs on the surface of the road due to water or moisture entering the pavement layer.(Anonymous, n.d.)

3. METHODOLOGY

3.1. Location of Study

This study was conducted on the national road section of SP. Jambula - SP. Dufa-Dufa (from Jambula intersection to Dufa-Dufa intersection) in Ternate City, North Maluku Province, Indonesia. The location was chosen for research because the SP Jambula - SP Dufa road section is the longest national road in Ternate city, as seen in Figure 1, and it surrounds the city of Ternate, making it an important land transportation area in the city. This makes it a desirable location for identifying and analyzing road damage conditions.

This location was chosen to analyze the road deterioration of the longest road in Ternate City, North Maluku Province, Indonesia, with a length of 28.4 kilometers. The study focused on a road segment from STA 00+00 to STA 00+2000, which is equivalent to a length of 2 kilometers. Direct observation methods were used for data collection, including manual traffic counting, recording travel times, and measuring road geometry.

Figure 1. Test Site: Sp.Jambula – Sp.Dufa-Dufa Road, Ternate, North Maluku, Indonesia

The objective of this study is to gather data on road deterioration and traffic flow, which includes four types of vehicles: light vehicles, heavy vehicles, motorcycles, and non-motorized vehicles. Data were obtained directly through field observations and measurements. The observed road section has a 2/4D divided lane configuration. The observations were conducted in this road section because it is a busy and important area for land transportation in Ternate City, North Maluku Province, Indonesia.

3.1. Data Geometric

Primary data was obtained directly from surveys of geometric road conditions. This data includes road width, number of lanes, lane width, road shoulder width, and road type. Where the observed location is at the point of the road, namely the national road section of SP. Jambula - SP. Dufa-Dufa. The following is a description of the geometric conditions of the road (Table 5).

Table 5. Road Geometric Characteristics

Road Characteristics	Observation (Existing)
Road Type	Four-lane Split or Two-way Street
Type of Road Pavement	Asphalt
Road Lane Width	7 meters
Road Length	28.8 kilometers
Road Shoulder Width	1 meter

The data obtained from field observations will be processed and analyzed to generate valuable information regarding road damage from STA 00+000 to STA 00+2000 (twenty samples). The data from this research can assist decision-makers in road repair methods in Ternate City. Road maintenance needs to be improved to address minor damages such as small cracks or surface defects that affect road users' comfort.

3.2. Data Analysis

3.2.1. Research Procedure

The research planning phase involves setting the objective of the study, which is to assess road conditions and determine the extent of damage. Additionally, it includes selecting the specific road to be evaluated and gathering important information such as road length, width, and pavement layer type. It is crucial to ensure that the necessary equipment and instruments, such as an IRI measuring device, a camera for documenting road conditions, and historical road data, are readily available.

Next, the data collection phase begins with a visual survey to identify various types of road damage, including cracks, potholes, and deformations. The roughness of the road surface is measured using an IRI measuring device. To support the analysis, photographs or videos are taken to provide visual references.

The analysis phase involves employing the PCI method. This entails calculating the PCI index by combining the road damage scores based on established criteria within the PCI method. The PCI value is then determined using appropriate formulas or software, and the results are interpreted to evaluate the overall condition of the road pavement.

Similarly, the IRI method is utilized in the analysis stage. The data acquired from the IRI measuring device is used to calculate the IRI value using relevant formulas or software. The IRI value is then interpreted to assess the level of road surface roughness, and a comparison is made with standards outlined in guidelines or specifications to categorize the road's roughness.

Furthermore, the analysis incorporates the Bina Marga guidelines. These guidelines are reviewed to identify the specific types of road damage present. The evaluation of road conditions and determination of appropriate repair actions are based on the provided criteria within the guidelines. Adjustments may be made according to observed road conditions, and the necessary steps are determined in accordance with the guidelines.

Following the analysis, evaluation, and recommendation phase, the findings are assessed using the PCI, IRI, and Bina Marga guidelines to identify significant road damage that requires urgent repairs. Repair recommendations are formulated based on the analysis results and relevant guidelines. The final step involves presenting the comprehensive research report, including the analysis findings and recommendations, in written form.

