The Distribution of Damage to District Roads in Karang Penag Sub-District in Sampang District Uses Pavement Condition Index (PCI) and Spatial Poisson Point Process (SPPP)

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***Abstract*—Karang Penang sub-district is a new sub-district after the division of territory in the Sampang Regency. This sub-district consists of seven villages. Sampang Regency is an area that is categorized as underdeveloped regions in East Java Province. This is indicated by the economic conditions and the low quality of human resources, and inadequate infrastructure. The last indication needs to be carried out regularly to ensure its continued functioning in supporting economic movements in this area. Delay in the identification of damage that often occurs in this area has caused delays in the maintenance of the facility. To overcome the delay in preparing the repair schedule, it is necessary to make a faster and more accurate assessment of road conditions. This study aims to assess the condition of the road pavement by combining the two approaches, namely the Pavement Condition Index (PCI) method and the Spatial Poisson Point Process (SPPP). The results of the modeling are expected to be able to identify the distribution pattern of the locations of damage points of the highway, to identify what parameters have a significant role in the distribution of the points of damage to the highway, and to be able to identify the level or condition of district highway conditions in Karang Penang District. The results of this study are able to provide predictions of the pattern of road damage conditions with varying intensity and influential factors between highway locations. These results, in turn, can provide information on the pattern of corrective actions that are more appropriate according to the damage criteria at these locations.**

***Keywords*—Regency Road, Pavement Condition Index (PCI), Spatial Poisson Point Process (SPPP), Road Damage Assessment, Road Damage Distribution Pattern.**

I. INTRODUCTION

SAMPANG Regency is a disadvantaged area in East Java Province, this is indicated by the non-equity condition of the level of economic development and the quality of human resources, which is still low, and inadequate infrastructure [1]. Equity is defined as an equitable development effort so that development disparities between regions are low or even non-existent. Karang Penang sub-district is the most underdeveloped sub-district of the 14 sub-districts in Sampang district and it is recommended that programs prioritize the development of disadvantaged areas in the district of Sampang namely infrastructure development especially road construction [2]. Karang Penang sub-district is a new sub-district after the expansion of the area located to the Northeast of the city of Sampang, a distance of about 28 Km from the city of Sampang with an area of 84.31 km^2 (18. + 31 Ha) consisting of seven villages, including Blu'uran Village, Tlambah Village, Bulmatet Village, Poreh Village, Karang Penang Oloh Village, Karang Penang Onjur Village, Gunung Kesan Village [3]. The transportation lane that connects the Karang Penang City to other areas is connected with the district road [4].

Table 1.
Goodness of Fit Distribution Tests

Goodness of Fit Distribution Tests		
Df	P-value	X^2
46	0	628.296

The condition of the connecting roads in the Subdistrict of Sokobanah, Karang Penang, Omben, and the City of Sampang is alarming. The only highway for residents in three sub-districts in the administrative center of Sampang City was severely damaged [5]. Because of concern, several residents' donations repaired the road independently without assistance from the government. Mentioned that the length of the highway in the Regency of Sampang classified as regency roads were 1,112.64 km until 2016 in a good condition of 875.01 km and conditions of minor damage amounted to 204, 12 km, and a heavily damaged condition of 58.26 km in the Department of Public Works of Sampang Regency (2018) [3]. Including damaged roads in Karang Penang District [6]. The road is a land transportation infrastructure in any form covering all parts of the road, including buildings, equipment, and equipment intended for traffic [7]. Roads as one of the transportation infrastructures which are the arteries of people's lives have an important role in efforts to develop national and state life. In this context, roads have a role to play in achieving development goals such as equitable development and its results, as well as economic growth [8]. In accordance with its characteristics, the road network always tends to experience a decrease in conditions as indicated by the occurrence of damage to the pavement. So, to slow down the speed of deterioration and maintain conditions at a reasonable level, the road network needs to be managed properly so that the road can still function properly [8]. The problem in road maintenance is a common problem

