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Prediction of Road Handling Cost Using Markov Chain Method in Regency Road Network

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Abstract: The use of budget in road management must be effective and efficient by providing the optimal pavement performance values. The problem in cost optimization of the road handling programs in West Bangka Regency is the lack of information regarding with the changes in conditions that will occur in the future due to the pattern of road handling that carried out, so that required a method that capable to predict road pavement conditions. The purpose of this study is to determine the cost of future road handling programs based on the value of road pavement conditions from the prediction results using Markov chain method. Modeling requires an initial condition vector and a Transition Probability Matrix (TPM). The main data used in the development of this model is pavement condition data and road handling history data for 2012 - 2017. The application of the Markov chain model on the road network in West Bangka Regency in the period of 2018 - 2022 shows a drastic decrease in pavement conditions, if not conducted the handling action on the road damage, with a change in the value of Good (B) condition from 63.7% in 2017 become 12.3% in 2022. Based on a simulation of a road management program during this period, produce an estimated cost of Rp. 45.338.471.000 by providing a change in the value of Good (B) conditions at the end of 2022 by 58.6%. The results of the study are expected could assist road managers in the context of the preparation of an optimal road management program.

Keywords: Road handling cost, Markov Chain method, road management

1. Introduction

Road is an infrastructure that has an important role in supporting economic growth and social welfare, because the distribution of goods and services as well as community mobility is mostly conducted through road infrastructure. In the service life cycle, road infrastructure will continue to experience a decline in conditions that usually begins with the appearance of damage on the road pavement, so that need to be conducted well planned and programmed road management in order to slow down the speed of decline in road pavement conditions and maintain conditions at a reasonable level.

In an effort to obtain the optimal road handling program planning, road managers need information on changes in road pavement conditions for years to come, either changes due to conducted the handling or not conducted the handling on the road pavement damage. Therefore, an effective method is needed to determine future road performance, by predicting or estimating the development of road pavement conditions.

In terms of pavement management, road operators can implement a pavement management system (PMS) which starts from the stage of planning, design, construction, service evaluation, as well as maintenance and rehabilitation [1].

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PMS is used to assist road organizers in making decisions, so that the implementation of road administration can be done effectively and efficiently [2]. One of the components from PMS is road performance modeling.

The road performance model that can be predicted is the level of road pavement damage. One of the mathematical models that can be used to predict the condition of the road pavement is a probabilistic model, which defined as a condition prediction model from the probability value of the occurrence of various possible outcomes [3]. At the level of the road network, probabilistic methods are used to predict a range of values from the dependent variable, where the road pavement will experience changes from various conditions to become other conditions in one cycle. The accuracy of predictions of future pavement conditions is a must, because this is an important part of the system [4]. One of the available method for this purpose is the Markovian technique, which is a probabilistic technique that is more appropriate to be used in predicting the pavement conditions in the future.

The Markov process assumes changes in pavement conditions depend on the current pavement conditions, in addition to pavement performance predictions with Markov chains can also integrate the level of decline in pavement conditions and the level of improvement in the condition of pavement [5]. In the process of its use, the Markov model requires a transition probability matrix (TPM) to define changes in pavement conditions from one condition to another. The advantage of using the Markov chain for prediction is the ability to overcome uncertainties from construction, environment and material quality [6].

Several studies that have been conducted previously concluded that the Markov model has advantages in terms of its ease of use in the preparation of annual maintenance budget plans by providing optimum results reviewed from costs for the type of routine maintenance [7]. In addition, the Markov chain prediction model provides fairly accurate results in predicting a decrease in pavement conditions. The sensitivity analysis conducted in this research shows a model that is very responsive to the level of decline in pavement conditions and performance limits [8].

The use of Markovian Probability Process in predicting pavement conditions in the future can help in comparing the overall condition of road pavement after maintenance measures are taken in the road network, so that appropriate and optimal maintenance actions can be taken [9]. From the simulation results of national road maintenance using the Markov chain model approach for 10 years, it provides a fairly good maintenance pattern, where the handling of road sections that are maintenance (repairing) carried out in the the range of 2 - 3 years [10].

The purpose of this study is to determine the cost of a regency road network handling program for a period of 5 years, based on information on changes in road pavement performance conditions from the condition prediction results using the Markov chain method. The study area of this research is on the road network in West Bangka Regency, Bangka Belitung Islands Province, Indonesia.

2. Research Method

In an outline, the research process carried out in 5 stages, namely: (i) Literature study; (ii) Data inventory; (iii) Markov chain modeling; (iv) Determination of road handling program cost; (v) Conclusion. The flowchart of this research process shown in Fig. 1.

