

The Prediction of Road Condition Value during Maintenance Based on Markov Process

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Abstract—The first step in the road handling effort is to survey to get an accurate road condition value to take correct action in implementing maintenance. As pavement performance is known to be probabilistic, various levels of uncertainty must be assumed. Modern pavement management methods are ineffective without an effective model to predict pavement performance. Discrete-time Markov chains are the most widely used probabilistic models, and examples from different countries worldwide can be found in pavement management systems. This research aims to predict the value of road conditions during maintenance and compare road assessments with real conditions during road maintenance using the IRI, SDI, and PCI methods using the Markov process. The analysis method used is to collect secondary data from related departments and carry out direct data collection in the field to obtain condition values based on IRI, SDI, and PCI to forecast by making a pavement condition prediction model based on the Markov process and then assessing road conditions by comparing the three index values with the slightest deviation value. The analysis showed that the average value of road conditions with the IRI indicator is 4.45, which is moderate, and the most negligible difference between the probability distribution of pavement condition prediction modeling and the actual survey results was the IRI (International Roughness Index) method. This model is closest to the actual conditions during implementation, with a difference value of 5.7%.

Keywords—Road condition; international roughness index; surface distress index; pavement condition index; Markov process.

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I. INTRODUCTION

The main objectives of pavement construction are to create a flat surface, a solid structure to support traffic loads, an even distribution of wheel loads across the surface, and non-skid characteristics [1]. Roads are one of the transportation facilities that have many essential functions in daily life, including interacting with the development of work and products between various regions, economies, and communities [2]. It can also improve people's living standards and increase economic growth.

Road conditions must remain optimal to ensure user comfort and protection. About one million people are consistently killed, 3,000,000 people are permanently disabled, and thirty million people are injured in traffic accidents, according to the WHO. By 2020, road accidents will be the third-largest cause of contamination and injury distress. Assessments of the structural and non-structural

aspects of the road need to be conducted regularly. The type of evaluation program that should be performed, such as a repair program, periodic maintenance, or routine maintenance, will then be determined using the road condition rating as a reference [3].

Pavement assessment justifies developing and operating a pavement maintenance implementation expectation model [4]. Recognizing that pavement performance is uncertain, stochastic-based models have been used to estimate future pavement conditions—discrete-time intervals (transitions) in Markov models. The state and transition probabilities used by the Markov model are estimated using pavement performance evaluation findings. Modern pavement management methods are only effective with an effective model to predict pavement performance [5]. Some pavement management systems have used stochastic-based models to develop the optimal long-term pavement maintenance and rehabilitation plan at the network level [6].

The deterioration level of the pavement will be determined using the deterioration parameters, which will be assessed based on low, medium, and high deterioration levels. Sample pavement projects will be subjected to the two assessment methods, and the results will be examined and compared [7]. Previous studies have shown how pavement section length affects the stochastic estimation of significant parameters [8]. State probability and transition probability are representative of these stochastic parameters. One cycle of pavement damage evaluation can be used to estimate the state probability at any given time, but two cycles are required to estimate the transition probability [9].

As pavement performance is known to be probabilistic, various levels of uncertainty must be assumed [10], [11]. Over the past three decades, most authors have created various probability-based models to predict future performance. Discrete-time Markov chains are the most widely used probabilistic models, and examples from different countries around the world can be found in pavement management systems [12], [13], [14]. Further discussion on Markov models is provided.

Three constraints are used for the stochastic process of the Markov prediction model [15]. The process meets the "Markov property," is discrete in time, and has a state space that can be calculated from a finite state space [16]. According to this feature, the future state of the process depends only on the current state and is independent of any previous states in either the past or present [17]. Generally assumed that Markov properties are satisfied in pavement deterioration [18]. The state probability vector, cycle or time step, and transition matrix are the three main components of a Markov process, and they are all correlated with the number of states [19], [20].