In the implementation and follow-up stage, the research report is delivered to relevant parties, such as BP2JN Kota Ternate, the road management authority. Based on the repair recommendations, a budget is planned and allocated for the necessary repair actions. Ongoing monitoring and evaluation of the road repair implementation are conducted to ensure compliance with the recommendations.

3.2.2. IRI (International Roughness Index) Method

The results obtained from the pavement condition assessment on the Sp. Jambula-Sp Dufa road section, STA 00+00-2+00, using the International Roughness Index method, obtained from the PPK 2.4 North Maluku National Road Implementing Agency, can be seen in the following Table 12.

3.2.3. PCI (Pavement Condition Index) Method

Procedure for Pavement Condition Index (PCI) Method Data Analysis :

1. Determining the PCI (Pavement Condition Index) or road damage level based on damage parameters. To obtain the PCI value, the following formulas can be used:

   a. Density $= \frac{\mathrm{Ad}}{\mathrm{As}} \times 100\%$ (1)

      Or

      Density $= \frac{\mathrm{Ld}}{\mathrm{As}} \times 100\%$ (2)

      For the type of distress "potholes," the density can be calculated using the following formula:

      Density $= \frac{\mathrm{n}}{\mathrm{As}} \times 100\%$ (3)

      Where:

      Ad: Total area of each distress level (m²)

      As: Total area of the road segment (m²)

      Ld: Total length of each distress level (m)

      n : Number of potholes for each distress level This formula is used to determine the density of damage on the road surface.

   b. PCIs = 100 – CDV (4)

      Where: PCIs: PCI for each sample unit or research unit, CDV: Corrected Deduct Value for each sample unit.

      This formula is used to calculate the deduction value or CDV (Condition Deduct Value), which is obtained from the curve relationship between the total deduction value (TDV) and the deduction value (DV) by selecting the appropriate curve.

   c. The deduction value represents the influence of each damage on the pavement condition or performance.

2. The PCI value is based on the results of manual condition surveys. The PCI value can be calculated manually, and it is based on the deduction value (DV), which ranges from 0 to 100.

3. The CDV value is obtained from the curve relationship between the TDV value and the CDV value. Therefore, the PCI value for each unit can be determined using the formula: PCI = 100 - CDV. The CDV value can be obtained after obtaining the damage values from the survey results.

4. The calculation of the overall PCI value for a road segment can be determined using the following equation:

   $\mathrm{PCIr} = \Sigma \frac{\mathrm{PCIs}}{n}$ (5)

Where:

PCIr: The average PCI Value of All Study Areas, Σ(PCIs): Sum of all individual PCIs for each sample unit, n: number of sample unit

3.2.4. Bina Marga Method

Procedure for Bina Marga Method Data Analysis :

1. Determine the road type and road class.
2. Calculate Load-carrying Capacity Reduction for the surveyed road and determine the road class using Table 1.
3. Tabulate the survey results and group the data according to the type of damage.
4. Calculate parameters for each type of damage and assess each type of damage based on Table 2.
5. Sum up the values for all types of damage and determine the road condition rating based on Table 3.
6. Calculate the priority value for road condition using the equation Priority Value

BM = 17 - (LHR Class + Road Condition Value) (6)

Table 6. Load-carrying Capacity Reduction and Road classification value/road class rating

Load-carrying Capacity Reduction (Smp/Day)	Road Class Value
< 20	0
20 – 50	1
50 – 200	2
200 – 500	3
500 – 2000	4
2000 – 5000	5
5000 – 20000	6
20000 – 50000	7
> 50000	8

Source: (Direktorat Jenderal Bina Marga, 1990a)

Table 7. Load-carrying Capacity Reduction and Road classification value/road class rating