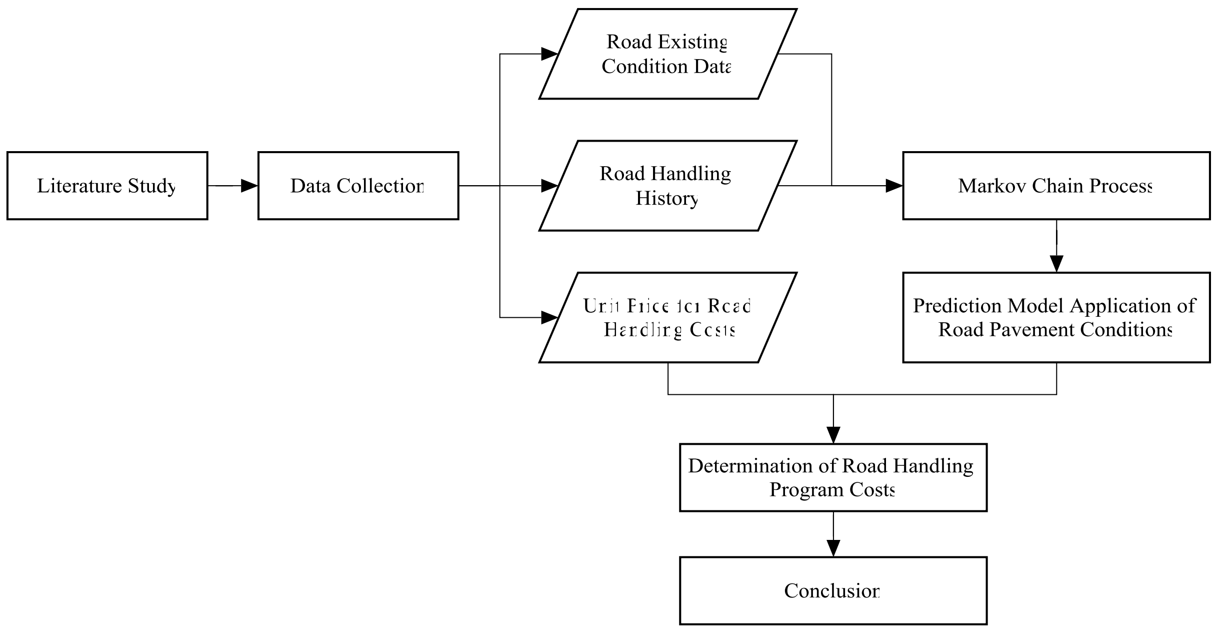

Fig. 1 - Research flow chart

2.1 Literature Study

This stage is carried out by collecting literature from various sources such as journal articles, conference proceedings, books, theses, and others that are relevant to the scope of the research. The aim is to find out more about the Markov chain method which is commonly used in mathematically predicting future events.

2.2 Data Inventory

The road sections reviewed in this study are those that have the regency road status that is in the road network in West Bangka Regency. In detail, the data of the regency road section used as the sample in this study shown in Table 1.