To ensure that roads will continue to provide a certain level of service and meet transportation needs, authorities should strive to maintain an excellent quality of road service. Efforts include evaluating and assessing the handling and condition of good roads [21]. The International Roughness Index (IRI) approach as well as direct visual observation in the field by using the Surface Distress Index (SDI) and Pavement Condition Index (PCI), represent both assessment and evaluation methodologies used in road maintenance [22]. This research aims to develop a model that will predict the deterioration of pavement sections to determine which indicator is closest to the actual pavement condition value. The model will be developed based on IRI, SDI, and PCI data and the Markov chain process [23], [24]. To anticipate the road's state during rehabilitation or maintenance, transition probabilities are calculated using a percentage prediction approach to develop a Markov process-based pavement condition prediction model.

II. MATERIALS AND METHODS

The data was collected directly through direct observation by separating the roadways into observation segments. The segment length for flexible pavements is 100 meters, whereas it is 50 meters for rigid pavements. IRI values were collected from secondary data from the Bina Marga agency [25]. This study was conducted in Daan Mogot road (see Fig. 1), a 12-kilometer-long national road stretch in the DKI Jakarta area that uses both flexible and rigid pavement.

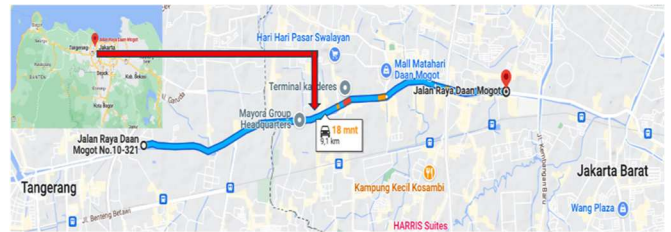


Fig. 1 Research Location

The research planning process necessitates proper and solid analysis, complete and correct data, and developed basic notions [26], [27]. The research findings are given in tables and figures to finish. Field surveys were used to collect data on the types and dimensions of road damage and traffic, road damage, and road geometry data [28], [29].

A. International Roughness Index (IRI)

The International Roughness Index (IRI) is an unevenness metric computed by dividing the total number of surface ups and downs in the direction of the longitudinal profile by the distance or length of the surface being measured. This test aims to determine the homogeneity and flatness of the road surface. The World Bank created IRI theoretically in the 1980s to depict the reaction of a single tire on a vehicle's suspension in determining the flatness of the pavement surface [30]. IRI is a road surface unevenness standard that describes the longitudinal profile of a road. Meters per kilometer (m/km) or millimeters per meter (mm/m) are often used as units [30]. Hawkeye data collection is considered effective when equipment is integrated into a commercial vehicle. Figure 2 shows the equipment used in Hawkeye.



Fig. 2 Hawkeye equipment

The international roughness index (IRI) is also used to assess pavement roughness. Roughness characteristics that affect vehicle response can also be summarized using this index. The level of driving comfort on a road surface is determined by several factors, one of which is the roughness of the road surface. These factors include safety, vehicle vibration, operating speed, operating costs, etc. IRI values have been determined for different pavement ages and speeds. [2], [28]. Vehicles can move at 100 km/h on new roads with uneven surfaces (an IRI of 4 m/km) and 80 km/h on old roads with uneven surfaces (an IRI of 6 m/km). In other words, the IRI value for new routes ranges from 1.75 to 3.5 m/km,

whereas the IRI value for existing pavement ranges from 2.5 to 6.00 m/km [4].

IRI data was obtained from the DKI Jakarta National Road Implementation Center along the observed road sections. The average IRI value was then used for each segment with a distance of every 100 m and a total of 120 observation segments [31]. The data analysis process uses Hawkeye Processing Toolkit software, as can be seen in Figure 3.