Type Of Cracks		Patch and Potholes	
Type Crack	Score	Area	Score
Alligator	5	> 30%	3
Random	4	20 – 30%	2
Across	3	10 -20%	1
Lengthwise	2	<10%	0
Nothing	1	Surface Roughness	
Crack Width		Type	Score
Indicator	Score	Desintegration	4
> 2 mm	3	Aggregate loss	3
1 – 2 mm	2	Rough (Hungry)	2
< 1 mm	1	Fatty	1
Nothing	0	Close Texture	0
Crack Quantity		Rutting	
Area	Score	Depth	Score
> 30%	3	> 5/100 m	4
10 – 30%	2	2 – 5/100 m	2
< 10%	1	0 – 2/100 m	1
Nothing	0	Nothing	0
Crack In The Form Of Ruts			
Depth	Score		
> 20 mm	7		
11 – 20 mm	5		
6 – 10 mm	3		
0 – 5 mm	1		
Nothing	0		

Source: (Direktorat Jenderal Bina Marga, 1990a)

Table 8. Determination Of Road Condition Value Based on Total Damage

Total Damage Score	Road Condition Value
26 – 29	0
22 – 25	1
19 – 21	2
16 – 18	3
13 – 15	4
10 – 12	5
7 – 9	6
4 – 6	7
0 – 3	8

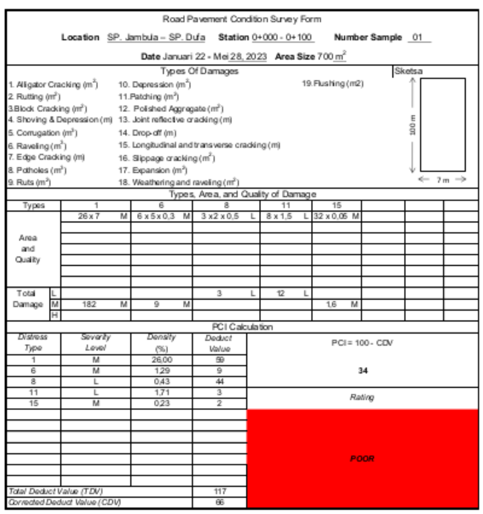
Source: (Direktorat Jenderal Bina Marga, 1990a)

4. RESULT AND DISCUSSION

4.1. Data Survey

4.1.1. PCI (Pavement Condition Index) Survey

The field data includes the type of damage, severity of damage, and quantity of damage, which are used to determine the PCI value that provides an assessment of the road pavement condition. The research data for determining the PCI value was collected on the road section from Sp. Jambula to Sp. Dufa (km 0 to km 2), consisting of 10 samples/segments, with each segment covering an area of 700 m^2. The field research results include data on flexible pavement damage for each sample/segment, measured in meters (m) and square meters (m^2), for each type of damage. The following is a sample data obtained in the field, as shown in Figure 2.


Road Pavement Condition Survey Form

Location SP. Jambula – SP. Dufa **Station** 0+000 - 0+100 **Number Sample** 01

Date Januari 22 - Mei 28, 2023 **Area Size** 700 m^2

Types Of Damages

1. Alligator Cracking (m^2)
2. Rutting (m^2)
3. Block Cracking (m^2)
4. Shoving & Depression (m)
5. Corrugation (m^2)
6. Raveling (m^2)
7. Edge Cracking (m)
8. Potholes (m^2)
9. Ruts (m^2)
10. Depression (m^2)
11. Patching (m^2)
12. Polished Aggregate (m^2)
13. Joint reflective cracking (m)
14. Drop-off (m)
15. Longitudinal and transverse cracking (m)
16. Slippage cracking (m^2)
17. Expansion (m^2)
18. Weathering and raveling (m^2)
19. Flushing (m2)

Sketsa

100 m

7 m

Types, Area, and Quality of Damage

Types		1	6	8	11	15			
Area and Quality		26 x 7 M	6 x 5 x 0,3 M	3 x2 x 0,5 L	8 x 1,5 L	32 x 0,05 M			
Total Damage	L			3 L	12 L				
	M	182 M	9 M			1,6 M			
	H								