Table 1 - Regency road section data

No	Road Section	Length (km)	No	Road Section	Length (km)	No	Road Section	Length (km)
1	Jebus - Kampak	5.52	36	Ledeng	1.57	71	Pelawan - Pala	7.84
2	Jebus - Sungai Buluh	6.22	37	Lingkar SDLB	0.72	72	Pelawan - Sinar Kelabat	4.37
3	Sungai Buluh - Pebuar	6.83	38	Menara Air	1.22	73	Parittiga - Paritempat	2.92
4	Johar - Parittiga	9.24	39	Menjelang Baru	0.78	74	Terminal Parittiga	0.48
5	Tambang 6 - Sungai Buluh	2.60	40	Lapangan Golf	1.51	75	Perumnas 5	0.49
6	Petar - Ranggi	5.95	41	Asmara 1	0.83	76	Sungai Tanggok	1.14
7	Terminal Jebus	0.23	42	Pait Pemda	0.73	77	Pasar Ikan Parittiga	0.18
8	Kantor Camat Jebus	0.13	43	Perumnas	2.14	78	Batu Tulis	1.46
9	Pabean	0.18	44	Sekip-Argotirto	4.09	79	SMKN 1 Parittiga	1.72
10	Tembus Terminal Jebus	0.53	45	Sekip-Pal I	1.33	80	Bukit Lintang - Vihara	1.39
11	Dendang - Baginda	16.55	46	Polaris	1.24	81	Kapit - Sinar Kelabat	12.23
12	BBI	2.95	47	Pait	3.09	82	Berang - Rumpis	6.67
13	Dendang - Juruh	4.46	48	Pait Jaya	1.17	83	Bulin	0.76
14	Jeragen Telkom	1.48	49	Teluk Rubiah	0.88	84	Pelangas - Rumpis	6.05
15	Kacung - Pangkal Beras	11.71	50	Kota Seribu	0.97	85	Pelangas - Kundi	21.33
16	Kelapa - Pusuk	11.39	51	Hos. Cokroaminoto	0.93	86	Peraceh - Belanak	3.91
17	Sinar Pagi	1.27	52	Menjelang	2.31	87	Peradong - Rimba Kendong	7.08
18	Keliling Pasar Kelapa	0.70	53	Raya Peltim	2.83	88	Rejak - Belar	14.67
19	Sp. Tuik - Sp. Manunggal	10.30	54	Peleburan	1.25	89	Sp. Tiga - Rumpis	10.36
20	Padat Karya	1.37	55	Muntok-Tj Ular	14.39	90	Sp.Teritip - Air Nyatoh	0.47
21	Air Samak	2.15	56	Jend Sudirman	1.11	91	Kundi - Sukal	9.40
22	Pintas Belo Laut-Terabek	0.70	57	Air Samak - Menjelang	0.72	92	Alhidayah - Parit 10	2.03
23	Campur Sari	1.31	58	Belo Laut-Terabek	7.94	93	Tempilang - Tj. Niur	13.02
24	Cik Mas	0.72	59	Alternatif	0.93	94	Cempaka	0.80
25	Flamboyan	0.75	60	Sukal-Terabek	10.85	95	Merabok	0.94
26	Damai	0.90	61	Komplek Pemda (G1)	0.88	96	Kampung Jawa	1.87
27	Gunung Menumbing	5.86	62	Komplek Pemda (A1)	1.58	97	Penyampak – Tj. Nibung	11.80
28	Balai	0.72	63	Komplek Pemda (G2)	0.92	98	Tempilang - Pasir Kuning	2.09
29	Siswa	1.00	64	Komplek Pemda (A)	1.60	99	Saing - Sangku	11.29
30	Siswa Dalam	0.71	65	Sawah	0.92	100	Selepuk 1	0.99
31	Tembus Samping PLN	0.60	66	Kadur Dalam	1.78	101	Selepuk 2	0.93
32	Kemang Masam-Jungku	8.54	67	Parittiga - Pelawan	15.53	102	Veteran - Air Lintang	1.32
33	Kapten Alizen	1.38	68	Parittiga - Penganak	10.11	103	Sp. Yul - Sp. Buyan	17.43
34	Tj. Kelian - Kp. Sawah	1.37	69	Pasar Parittiga	0.17	104	Sp.Lingkun - Kamat	5.36
35	Pemuda Sungai Baru	0.78	70	Teluk Limau - Cupat	4.02	105	Air Lintang - Basun	3.85

All of the data used are data from the period 2012 - 2017. The total sample of road sections used in this study amounted to 105 sections, divided into two data groups. The first group is a total of 85 road sections used for calculations in the development of the condition prediction models. The second group, namely the remaining 20 road sections used for validation of the developed model.

The data used in this study are secondary data obtained from relevant agencies, including: (i) Data on existing road pavement conditions, is a variable that will be used in the development of the model, where road conditions are divided into four levels, namely: Good, Moderate, Lightly Damaged and Severely Damaged; (ii) Road handling history data, to find out the type and amount of road handling costs that have been carried out the previous year; (iii) The unit price of road handling costs, is the standard cost required per kilometer according to each type of treatment in West Bangka Regency.

2.3 Markov Chain Modeling

Prediction model that will be developed in this study is conducted using the Markov chain method. In an outline, there are four stages carried out in this modeling, namely: (i) Determination of state conditions; (ii) Calculation of initial condition distribution; (iii) Calculation of the value of the transition probability; (iv) Predictions for pavement conditions.

The state conditions are determined to become four types, according to the number of types of existing condition levels, namely Good (B) condition, Moderate (S), Lightly Damaged (RR) and Severely Damaged (RB). State 1 shows road pavement in Good (B) condition, while state 4 shows the road pavement in a Severely damaged (RB) condition. The road pavement state conditions for the four types of existing condition levels, shown in Table 2.