Fig. 3 Hawkeye processing toolkit interface application

B. Surface Distress Index

The Surface Distress Index (SDI) measures road performance based on field observations of visible road defects. The average crack width, total area, and other deterioration conditions resulting from the number of potholes per 100 meters of road length, as well as the depth of ruts and furrows, all impact the SDI rating [32]. SDI calculations are carried out by accumulation based on damage to the road. The total width of the pavement is checked for a sample length of 100 meters. The survey is conducted through the entire pavement section by dividing it into 100-meter sample lengths. The extent of the damage is then recorded on a survey sheet, considering the sample size and units depending on the level of damage [33], [34]. Before calculating the percentage of total damage area for each major and minor damage separately, it is necessary first to separate primary and minor damage. The information collected in the field was then used for additional analysis and evaluation of the pavement while considering the SDI. On the Excel sheet, the relevant SDI for each sample unit was calculated [22]. The road condition can be determined from these values as specified in Table 1.

TABLE I
ROAD CONDITION BASED ON SDI

Road Conditions	SDI
Good	<50
Fair	50-100
Poor	100-150
Very Poor	>150

C. Pavement Condition Index

The Pavement Condition Index (PCI) is a rating system considering the pavement condition type and the deterioration level. It can be used to compare repair efforts [35]. A field survey was used to collect PCI data. The value is determined by visually assessing road conditions and detecting different forms of road damage. The procedure followed in this study to calculate the PCI (Pavement Condition Index) value is as

follows: measurement of the amount of each form of damage, its severity, the amount of road damage, the value of its reduction, the value of its total reduction, the reduction of the repaired, then used to determine the value of the condition of the road [36]. As illustrated in Figure 4, this PCI score ranges from 0 to 100, with the criteria of good, satisfactory, fair, poor, very poor, serious, and failed [33].

PCI	Rating	Colour
85-100	Excellent	Dark Green
70-85	Very Good	Light Green
55-70	Good	Yellow
40-55	Fair	Light Red
25-40	Poor	Medium Red
10-25	Very Poor	Dark Red
00-10	Failed	Dark Grey

Fig. 4 Recommended PCI Value, Damage Scale, and Color

Determining the extent and percentage of defects depending on their level and type after the survey is completed [37]. The PCI value is then determined for each road section sample unit.

D. Markov Process

Markov chains are often used to represent different commercial systems and processes. Based on previous changes, it can estimate future changes in dynamic variables. [38] Predicting future conditions using a Markov chain is a stochastic process based on three constraints: 1) discrete processes concerning time, 2) state processes that can be calculated, and 3) finite. These processes must have Markov properties [16]. Furthermore, the transition probability matrix is prepared based on the transition data of road conditions in one year of pavement operation (2020–2021). The category used is handling. The pavement condition rating can improve after one cycle if efforts are made to repair the road defect. The types of road management programs can be routine, periodic maintenance, rehabilitation, and reconstruction. The transition probability matrix organized into this category contains the increasing transition probability values [39].

The probability P_{ij} of pavement condition transition from state i to state j can be estimated by the following equation [40]

$$P_{ij} = \frac{n_{ij}}{n_i} \quad (1)$$

Where n_{ij} is the number of road sections that transition from state i to state j at a defined period and n_i is the total road sections in state i before the transition.

III. RESULT AND DISCUSSION

A. Road Damage Identification

Several damages were discovered in each segment due to the survey and analysis. The wear ranged from mild to moderate. It can obstruct smooth driving and threaten other road users [35]. Figure 5 depicts several types of damage to flexible and rigid pavements.



Fig. 5 Identification of Road Damage on Flexible and Rigid Pavement

Daan Mogot road has a 700-meter-long rigid impression structure, so the test is carried out by dividing seven segments on this pavement. Several types of damage can be found, as shown in Figure 6 below, based on the survey results in the field directly and analysis.