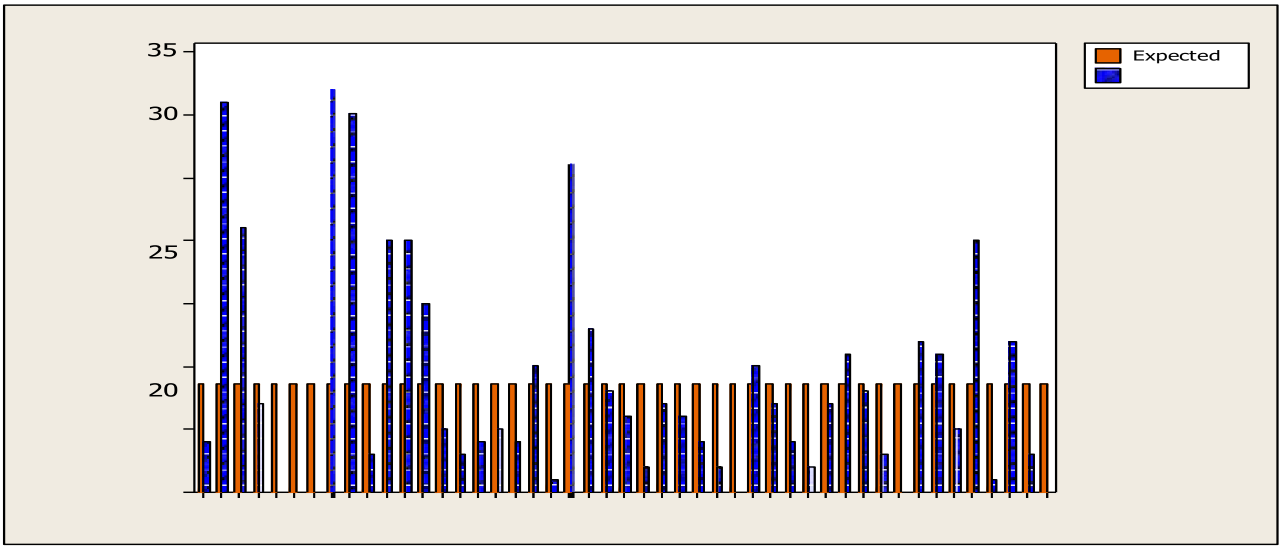

Figure 1. Distribution plot of goodness of fit test for each damage category.

that is always faced by countries in the world, both by developing countries and even in developing countries. According to the results of a World Bank study, it was stated that any reduction of US$ 1 towards road maintenance costs would increase vehicle operating costs of US$ 2 to US$ 3 because the road became more damaged. This condition will eventually burden the economy as a whole [8].

Pavement Condition Index (PCI) is one of the road pavement condition evaluation systems based on the type, level of damage that occur, and can be used as a reference in maintenance efforts on road pavement [9]. Pavement condition assessment is needed to determine the level or level of road conditions [10]. In its development many studies on the PCI method in the field of studying the Applicability of the International Roughness Index as a Predictor of Asphalt Pavement Condition [11], road pavement conditions [12], Evaluation and road maintenance [13], Assessment of road conditions [14], and potential road damage [15]. However, the above research still has not examined the spatial method approach for the distribution of road damage. The spatial point process is very useful as a statistical model for analyzing observations of point patterns where points indicate the location of research objects. A point pattern can be seen as a Poisson process if it is assumed that among the points of the location of the damage to the road is mutually independent, which is then called the Poisson Point Processes. This spatial method is used to obtain information from data that is influenced by the effects of space or location. The spatial point process is a statistical method for random patterns at points in a dimensional space, where the points represent the location of the research object [16]. Previous research has been carried out through the spatial point process approach regarding traffic accidents [17], and regarding the distribution pattern of piped water distribution leaks [18]. There are no studies related to the use of spatial point process related to the determination of road damage conditions.

The slow maintenance of roads is caused by, among other things, delays in the field survey process and reporting the condition of road damage. The spatial point approach to the process is assumed to reduce the time needed to survey and analyze road damage conditions. Based on this background, this research will analyze the distribution pattern of the locations of damage points on the regency highway in Karang Penang District, Sampang Regency. Based on several previous studies, this research will use the Spatial Poisson Point Process (SPPP) and PCI method to answer the research problem. The use of the Poisson point process in this study was carried out as an approach to the distribution of damage points in district highways in Karang Penang Subdistrict, Sampang Regency, which in this case was allegedly distributed with Poisson. While the PCI is conducted to determine the level or level of road conditions in the Karang Penang District, Sampang Regency. The analysis of the pattern of distribution of damage locations for district roads will be carried out to answer the problem statements below:

1. What is the pattern of distribution of location points Damage District Highway in Karang Penang District?
2. What parameters have a significant role in the distribution of damage points in the Regency Highway in Karang Penang District?
3. What is the level or level of condition of the Regency Highway in Karang Penang District?

II. METHODS AND MATERIALS

This research uses quantitative to answer the problem, the variable that applies is quantitative. The analytical method used in this study is the Spatial Poisson Point Process (SPPP) and the Pavement Condition Index (PCI).