Table 2 - State conditions

State Condition	Level of Condition of Road Section	
1	Good	(B)
2	Moderate	(S)
3	Lightly Damaged	(RR)
4	Severely Damaged	(RB)

The initial conditions of each process can be described by an initial vector that shows the probability or distribution of the pavement segments in certain conditions or state. The initial condition is described as an initial vector, as shown in Eqn. (1) [3].

$$a_0 = (\alpha_1, \alpha_2, \ldots, \alpha_n) \tag{1}$$

Calculation of the value of the transition probability is done based on two categories, namely without handling and with handling. The category transition probability without treatment is the pavement transition probability that moves to a worse condition after one transition cycle, where the probability represents the level of pavement damage, so that it is called the damage transition probability. The form of transition probability matrix (TPM) of the damage contains two sets of transition probabilities ($P_{i,i}$) and ($P_{i,i+1}$), presented in Eqn. (2). Damage transition probabilities ($P_{i,i+1}$) shows the possibility of pavement moving to the next worse state (i+1) after one transition [11].

$$P = \begin{pmatrix} P_{1,1} & P_{1,2} & 0 & 0 & 0 & \cdots & 0 \\ 0 & P_{2,2} & P_{2,3} & 0 & 0 & \cdots & 0 \\ 0 & 0 & P_{3,3} & P_{3,4} & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & P_{m-1,m-1} & P_{m-1,m} \\ 0 & 0 & 0 & 0 & 0 & \cdots & P_{m,m} \end{pmatrix} \tag{2}$$

Category transition probability with handling is pavement transition probability that move to better state conditions after one transition or is called improvement transition probability [11]. The TPM form which contains a combination of damage and improvement probabilities, presented in Eqn. (3). f_{ij} is the probability which shows that the part of pavement will increase from state i to state j in a single time interval as a result of active maintenance and rehabilitation measures. The values of f_{ij} will disappear without the program of maintenance and rehabilitation [5].

$$P = \begin{pmatrix} P_{11} & P_{12} & 0 & 0 & 0 \\ f_{21} & P_{22} & P_{23} & 0 & 0 \\ f_{31} & f_{32} & P_{33} & p_{34} & 0 \\ f_{41} & 0 & f_{43} & P_{44} & P_{45} \\ f_{51} & 0 & 0 & f_{54} & P_{55} \end{pmatrix} \tag{3}$$

Transition probability value of each category for each operational cycle of road pavement that will be used in the prediction of road pavement conditions, then compiled into TPM. The matrix formed is a square matrix (4 × 4), in accordance with the number of predefined state conditions criteria.

The next stage is to predict the condition of the road pavement based on the model that has been built, namely the value of TPM (P) and initial condition vector (a_0) obtained from the results of previous calculations. Prediction of road pavement condition in the future is calculated using Eqn. (4) [3].

$$a_t = a_0 \times P^t \tag{4}$$

2.4 Determination of Road Handling Program Costs

The estimation amount of the cost of the road handling program is determined based on the pavement conditions resulting from the prediction of the Markov chain method. The calculation is done by multiplying the length of the damaged road section by the cost of the road handling unit price per kilometer, according to the type of handling program specified. Determination of the type of road handling program refers to Regulation of the Minister of Public Works Number: 13/PRT/M/2011, on road maintenance and surveillance procedures is shown in Table 3.

Table 3 - Determination of road handling type [12]

Road condition	Percentage of Damage Limits (Percent on the Surface Pavement Layer Area)	Handling Program
Good (B)	< 6%	Routine Maintenance
Moderate (S)	6 - < 11 %	Routine / Periodic Maintenance
Lightly Damaged (RR)	11 - < 15 %	Rehabilitation Maintenance
Severely Damaged (RB)	15 > %	Structural Reconstruction / Improvement

3. Results and Discussion

3.1 Prediction Model Validation

Validation is intended to determine the level of accuracy of the prediction model toward the actual conditions. Validation is conducted by comparing data from prediction result of the Markov chain method with actual condition data, where data that can be validated is only limited to road condition data for the period 2014 - 2017 according to the existing categories.

As an example, in this paper, conducted validation on the prediction model for the category of without handling on the Peleburan road section, where conducted predictions for a period of four years (2014, 2015, 2016 and 2017), where 2013 is used as the base year (t = 0). The value of the difference (deviation) from the comparison between the prediction and actual results for the Peleburan road section, shown in Fig. 2 dan Fig. 3.

Diagram for 2014 condition shows the prediction of Good condition, slightly lower than the actual condition. Conversely, for Moderate conditions a little higher than the actual conditions. Furthermore, it can be seen that, the difference in the value of conditions between predictions and actual in each state equal to 5%.