Fig. 6 Graph of Damage Types in Rigid Pavement

Meanwhile, for 11.3 km long flexible pavement, more types of damage occurred than those on rigid pavement. It can be seen in Figure 7 below:

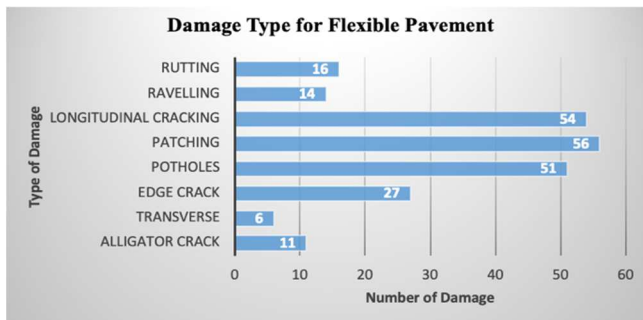


Fig. 7 Graph of Types of Damage on Flexible Pavement

The average IRI value for flexible pavement is 4.47 mm/m, which means that the condition of Daan Mogot road for flexible pavement is Fair. On the other hand, the IRI value on the rigid pavement is 4.25, with the road condition value being Fair. Each IRI value on this road section can be seen in Figure 8 below:

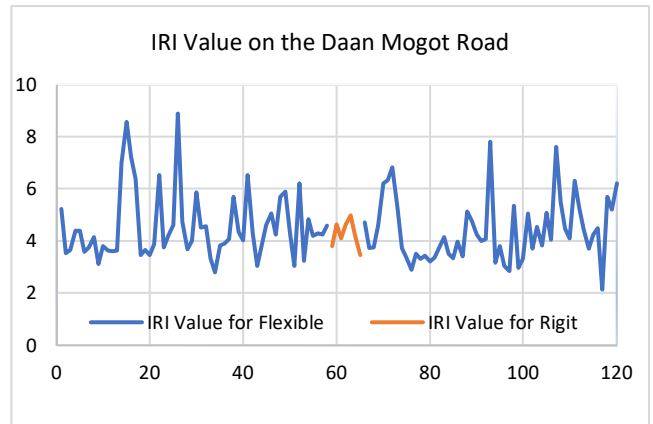


Fig. 8 IRI value on the flexible and rigid pavement on Daan Mogot road (mm/m)

The calculation of the SDI value summary for the Daan Mogot road section is based on direct observation in the field. It can be seen in Figure 9 below:

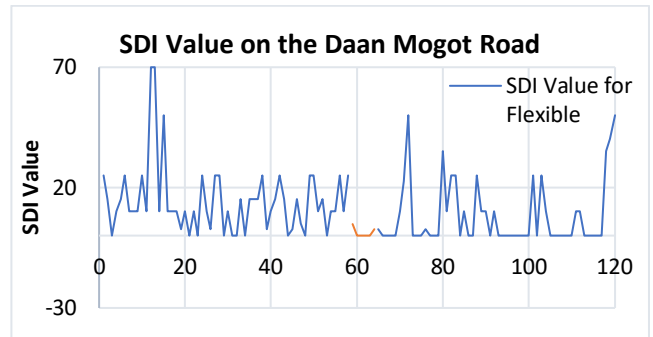


Fig. 9 SDI values for sections of flexible and rigid pavement

Figure 10 shows the analysis of calculating the PCI value on Daan Mogot road. The average PCI value for flexible pavements was 86.9. This signifies that the intermediate state of Daan Mogot road is Excellent, with the lowest value of 50 found in segment 97 and the highest value of 100 found in segment 98. The average PCI value on rigid pavements is 96, indicating that the road conditions for rigid pavements are Excellent.