A. Spatial Poisson Point Process

The spatial point process is a random pattern of points in space dimensions (with the number of dimensions equal to or more than two). Spatial point process are used as statistical models to analyze the distribution patterns of points, where they represent the location of an object of study. Examples are the distribution of tree locations in forests, gold deposits mapped in geological surveys, stars in the constellations, accident points on roads, earthquake locations, cell phone calls, animal sightings, or rare disease cases. Analysis of

Table 2.
Recapitulation of PCI Calculation Results

No Segment	STA/KM	Deduct Value (DV)								Total Deduct Value (TDV)	Q	CDV	PCI= 100-CDV		Explanation
1	0-500	7	5								12	2	10	90	Excellent
2	500-1000	10	5	7	3	24	1	5	3		58	5	28	72	Very Good
3	1000-1500	8	21	7	3	5	14				58	5	28	72	Very Good

JL. RAYA BLU'URAN

4	1500-2000	2	2	4	1	9	91	Excellent
5	2000-2500			0			100	Excellent
6	2500-2700			0			100	Excellent

JL. RAYA TLAMBAH

No Segment	STA/KM	Deduct Value (DV)					Total Deduct Value (TDV)	Q	CDV	PCI= 100-CDV	Explanation
1	0-500	0	0				0	0	0	100	Excellent
2	500-1000	100	29	11	9	8	157	4	88	12	Very Poor
3	1000-1500	100	24	11	8		143	4	79	21	Very Poor
4	1500-1600	70	15				85	2	50	50	Fair

JL. RAYA GELIDIGEN

No Segment	STA/KM	Deduct Value (DV)						Total Deduct Value (TDV)	Q	CDV	PCI= 100-CDV	Explanation
1	0-500	12	84	11	0		6	113	4	69	31	

Poor JL. RAYA KARANG PENANG

No Segment	STA/KM	Deduct Value (DV)					Total Deduct Value (TDV)	Q	CDV	PCI= 100-CDV	Explanation
1	0-500	8	34	8	15	14	79	5	44	56	Good
2	500-1000	8	43	8			59	3	35	65	Good
3	1000-1500	8	4				12	1	11	89	Excellent
4	1500-2000	4	5				9	1	9	91	Excellent
5	2000-2500	11					11	1	12	88	Excellent
6	2500-3000	9					9	1	9	91	Excellent
7	3000-3300	32					32	1	32	68	Good

JL. RAYA ROBATAL - PALENGAAN

No Segment	STA/KM	Deduct Value (DV)					Total Deduct Value (TDV)	Q	CDV	PCI= 100-CDV	Explanation
1	0-500	12	7	8	8	9	44	5	22	78	Very Good
2	500-1000	8					8	1	8	92	Excellent
3	1000-1500	100	29	5	8		142	4	78	22	Very Poor
4	1500-2000	14	100				114	2	79	21	(Very Poor
5	2000-2500	16	100				116	2	78	22	Very Poor
6	2500-3000	20	20				40	2	39	61	Good
7	3000-3500	8					8	1	8	92	Excellent
8	3500-4000	8	48	4			60	2	43	57	Good
9	4000-4600	44	13	20	8		85	4	49	51	Fair
10	4500-5000	16	22	48	5		91	4	53	47	Fair
11	5000-5500	8					8	1	9	91	Excellent
12	5500-5700						0	0	0	100	Excellent

(continued)

distribution patterns, in this case, is the main focus that is important to study in a spatial point pattern [19].

Poisson Point Process can be used as an approach to the spatial point process if it has the assumption that there is no interaction between one location point with another location. In this study, it is assumed that the location between one road damage point and another does not have an interaction, so it meets the requirements to use the spatial Poisson point process method. Poisson Point Processes are divided into two types, namely inhomogeneous [19].

B. Pavement Condition Index (PCI)

PCI is a road pavement condition evaluation system based on the type, level of damage that occur, and can be used as a reference in the maintenance effort on pavement roads. PCI values range from 0 (zero) to 100 (one hundred) with perfect criteria, excellent, very good, fair, fair, poor, and failed [8]. Pavement condition assessment is needed to determine the value of the PCI [6]. There are several parameters of the PCI method to determine the value of the PCI so that the pavement conditions observed are observed, the following are the parameters in the assessment of pavement conditions:

1. Density
2. Deduct Value (DV)
3. Total Deduct Value
4. Value Q (number of deduct greater than 5 points)
5. Corrected Deduct Value (CDV)
6. Calculating the Value of Pavement Conditions
7. Pavement Quality Classification

The research variables used in this study consisted of response variables and covariate variables. The response variable used is data on the number of road damage points in a location that has a certain latitude and longitude coordinates.