Diagram for 2015 condition shows a higher accuracy than 2014 with the difference value between the prediction and actual in each state less than 4%. From the results of prediction of the conditions in the 2 years, it shows that the Markov chain model is able to produce values with relatively good accuracy. Conversely, in the 2016 condition diagram has a lower accuracy than the prediction of 2 years before (2014 and 2015) with the difference value between predictions and actual up to 13%. It can be observed, that the value of the actual conditions in state 2 dropped dramatically from 13% in 2015 to 4% in 2016. The value of state 2 mostly moves to other states (states 2 and 3) which show a worse condition, which is seen in the value of state 4 increasing dramatically, from 0% in 2015 to 10% in 2016. This significant value movement can be caused by sudden large damage on the road segment that is affected by certain factors. Whereas in the 2017 condition, it shows better accuracy than in 2016 with the difference value between predictions and actual in each state less than 10%.

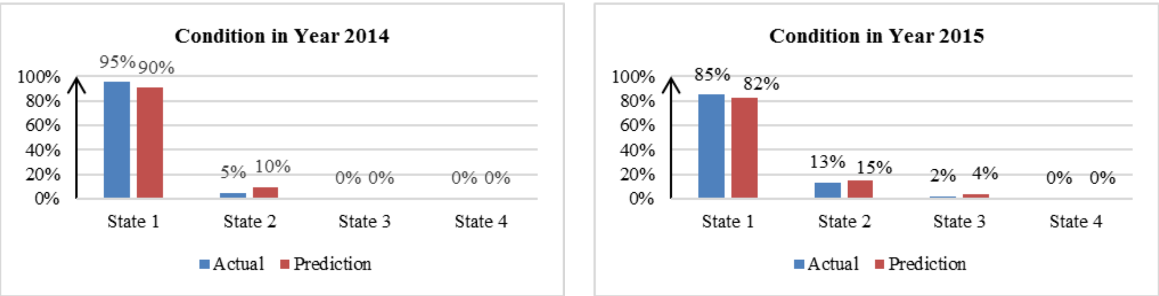

Fig. 2 - Comparison of actual condition and prediction for Peleburan Road in 2014 and 2015

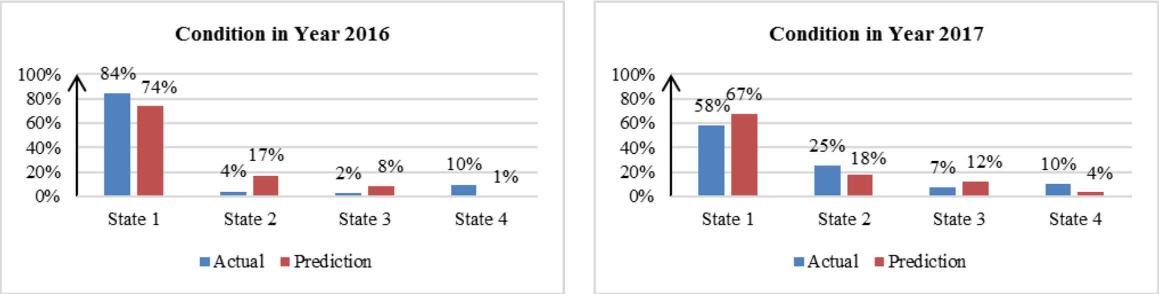

Fig. 3 - Comparison of actual condition and prediction for Peleburan Road in 2016 and 2017

Validation on the prediction model of with handling category, an example is given for the Simpang Lingkun - Kamat road section, with a prediction period of two years (2014 and 2015), where 2013 is used as a base year (t = 0). For the years of 2016 and 2017 not conducted validation, because in that year not conducted handling action on Simpang Lingkun - Kamat road section. The value of the difference (deviation) from the comparison between the prediction and actual results for the Simpang Lingkun - Kamat road section, shown in Fig. 4.