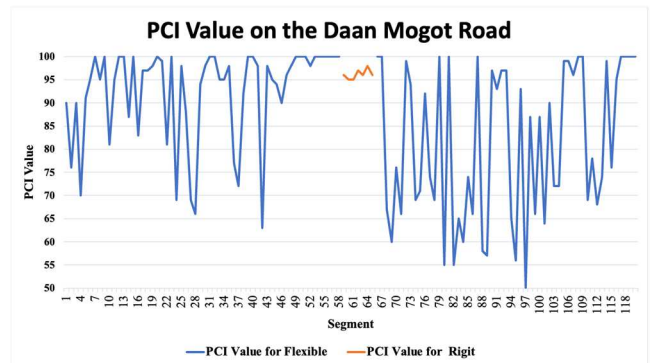


Fig. 9 PCI values for sections of flexible and rigid pavement

B. Condition Vector Current State

The current state of this study is in the second semester of 2022. The data used as input in modeling are IRI, SDI, and PCI data carried out by direct field observations. The following is the condition state distribution for each observation model.

TABLE II
DISTRIBUTION OF CONDITION STATES FOR IRI

Conditions	IRI Rating	length (km)	Probability Distributions
Good	1 – 4	5	41.7%
Moderate	4 – 8	6.8	56.7%
Light			
Damage	8 – 12	0.2	1.7%
Heavy			
Damage	> 12	0	0%
Total km		12	100%

From Table II above, the condition probability can be displayed as condition state vector $IRI_D1 = [0.417 \ 0.567 \ 0.017 \ 0.000]$. This is the condition probability vector of the pavement section during the second semester of 2022.

TABLE III
DISTRIBUTION OF CONDITION STATES FOR SDI

Conditions	SDI Rating	length (km)	Probability Distributions
Good	< 50	11.5	95.8%
Moderate	50 – 100	0.5	4.2%
Light			
Damage	100 – 150	0	0%
Heavy			
Damage	> 150	0	0%
Total km		12	100%

Table III above shows the condition probability as the condition state vector $SDI_D2 = [0.958 \ 0.420 \ 0.000 \ 0.000]$. This is the condition probability vector of the pavement section during the second semester of 2022.

TABLE IV
DISTRIBUTION OF CONDITION STATES FOR PCI

Conditions	PCI Rating	length (km)	Probability Distributions
Good	85 - 100	8.1	67.5%
Satisfactory	70 – 84	1.6	13.3%
Fair	55 – 69	2.2	18.3%
Poor	< 55	0.1	0.8%
Total km		12	100%

Table IV above shows the condition probability as the condition state vector $PCI_D3 = [0.675 \ 0.133 \ 0.183 \ 0.000]$. This is the condition probability vector of the pavement section during the second semester of 2022. From the condition probabilities in Tables 2, 3, and 4 above, the findings for the current state condition vector for IRI, SDI, and PCI are as follows:

$$\begin{aligned}
 IRI &= D1 = [0.417 \ 0.567 \ 0.017 \ 0.000] \\
 SDI &= D2 = [0.958 \ 0.420 \ 0.000 \ 0.000] \\
 PCI &= D3 = [0.675 \ 0.133 \ 0.183 \ 0.080]
 \end{aligned}$$

C. Transition Probability Matrix

The data used in making the transition probability matrix to predict road conditions at the study site when road handling begins historical road condition data, namely IRI, SDI, and PCI data for the Daan Mogot Road Section due to similarities in average daily traffic, geological conditions, and weather conditions, and the data used is data in semester 2 of 2020 and semester 1 of 2021 because this modeling aims to predict the condition of the study site roads when road handling begins in semester 1 of 2022. Several assumptions were used in

constructing the transition probability matrix using data showing the deterioration of the condition and the deterioration of the condition one level below.

The following Table V shows the history of the distribution of the pavement condition rating and the condition rating for the IRI indicator, which is based on the pavement condition transition data for the IRI indicator from semester 2 of 2020 to semester 1 of 2021

TABLE V
MATRIX INTERMEDIATE TRANSITION PROBABILITIES WITH IRI INDICATOR

Pavement Conditions Before	Pavement Condition After				Total Road Sections
	Good	Moderate	Light Damage	Heavy Damage	
Good	214	223	0	0	437
Moderate	0	107	16	0	123
Light	0	0	4	0	4
Damage					
Heavy	0	0	0	0	0
Damage					
					564

The table above shows that an intermediate transition probability matrix is obtained from the pavement history data, where the row shows the condition before the transition. The transition matrix can be seen in Table VI below.