PCI Calculation

Distress Type	*Severity Level*	*Density (%)*	*Deduct Value*
1	M	26,00	59
6	M	1,29	9
8	L	0,43	44
11	L	1,71	3
15	M	0,23	2
Total Deduct Value (TDV)			117
Corrected Deduct Value (CDV)			66

PCI = 100 - CDV

34

Rating

POOR

Figure 2. Form Survey PCI : Sp.Jambula – Sp.Dufa-Dufa Road, Ternate, North Maluku, Indonesia

4.2.2. Bina Marga Survey

From the field research results, the data on flexible pavement damage for each sample/segment is provided in meters (m) and square meters (m^2) as the measurement units for each type of damage. The following is a sample data obtained in the field, as shown in Figure 3.

DETERMINATION OF SCORES FOR CRACK QUANTITY FORM							
Number	Stasioner (m)	Width (m)	Length (m)	< 10%	10 – 30%	> 30%	Total
1	0 + 000 – 0 + 100	7	100	1	2		3
2	0 + 100 – 0 + 200	7	100	1	-	3	4
3	0 + 200 – 0 + 300	7	100	1	-	-	1
4	0 + 300 – 0 + 400	7	100	-	2	-	2
5	0 + 400 – 0 + 500	7	100	-	-	3	3
6	0 + 500 – 0 + 600	7	100	1	-	-	1
7	0 + 600 – 0 + 700	7	100	1	-	-	1
8	0 + 700 – 0 + 800	7	100	1	-	-	1
9	0 + 800 – 0 + 900	7	100	-	2	-	2
10	0 + 900 – 1 + 0	7	100	-	2	-	2
11	1 + 0 – 1 + 100	7	100	-	-	-	0
12	1 + 100 – 1 + 200	7	100	1	-	-	1
13	1 + 200 – 1 + 300	7	100	-	-	-	0
14	1 + 300 – 1 + 400	7	100	-	-	-	0
15	1 + 400 – 1 + 500	7	100	1	-	-	1
16	1 + 500 – 1 + 600	7	100	-	-	-	0
17	1 + 600 – 1 + 700	7	100	-	-	-	0
18	1 + 700 – 1 + 800	7	100	-	-	-	0
19	1 + 800 – 1 + 900	7	100	-	-	-	0
20	1 + 900 – 2 + 000	7	100	-	-	-	0

Figure 3. Form Survey PCI : Sp.Jambula – Sp.Dufa-Dufa Road, Ternate, North Maluku, Indonesia

4.2.3. IRI (International Roughness Index) Survey

The survey results for the pavement condition on the road section Sp. Jambula-Sp Dufa STA 00+00-2+00 obtained from the Regional Road Implementing Agency (PPK) 2.4 North Maluku National Road can be seen in Figure 4.