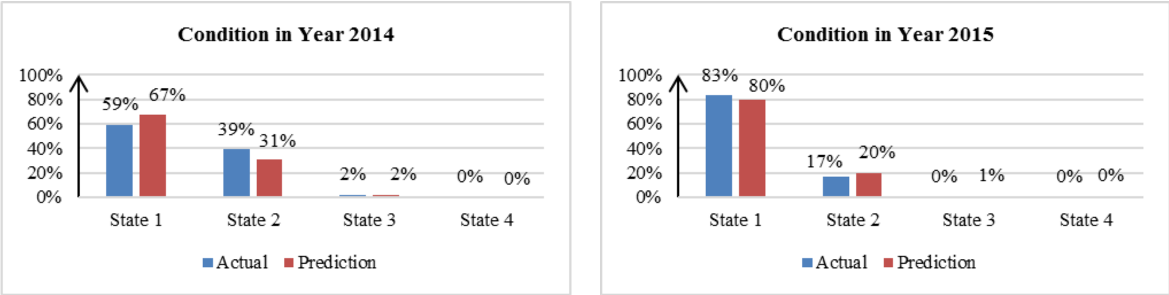

Fig. 4 - Comparison of actual conditions and prediction of Sp. Lingkun – Kamat Road Section

Diagram for 2014 condition, showing prediction of Good condition, higher than the actual condition with a difference of 8%. On the other hand, the Moderate condition is lower than the actual condition with a difference of 8%, while in the Slightly Damaged condition is relatively the same.

In the 2015 condition diagram, it shows a higher accuracy than 2014, with the value of the difference between predictions and actual in each state a maximum of 3%. From the results of prediction of the conditions in the 2 years, it shows that the Markov chain model is able to produce values with relatively good accuracy.

3.2 Application of Markov Chain Prediction Model

The Markov chain model is applied to predict the road pavement conditions for the five-year period (2018 - 2022), where 2017 is used as a base year (t = 0). TPM used in this model is a probability of transition to pavement conditions in 2016 - 2017, with an initial condition vector (a_0) which arranged based on the distribution of conditions in early 2017. Pavement conditions prediction is done for 20 roads that represent the Regency road network. The prediction model applied using the damage Transition Probability Matrix (TPM), to see changes in conditions of road pavement, assuming no road handling is taken. As an example of Markov chain model application in the prediction of road pavement conditions in 2017 - 2022 for Peleburan and Simpang Lingkun - Kamat Road, shown in Table 4.

Table 4 - Application of Markov chain prediction model for Peleburan and Sp. Lingkun - Kamat road section

No.	Road Section	Condition	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2022 (%)
1.	Peleburan	Good	58.0	41.7	30.0	21.6	15.5	11.2
		Moderate	24.9	22.7	17.6	13.0	9.4	6.8
		Lightly Damaged	7.2	24.2	36.2	42.0	43.2	41.6
		Severely Damaged	9.9	11.3	16.2	23.4	31.8	40.5
2.	Simpang Lingkun – Kamat	Good	54.6	39.3	28.3	20.3	14.6	10.5
		Moderate	25.4	21.9	16.7	12.3	8.9	6.4
		Lightly Damaged	20.0	34.8	44.0	47.6	47.2	44.3
		Severely Damaged	0.0	4.0	11.0	19.8	29.3	38.7

The table above shows the proportion of deterioration in road conditions on each road section each year. Can be observed on the Peleburan road section, the value of Good condition in 2017 of 58.0% experienced a significant decrease during 5 years to 11.2% in 2022, with a difference of 46.8%. This proves that the proportion of Good conditions will move from the best condition to the worst condition (S, RR, and RB), if not conducted handling action on the road section. The recapitulation of road pavement conditions from the prediction results of the Markov chain model for the entire regency road network is presented in Fig. 5.

The graph shows decreasing pattern of Good (B) conditions level on the entire road network for five years, from 63.7% in 2017 to 12.3% in 2022. Conversely, the value of bad conditions continues to increase which can be observed in the condition of Severely Damaged (RB) in 2017 equal to 5.4% become 36.9% in 2022. This condition will continue to move linearly, if no action is taken to deal with the damage that occurs. Therefore, good programming from the Regional Government is needed in order to maintain and improve road conditions to remain in a stable position.