TABLE VI
TRANSITION MATRIX FOR IRI INDICATOR

Pavement Conditions Before	Pavement Condition After				Total Road Sections
	Good	Moderate	Light Damage	Heavy Damage	
Good	0.490	0.510	0.000	0.000	0.490
Moderate	0.000	0.870	0.130	0.000	0.000
Light					
Damage	0.000	0.000	1.000	0.000	0.000
Heavy					
Damage	0.000	0.000	0.000	0.000	0.000

The MPT compilation of Markov chain modeling for model application on the road-based IRI indicator is given as follows:

$$MPT_IRI = \begin{bmatrix} 0.490 & 0.510 & 0.000 & 0.000 \\ 0.000 & 0.870 & 0.130 & 0.000 \\ 0.000 & 0.000 & 1.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 \end{bmatrix}$$

Furthermore, Table VII shows the distribution history of pavement condition rating distribution and condition rating for the SDI indicator:

TABLE VII
MATRIX INTERMEDIATE TRANSITION PROBABILITIES WITH SDI INDICATOR

Pavement Conditions Before	Pavement Condition After				Total Road Sections
	Good	Moderate	Light Damage	Heavy Damage	
Good	497	44	0	0	541
Moderate	0	0	11	0	11
Light					
Damage	0	0	0	0	0
Heavy					
Damage	0	0	0	0	0
					552

For the transition matrix, SDI can be seen in Table VIII below:

TABLE VIII
TRANSITION MATRIX FOR SDI INDICATOR

Pavement Conditions Before	Pavement Condition After				Total Road Sections
	Good	Moderate	Light Damage	Heavy Damage	
Good	0.919	0.081	0.000	0.000	0.919
Moderate	0.000	0.000	1.000	0.000	0.000
Light Damage	0.000	0.000	0.000	0.000	0.000
Heavy Damage	0.000	0.000	0.000	0.000	0.000

The MPT compilation of Markov chain modeling for model application on the road-based SDI indicator is given as follows:

$$MPT_SDI = \begin{bmatrix} 0.919 & 0.081 & 0.000 & 0.000 \\ 0.000 & 0.000 & 1.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 \end{bmatrix}$$

From the pavement history data, the intermediate transition probability matrix for PCI is obtained, where the row shows the condition before the transition, as shown in Table IX below:

TABLE IX
MATRIX INTERMEDIATE TRANSITION PROBABILITIES WITH PCI INDICATOR

Pavement Conditions Before	Pavement Condition After				Total Road Sections
	Good	Satisfactory	Fair	Poor	
Good	41	165	0	0	206
Satisfactory	0	133	48	0	181
Fair	0	0	27	11	38
Poor	0	0	0	5	5
					430

The transition matrix for the PCI indicator is obtained in Table X as follows:

TABLE X
TRANSITION MATRIX FOR PCI INDICATOR

Pavement Conditions Before	Pavement Condition After				Total Road Sections
	Good	Satisfactory	Fair	Poor	
Good	0.199	0.801	0.000	0.000	0.199
Satisfactory	0.000	0.735	0.265	0.000	0.000
Fair	0.000	0.000	0.711	0.289	0.000
Poor	0.000	0.000	0.000	1.000	0.000

The MPT compilation of the Markov chain modeling for the PCI indicator is shown below:

$$MPT_PCI = \begin{bmatrix} 0.199 & 0.801 & 0.000 & 0.000 \\ 0.000 & 0.735 & 0.265 & 0.000 \\ 0.000 & 0.000 & 0.711 & 0.289 \\ 0.000 & 0.000 & 0.000 & 1.000 \end{bmatrix}$$