STA (Km)	Kode	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1,0
Condition	L2										
IRI/Score	L2										
Condition	L1	RR	RR	RR	RB	RR	B	B	B	S	S
IRI/Score	L1	8,2	10,1	8,2	12,1	10,4	3,5	2,0	3,8	6,4	4,9
Condition Lane N	LN	RR	RR	RR	RB	RR	B	B	B	S	S
IRI/Score Lane N	LN	8,2	10,1	8,2	12,1	10,4	3,5	2,0	3,8	6,4	4,9
Condition	R1	RR	RR	RR	RB	RR	B	B	B	S	S
IRI/Score	R1	8,4	10,1	8,2	12,1	10,4	4,0	1,2	3,8	5,8	7,0
Condition	R2										
IRI/Score	R2										
Condition Lane O	LO	RR	RR	S	RR	RR	B	B	B	S	S
IRI/Score Lane O	LO	8,4	10,1	7,8	10,4	10,4	4,0	1,2	3,8	5,8	7,0
Condition CL	CL	RR	RR	RR	RR	RR	B	B	B	S	S
IRI/Score CL	CL	8,3	10,1	8,1	11,7	10,4	3,8	1,6	3,8	6,1	6,0
Lane Type		2/2UD	2/2UD	2/2UD	2/2UD	2/2UD	2/2UD	2/2UD	2/2UD	2/2UD	2/2UD
Surface		9-AC	9-AC	9-AC	9-AC	9-AC	9-AC	9-AC	9-AC	9-AC	9-AC
Road Width		7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0
STA (Km)	Kode	1,1	1,2	1,3	1,4	1,5	1,6	1,7	1,8	1,9	2,0
Condition	L2										
IRI/Score	L2										
Condition	L1	RR	S	RR	B	S	RR	RR	RR	RR	RR
IRI/Score	L1	10,2	6,3	8,1	3,7	6,7	8,4	8,5	8,6	9,8	10,0
Condition Lane N	LN	RR	S	RR	B	S	RR	RR	RR	RR	RR
IRI/Score Lane N	LN	10,2	6,3	8,1	3,7	6,7	8,4	8,5	8,6	9,8	10,0
Condition	R1	S	S	S	B	S	RR	RR	RR	RR	RR
IRI/Score	R1	5,9	5,7	5,4	3,7	4,8	8,4	8,5	8,6	9,2	10,0
Condition	R2										
IRI/Score	R2										
Condition Lane O	LO	S	S	S	B	S	RR	S	RR	S	RR
IRI/Score Lane O	LO	5,9	5,7	5,4	4,0	4,8	8,3	6,3	8,6	6,2	10,0
Condition CL	CL	RR	S	S	B	S	RR	RR	RR	RR	RR
IRI/Score CL	CL	8,1	6,0	6,8	3,8	5,8	8,4	8,0	8,6	8,8	10,0
Lane Type		2/2UD	2/2UD	2/2UD	2/2UD	2/2UD	2/2UD	2/2UD	2/2UD	2/2UD	2/2UD
Surface		9-AC	9-AC	9-AC	9-AC	9-AC	9-AC	9-AC	9-AC	9-AC	9-AC
Road Width		7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0

Figure 4. Form Survey IRI : Sp.Jambula – Sp.Dufa-Dufa Road, Ternate, North Maluku, Indonesia

4.2. Analysis Data

4.2.1. Result Data Analysis Using The Pavement Condition Index (PCI)

The determination of the most dominant type of damage on the pavement surface of the Sp.Jambula - Sp.Dufa road section in Ternate City, STA 0+00-2+00, can be seen in table 9, and the average PCI values can be seen in the following table 10.

TABLE 9. Summary Of Damage Level Values For Each Type Of Damage

Number/Damaged Type	Volume of Damage	persentase	Damaged Point
	m^2	%	
1. Alligator Cracking (m^2)	1393	27,66	7
5. Corrugation (m^3)	292,6	5,81	5
6. Raveling (m^3)	111,45	2,21	5
8. Potholes (m^3)	15	0,30	5
10. Depression (m^2)	119	2,36	2
11.Patching (m^2)	42	0,83	2
15. Longitudinal and transverse cracking (m)	24,2	0,48	7
18. Weathering and raveling (m^2)	3038	60,33	11
	5035,25	100,00	44

Table 10. Summary Of PCI Category

No	Stasioner (m)	CDV	Nilai PCI	Ratting Condition
1	0+000 - 0+100	66	34	POOR
2	0+100 - 0+200	84	16	VERY POOR
3	0+200 - 0+300	64	36	POOR
4	0+300 - 0+400	90	10	FAILED
5	0+400 - 0+500	83	17	VERY POOR
6	0+500 - 0+600	35	65	GOOD
7	0+600 - 0+700	12	88	EXCELLENT
8	0+700 - 0+800	28	72	VERY GOOD
9	0+800 - 0+900	55	45	FAIR
10	0+900 - 1+000	56	44	FAIR
11	1+000 - 1+100	72	28	POOR
12	1+100 - 1+200	47	53	GOOD
13	1+200 - 1+300	60	40	FAIR
14	1+300 - 1+400	41	59	GOOD
15	1+400 - 1+500	45	55	FAIR
16	1+500 - 1+600	65	35	POOR
17	1+600 - 1+700	62	38	POOR
18	1+700 - 1+800	61	39	POOR
19	1+800 - 1+900	74	26	POOR
20	1+900 - 2+000	76	24	VERY POOR
		AVERAGE	41.2	FAIR

The average PCI value for the pavement condition of the Sp.Jambula - Sp.Dufa road section (km 0 to km 2) is 41.2, based on the severity level and size of the damage in determining the Pavement Condition Index (PCI) and the Standard Rating Scale explained in table 2 of the Sp.Jambula - Sp.Dufa road section in Ternate City at STA 00+000-02+000. The condition is categorized as Fair, indicating the need for periodic maintenance on the road.