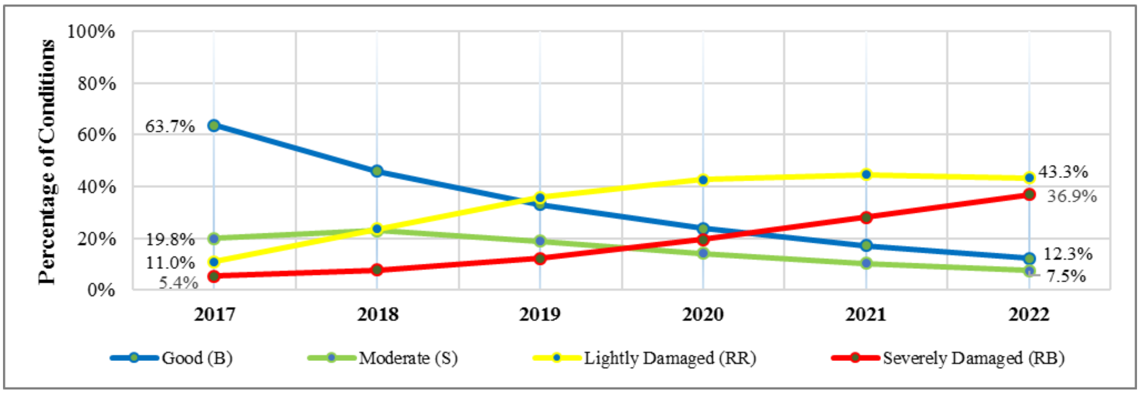

Fig. 5 - Recapitulation of prediction results condition on the Regency road network

3.3 Road Handling Program Costs

The road handling program is compiled for the next five years that aims to find out the estimation costs needed in the road network management during this time period and its effect on the changes of road pavement conditions. In this study, a road network handling program was simulated using the previous year's handling pattern, namely 2016 - 2017. Implementation of handling in that year, carried out by prioritizing treatment/handling measures for the handling type of road improvement.

Road handling costs estimated after determined the type of handling of the road segment or network being reviewed, based on the value of the pavement conditions. In this study, the price amount of the unit cost per type of road handling for 2018 - 2022 is assumed to remain without an increase in inflation from 2017. An example of the determination of the cost of a road handling program in 2018 - 2022 for the Simpang Lingkun - Kamat road section, is shown in Table 5.

Table 5 - The cost of a road handling program for the Simpang Lingkun - Kamat road section

Road Section	Information	2017		2018		2019		2020		2021		2022	
		km	%	km	%	km	%	km	%	km	%	km	%
Simpang Lingkun - Kamat	Good (B)	2.93	54.6	4.81	89.7	3.46	64.5	2.49	46.4	4.64	86.5	3.34	62.2
	Moderate (S)	1.36	25.4	0.47	8.8	1.47	27.4	1.35	25.2	0.57	10.7	1.45	27.0
	Lightly Damaged (RR)	1.07	20.0	0.08	1.6	0.41	7.7	1.42	26.5	0.15	2.8	0.54	10.2
	Severely Damaged (RB)	-	0.0	-	0.0	0.02	0.3	0.10	1.9	-	0.0	0.03	0.6
	Steady Condition (B+S)	4.29	80.0	5.28	98.4	4.93	92.0	3.84	71.6	5.21	97.2	4.79	89.3
	Unsteady Condition (RR+RB)	1.07	20.0	0.08	1.6	0.43	8.0	1.52	28.4	0.15	2.8	0.57	10.7
	Type of Handling	-		Improvement		-		-		Improvement		-	
	Handling Cost (IDR Thousand)	-		1,202,880.00		-		-		1,703,188.91		-	

The table above shows that, road handling actions are not carried out every year, but are carried out based on the value of the unsteady conditions (RR+RB) > 15%, with a time interval between handling at least 2 years. It can observe on the Simpang Lingkun - Kamat road section, the value of the unsteady condition (RR + RB) at the end of 2017 was 20.0%, then road improvement action in 2018 using a cost of Rp. 1,202,880,000, so that the value of the unsteady condition decreased to 1.6% in that year. Based on the handling pattern, the road improvement program will be implemented again after 3 years (2021) with unsteady condition value of 28.4%, with a handling cost of Rp. 1.703.188.910. The recapitulation of road network handling program costs in this simulation is presented in Table 6.

Table 6 - Recapitulation of road network handling program costs 2018 - 2022

No.	Road Section	2018	2019	2020	2021	2022
1	Petar – Ranggi	2,409,120.00	-	-	2,217,005.67	-
2	BBI	760,480.00	-	-	966,308.21	-
3	Kacung - Pangkal Beras	-	-	3,571,769.97	-	-
4	Air Samak	-	492,303.84	-	-	690,465.01
5	Campur Sari	298,860.63	-	-	418,849.78	-
6	Flamboyan	184,828.99	-	-	241,934.94	-
7	Gunung Menumbing	1,413,440.00	-	-	1,901,411.09	-
8	Balai	-	191,527.56	-	-	238,749.69
9	Kapten Alizen	-	-	400,881.55	-	-
10	Tj. Kelian - Kp. Sawah	324,800.00	-	-	440,418.10	-