D. Markov Chain Pavement Model

In the Markov Chain method, the pavement condition state position t , of the pavement at any state is calculated from the initial condition vector. The pavement condition during the first semester of 2022 is considered the initial condition of the second semester of 2021. The modeling process involves multiplying the condition state vector with the transition probability matrix obtained previously by each indicator for IRI, SDI, and PCI. Modeling at $t=0$, the road condition is expressed in the condition state vector as follows:

$$\begin{aligned} IRI &= D1 = [0.417 \ 0.567 \ 0.017 \ 0.000] \\ SDI &= D2 = [0.958 \ 0.420 \ 0.000 \ 0.000] \\ PCI &= D3 = [0.675 \ 0.133 \ 0.183 \ 0.000] \end{aligned}$$

At $t = 1$, it is the end of the analysis with maintenance routine $M = 1$. The condition distribution is the percentage of pavement in good, moderate, lightly damaged, and heavily damaged condition. The change in pavement condition distribution at $t = 1$ after applying routine maintenance is obtained by multiplying the condition at $t = 0$ with the transition probability matrix $M1$

E. End State Vector Analysis

End state for the IRI indicator:

$$IRI_1 = IRI_D1 \times MPT_IRI$$

$$IRI_1 = [0.417 \ 0.567 \ 0.017 \ 0.000] \times \begin{bmatrix} 0.490 & 0.510 & 0.000 & 0.000 \\ 0.000 & 0.870 & 0.130 & 0.000 \\ 0.000 & 0.000 & 1.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 \end{bmatrix}$$

$$IRI_1 = [0.204 \ 0.706 \ 0.091 \ 0.000], \text{ is the end state vector}$$

Based on this modeling, the pavement condition in 2022 for the first semester with probability is shown in Table XI below:

TABLE XI
END STATE CONDITION DISTRIBUTION FOR IRI INDICATORS

Conditions	IRI Rating	length (km)	Probability Distributions
Good	1 – 4	2.45	20.40%
Moderate	4 – 8	8.46	70.60%
Light Damage	8 – 12	1.09	9.10%
Heavy Damage	> 12	0	0%
Total km		12	100%

The table above shows the distribution of pavement conditions in the study areas in the first semester of 2022 due to modeling for the IRI indicator. There are 2.45 km, or 20.4%, of 12 km of pavement in good condition. There are 8.46 km, or 70.6%, of 12 km of pavement in moderate condition. There is 1.09 km, or 9.10% of the 12 km, of pavement in lightly damaged condition.

End state for the SDI indicator:

$$SDI_1 = SDI_D2 \times MPT_SDI$$

$$SDI_1 = [0.958 \ 0.420 \ 0.000 \ 0.000] \times \begin{bmatrix} 0.919 & 0.081 & 0.000 & 0.000 \\ 0.000 & 0.000 & 1.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.000 & 0.000 \end{bmatrix}$$

$$SDI_1 = [0.880 \ 0.078 \ 0.042 \ 0.000], \text{ is the end state vector}$$

Based on this modeling, the condition of the SDI indicator pavement in 2022 for the first semester is obtained with probabilities, as shown in Table XII below.

TABLE XII
END STATE CONDITION DISTRIBUTION FOR SDI INDICATORS

Conditions	SDI Rating	length (km)	Probability Distributions
Good	< 50	10.56	88.00%
Moderate	50 – 100	0.94	7.80%
Light Damage	100 – 150	0.50	4.20%
Heavy Damage	> 150	0	0%
Total km		12	100%

Based on the modeling results for SDI indicators, 88.0% of the pavement is in good condition, 7.8% is in moderate condition, and 4.20% is lightly damaged.