4.2.2. Result Data Analysis Using The Bina Marga Method

In the guideline book of the Directorate General of Highways No. 018/T/BNKT/1990, there are steps provided to determine the road condition value based on the type of damage.

1. Road Class Value
   Based on the average daily traffic data (LHR) obtained from the Public Works, Spatial Planning, and Housing Agency of Ternate City, the LHR for this road section is 33,957 per day. Using Table 6, the road class value is determined to be 7 (20,000 - 50,000).
2. Road Damage Value
   Based on the survey results of the surface layer damage condition on the road, numerical values are assigned for each type of damage. The road section consists of two directions, and the numerical values for road damage are determined based on Table 7. The group of cracks includes various types of cracks, crack width, and crack area. For patching, potholes, and surface roughness, the numerical values are assigned based on the type of damage. In the group of cracks, the highest numerical value is used among the different types of cracks present. For rutting, the numerical value is based on the depth of the rutting that occurs, while for depressions, the numerical value is based on the length of depressions per 100 meters. Once the numerical values are determined for each type of damage, the highest numerical value for each type is selected and summed to obtain the total numerical value representing the road damage condition, as shown in Table 8.
3. Road Condition Value
   The road condition value is determined based on Table 8 for the Sp.Jambula - Sp.Dufa road section at STA 00+00-0+100. If the damage value is 15, then the road condition value is 4. The road condition value for each sample/segment is then used to calculate the road priority value in determining the type of road maintenance program. This allows for prioritization and allocation of resources based on the severity of the road condition to ensure effective road maintenance planning and implementation.
4. Road Priority Value
   The priority value for each sample is calculated using Equation 6, and the priority values for each segment can be seen in Table 11.

Table 11. Summary Of Priority Bina Marga

Stasioner (m)	Total Damage	Bina Marga Value	Maintenance Program Type
0+000 - 0+100	4	6	Periodic Maintenance
0+100 - 0+200	6	4	Periodic Maintenance
0+200 - 0+300	3	7	Routine Maintenance
0+300 - 0+400	4	6	Periodic Maintenance
0+400 - 0+500	5	5	Periodic Maintenance
0+500 - 0+600	3	7	Routine Maintenance
0+600 - 0+700	3	7	Routine Maintenance
0+700 - 0+800	3	7	Routine Maintenance
0+800 - 0+900	5	5	Periodic Maintenance
0+900 - 1+000	5	5	Periodic Maintenance
1+000 - 1+100	2	8	Routine Maintenance
1+100 - 1+200	4	6	Periodic Maintenance
1+200 - 1+300	1	9	Routine Maintenance
1+300 - 1+400	1	9	Routine Maintenance
1+400 - 1+500	4	6	Periodic Maintenance
1+500 - 1+600	2	8	Routine Maintenance
1+600 - 1+700	2	8	Routine Maintenance
1+700 - 1+800	2	8	Routine Maintenance
1+800 - 1+900	2	8	Routine Maintenance
1+900 - 2+000	2	8	Routine Maintenance
		Total 137	Periodic Maintenance
		Average 6,85	

Based on the Bina Marga method, it can be concluded that the average priority value for the Sp.Jambula - Sp.Dufa road section is 6.85. This value is determined based on field survey results and according to Table 3, the recommended program for this road section is Periodic Maintenance. This program involves regular maintenance activities to preserve the condition of the road and ensure its long-term functionality and safety.