11	Menara Air	-	-	284,592.76	-	-
12	Hos. Cokroaminoto	-	-	239,116.35	-	-
13	Menjelang	-	884,042.27	-	-	837,631.48
14	Peleburan	238,968.97	-	-	386,294.03	-
15	Muntok – Tj. Ular	2,597,616.00	-	-	4,396,535.96	-
16	Jend Sudirman	-	263,656.65	-	-	356,790.43
17	Parittiga – Penganak	-	-	3,405,342.88	-	-
18	Tempilang - Tanjung Niur	5,608,288.00	-	-	4,869,723.49	-
19	Kampung Jawa	369,600.00	-	-	581,047.79	-
20	Sp.Lingkun – Kamat	1,202,880.00	-	-	1,703,188.91	-
	Handling Cost (IDR Thousand)	15,408,882.59	1,831,530.31	7,901,703.51	18,122,717.97	2,123,636.62
	Total Cost (IDR Thousand)			45,388,471.00		

Table 6 shows that the cost of the road network handling program needed for a period of five years (2018 - 2022) in this simulation, is estimated to be Rp. 45.338.471.000, where the amount of handling costs required varies each year, according to the existing pavement conditions value. The recapitulation of changes in pavement conditions throughout the road network in accordance with the simulation of the road handling program for 5 years (2018 - 2022) is presented in Fig. 6.

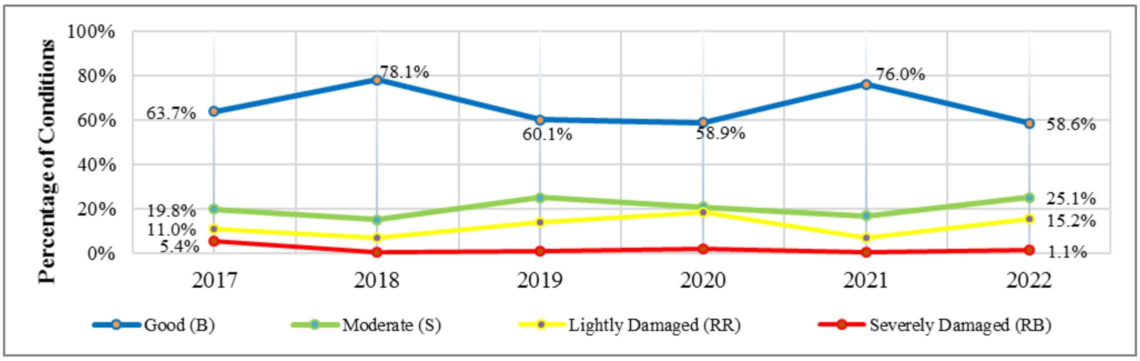

Fig. 6 - Recapitulation of changes in road pavement conditions for 2017 - 2022

The graph above shows that the cost required for the road handling program for a period of five years equal to Rp. 45.338.471.000, where with the allocated costs can reduce the value of the Severely Damage condition from 5.4% to 1.1%. However, by implementing the road handling program according to the simulation has not been able to improve the best conditions for the entire road network, where the value of the Good (B) condition level can only be maintained up to 58.6% in 2022 or still below the Good (B) condition value in 2017. This shows that the handling pattern used in the simulation is not yet optimal, where handling actions are only prioritized on the type of road improvement. Means that, the speed of decline in road pavement conditions has not been comparable to the speed of improvement of road pavement conditions in a five-year period.

4. Conclusion

Based on the results of research that has been done, the following conclusions can be drawn:

- Comparison between prediction and actual results as a whole with a four-year period (2014, 2015, 2016 and 2017) for the category of without handling, shows an average difference of 5%, with the highest deviation value of 13%, while for the category of with handling shows a better value, namely the maximum deviation value of 8%.
- The application of the Markov chain prediction model for 2018-2022, using the pattern of handling the previous year (2016 - 2017), where 2017 as a base year (t = 0) shows the value of road pavement conditions has decreased quite dramatically if not conducted the handling action on the road damage, with a change in the value of Good (B) conditions from 63.7% in 2017 become 12.3% in 2022.
- The amount of the cost of the road network handling program needed in a five-year period in accordance with the simulations in this study is equal to Rp. 45.338.471.000, where handling actions are only prioritized on the type of improvement by giving a change in the value of Good (B) condition at the end of 2022 by 58.6%. From the results of this simulation show that the delay in the road handling will make handling in the following year more difficult and require relatively higher costs, because road conditions will continue to decline if left untreated. Therefore, handling actions such as routine maintenance and periodic maintenance cannot be ignored in road management.

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