End state for the PCI indicator:
 $PCI_1 = PCI_D3 \times MPT_PCI$

$$PCI_1 = [0.675 \ 0.133 \ 0.183 \ 0.000] \times \begin{bmatrix} 0.199 & 0.801 & 0.000 & 0.000 \\ 0.000 & 0.735 & 0.265 & 0.000 \\ 0.000 & 0.000 & 0.711 & 0.289 \\ 0.000 & 0.000 & 0.000 & 1.000 \end{bmatrix}$$

$PCI_1 = [0.134 \ 0.638 \ 0.165 \ 0.053]$, is the end state vector

Based on this modeling, the condition of the PCI indicator pavement in 2022 for the first semester is obtained with probabilities, as shown in Table XIII. Based on modeling results for PCI indicators, 13.43% of pavement is in good condition, 63.83% is in satisfactory condition, 16.53% is in fair condition, and 6.1% is in poor condition.

TABLE XIII
 END STATE CONDITION DISTRIBUTION FOR PCI INDICATORS

Conditions	PCI Rating	length (km)	Probability Distributions
Good	85 - 100	1.61	13.43%
Satisfactory	70 - 84	7.67	63.83%
Fair	55 - 69	1.98	16.53%
Poor	< 55	0.73	6.1%
Total km		12	100%

Referring to the survey results, the actual conditions at the end of the observation were obtained for each indicator, as shown in Table XIV. Based on Table XIV above, the difference between the probability distribution of modeling and actual survey results is obtained with an average indicator of IRI = 5.70%, SDI = 7.74%, and PCI = 29.15%.

TABLE XIV
 CURRENT STATE AND END STATE ANALYSIS FOR IRI, SDI, AND PCI INDICATORS

Conditions	IRI Rating	2nd Semester Year 2021		1st Semester of 2022			
		Length (km)	Distribution Probability	Modeling		Actual Survey Results	
				Length (km)	Distribution Probability	Length (km)	Distribution Probability
Good	1 - 4	5.00	41.67%	2.448	20.40%	3.12	26.00%
Moderate	4 - 8	6.80	56.67%	8.46	70.60%	7.44	62.00%
Light Damage	8 - 12	0.20	1.67%	1.092	9.10%	1.44	12.00%
Heavy Damage	> 12	0.00	0.00%	0	0.00%	0	0.00%
Total km		12	100%	12	100%	12	100%

Conditions	SDI Rating	2nd Semester Year 2021		1st Semester of 2022			
		Length (km)	Distribution Probability	Modeling		Actual Survey Results	
				Length (km)	Distribution Probability	Length (km)	Distribution Probability
Good	< 50	11.50	95.83%	10.56	88.00%	9.67	80.58%
Moderate	50 - 100	0.50	4.17%	0.936	7.80%	2.33	19.42%
Light Damage	100 - 150	0.00	0.00%	0.504	4.20%	0	0.00%
Heavy Damage	> 150	0.00	0.00%	0	0.00%	0	0.00%
Total km		12	100%	12	100%	12	100%

Conditions	PCI Rating	2nd Semester Year 2021		1st Semester of 2022			
		Length (km)	Distribution Probability	Modeling		Actual Survey Results	
				Length (km)	Distribution Probability	Length (km)	Distribution Probability
Good	85 - 100	8.10	67.50%	1.612	13.43%	4.72	39.33%
Satisfactory	70 - 84	1.60	13.33%	7.67	63.83%	2.42	20.17%
Fair	55 - 69	2.20	18.33%	1.984	16.53%	2.14	17.83%
Poor	< 55	0.10	0.83%	0.732	6.10%	2.72	22.67%
Total km		12	100%	12	100%	12	100%

IV. CONCLUSION

The average value of road conditions with the IRI indicator is 4.45, which is moderate; for SDI, the average value of road conditions is 10.79, which is good; and for PCI, the average value of road conditions is 87.54, which is good. Based on the three indicators above, modeling with the International Roughness Index (IRI) method with the minor probability distribution averaged 5.7%; therefore, the IRI method is the closest to the actual conditions during implementation.

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