4.2.3. Result Data Analysis Using The IRI (International Roughness Index)

Table 12. Summary Of International Roughness Index (IRI)

Stasioner (m)	IRI Average	Ratting Condition
0+000 - 0+100	8.3	Slightly Damage
0+100 - 0+200	10.1	Slightly Damage
0+200 - 0+300	8.1	Slightly Damage
0+300 - 0+400	11.7	Slightly Damage
0+400 - 0+500	10.4	Slightly Damage
0+500 - 0+600	3.8	Good
0+600 - 0+700	1.6	Good
0+700 - 0+800	3.8	Good
0+800 - 0+900	6.1	Fair
0+900 - 1+000	6.0	Fair
1+000 - 1+100	8.1	Slightly Damage
1+100 - 1+200	6.0	Fair
1+200 - 1+300	6.8	Fair
1+300 - 1+400	3.8	Good
1+400 - 1+500	5.8	Fair
1+500 - 1+600	8.4	Slightly Damage
1+600 - 1+700	8.0	Slightly Damage
1+700 - 1+800	8.6	Slightly Damage
1+800 - 1+900	8.8	Slightly Damage
1+900 - 2+000	10.0	Slightly Damage
Average	7.2	Fair

Overall, based on Table 3, it can be concluded that the average International Roughness Index (IRI) value for the pavement condition on the Sp.Jambula - Sp.Dufa road section is 7.2, which can be categorized as fair condition.

4.2.4. Comparison of IRI, PCI and Bina Marga Method

To compare the PCI (Pavement Condition Index) method, the Bina Marga method, and the IRI (International Roughness Index) method, several aspects need to be considered:

1. Assessment Approach: Each method has a different approach in evaluating the road pavement condition. The PCI method uses damage scores based on damage categories and category weights. The Bina Marga method classifies damages based on the type and severity of the damage. The IRI method measures road surface roughness using an international roughness index.
2. Required Data: Each method requires different data for analyzing the road pavement condition. The PCI method requires data on damages in various categories. The Bina Marga method requires data on damages and the type of road pavement. The IRI method requires data on road surface roughness measured using a Roughmeter or similar measuring device.
3. Interpretation of Results: Each method has a different interpretation scale for evaluating the road pavement condition. The interpretation scale may vary depending on the method used and the applicable standards or guidelines. And
4. Advantages and Limitations: Evaluating the advantages and limitations of each method is also important in comparing them. For example, the PCI method can provide more detailed information about road pavement damages, while the IRI method provides information about surface roughness that can affect the comfort of road users.

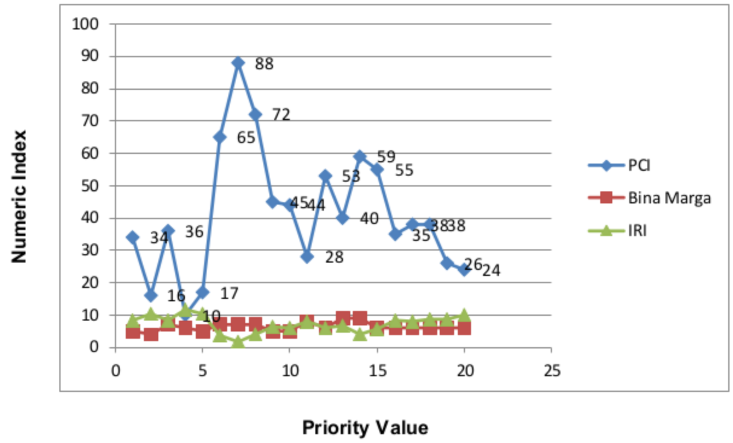


Figure 5. Relationship Graph of PCI, IRI, and Bina Marga Methods : Sp.Jambula – Sp.Dufa-Dufa Road, Ternate, North Maluku, Indonesia

Based on the identification results from Tables 10, 11, and 12, as well as Figure 5 of the three methods, namely IRI, PCI, and the Bina Marga method, several conclusions can be drawn that the road conditions vary from poor to good. From the graph results in Figure 5, it is evident that the Pavement Condition Index (PCI) method shows an inverse assessment pattern compared to the assessment graph of road conditions using the International Roughness Index (IRI) and Bina Marga methods. The International Roughness Index (IRI) provides an indication of the level of road surface roughness. The IRI results show that there are damaged sections of the road, both in the category of light and severe damage. However, the majority indicates that the road section falls into the moderate category. The Pavement Condition Index (PCI) provides an overall assessment of the road surface condition. The PCI values indicate that the majority of the road sections experience poor or fairly poor conditions, although there are some sections that show good or very good conditions. The Bina Marga method provides classification based on the level of road maintenance needs. In this case, the majority of the values require routine maintenance, with some values requiring periodic maintenance and road improvement.

It is important to consider other methods, such as the Bina Marga method and the PCI method, together with the IRI method to get a more complete picture of pavement conditions. For example, in STA 00+00-00+100, the PCI method calculates potholes with a density value of 0.43%, then the Bina Marga method calculates the value 0 because it is not included in the range (10 > 30%). Of course, this is what makes the calculation difference between the analysis of the PCI method and the Highways.

Based on the identification results, although there are variations between the three methods, it can generally be concluded that the road conditions indicate the need for maintenance and improvement. In planning road maintenance, a combination of the three methods can provide a more comprehensive understanding and help in determining the priority of necessary repair actions. This is in line with the theory in sub chapter 2.4 Page 4 that the PCI, IRI, and Bina Marga methods complement each other. The IRI method is more suitable for measuring road surface roughness, while the PCI and Bina Marga methods are more suitable for assessing surface damage. Therefore, using multiple assessment methods can assist in making better decisions related to road repair and maintenance.

Based on research result, it is recommended to use a maintenance program based on the results of the Pavement Condition Index method because the PCI method has a more detailed and objective analysis regarding all aspects of the damage (Faisal et al., 2021; Ramadhan et al., 2020). In line with research (Ayu et al., 2022) Although the PCI method is highly dependent on the skill and subjectivity of the surveyor (Prasetyo et al., 2021) The quality of manual surveys can be improved by not relying solely on human-based manual surveys, but must be improved gradually by using machine-based survey tools that can record road conditions exactly as they are, equipped with location detectors so as to create a continuous reference location (Hapsari et al., 2018) as an example of using the hawkeye 2000 on the jl.ahmad yani section in East Kalimantan in 2021. There are only 4 Hawkeye in Indonesia and specifications most complete, there is only 1 (one) Hawkeye unit owned by the Ministry of Public Works (Setia, 2019) Sensor equipment includes Global Positioning System (GPS) and Differential GPS, Laser Profiler, Auto Crack Detection Profiler, Gipsitrec Geometry, Distance Measurement Instrument, and Asset Cameras. Apart from that, this vehicle is also supported by the Hawkeye Processing Toolkit Software (Samsuri et al., 2019; Surbakti et al., 2021).

5. CONCLUSIONS AND RECOMMENDATIONS

In conclusion, despite the variation in interpretation and classification among the three methods, it can be generally concluded that the road conditions indicate the need for maintenance and improvement. In road maintenance planning, a combination of these three methods can provide a more comprehensive understanding and assist in determining the priority of necessary repair actions. By observing the patterns from the combined results of the road condition categories, it can be seen that the majority of road conditions tend to fall into the "Moderate" category. This pattern indicates that most roads experience a moderate level of damage but require attention in maintenance. Another pattern that can be observed is the presence of some roads classified as "Good". Although the number is not as high as the "Moderate" category, it still shows the existence of roads with relatively good conditions. Meanwhile, there are also some roads categorized as "Lightly Damaged", indicating more significant damage compared to the "Moderate" category. However, no roads fall into the "Severely Damaged" category. In terms of maintenance, the majority of roads require periodic maintenance, with only a few roads requiring routine maintenance. This indicates the need for regular maintenance to keep the road conditions optimal. The recommendation that can be given for further research is to add the SDI method to the method comparison. this needs to be done because the SDI value is influenced by the IRI value. Besides that, you can also add the IKP method and the RCI method.

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