Table 2.
Recapitulation of PCI Calculation Results

No Segment	STA/KM	Deduct Value (DV)					Total Deduct Value (TDV)	Q	CDV	PCI= 100-CDV	Explanation
JL. RAYA KARANG PENANG - SOKOBANAH											
1	0-500	5	4	4	11		24	2	9	91	Excellent
2	500-1000	12	5	3	5	6	31	4	5	95	Excellent
3	1000-1500	18	3				21	1	20	80	Very Good
4	1500-2000	19	0				19	1	19	81	Very Good
5	2000-2500	17	8				25	2	17	83	Very Good
6	2500-3000	63	5	8	19		95	4	55	45	Fair
7	3000-3500	45	19				64	2	48	52	Fair
8	3500-4000	10	8				18	2	12	88	Excellent
9	4000-4600						0	0	0	100	Excellent
JL. TLAMBAH 2											
No Segment	STA/KM	Deduct Value (DV)					Total Deduct Value (TDV)	Q	CDV	PCI= 100-CDV	Explanation
1	0-500	6	9	10			25	3	15	85	Very Good
2	500-1000	9	26	8	9		52	3	53	47	Fair
3	1000-1500	4	8	8	5		25	3	14	86	Excellent
4	1500-2000	8	34	14	5		61	4	33	67	Good
5	2000-2300	8					8	1	9	91	Excellent
JL. SUMBER ANOM											
No Segment	STA/KM	Deduct Value (DV)					Total Deduct Value (TDV)	Q	CDV	PCI= 100-CDV	Explanation
1	0-500	8	52	16	18	12	106	5	55	45	Fair
2	500-1000	10	5	18			33	3	19	81	Very Good
3	1000-1300						0			100	Excellent

The covariate variable used is the physical damage variable at each point of damage. In this study, the distribution of points of damage to the road is divided into several grids. In this study, there were 7 road segments extracted from the distribution of the grid as many as 47 segments based on the number of road segments with a length of 500m in each grid/segment. The data analysis process carried out in this study are:

1) Data Analysis Procedure of the Spatial Poisson Point Process Method as follows:

1. Analyzing the characteristics of the distribution pattern of road damage.
2. Conduct homogeneity testing.
3. Identifying the mixture model if it is not homogeneous
4. Estimating model parameters using the Bayesian coupled with the Markov Chain Monte Carlo (MCMC) method

2) Data Analysis Procedure PCI Method as follows:

1. Establish deduct value
2. Determine the permit value of the deduct (m)
3. Determine the value Q
4. Determine the Maximum CDV
5. Calculate PCI

III. RESULT AND DISCUSSION

A. Spatial Poisson Point Process

The homogeneity test in the Spatial Point Process aims to find the intensity of the pattern of road damage points that are categorized into homogeneous point patterns or non-homogeneous point patterns. The goodness of fit test for distribution homogeneity results in Table 1 show that χ^2 has a big value with P_value is zero. Figure 1 shows the mismatch between the frequency of damage categories and their estimated homogeneity. It can be said that H_0 which states 'the road damage intensity of locations is in homogeneous condition', has to be rejected and the pattern of road damage points is categorized as a non-homogeneous point process.

Failure to form a homogeneous Poisson uni-modal pattern will be overcome by modeling the data on the highway damage with a multi-modal Poisson, namely the Poisson mixture model approach. By using Bayesian approach coupled with MCMC, the estimated Poisson mixture model for the road damage point in Karang Penang District, Sampang Regency has two components. The model can be written as follows.

$$fmix(\boldsymbol{x}(\boldsymbol{u})) = 0.05132 \times [\exp(2.941 + 1.798x1_{i1}(u_{i1}) + 1.548x2_{i1}(u_{i1}) + 1.285x3_{i1}(u_{i1}) + 2.722x4_{i1}(u_{i1}) - 0.5085x5_{i1}(u_{i1}) + 2.567x8_{i1}(u_{i1}) + 3.132x9_{i1}(u_{i1}) + 2.527x10_{i1}(u_{i1}) + 3.008x11_{i1}(u_{i1}) + 2.72x12_{i1}(u_{i1}) + 2.603x13_{i1}(u_{i1}) - 4.19x14_{i1}(u_{i1}))] + 0.9487 \times [\exp(2.428 + 0.2107x1_{i2}(u_{i2}) - 0.1928x2_{i2}(u_{i2}) + 0.07046x3_{i2}(u_{i2}) + 0.06981x4_{2}(u_{i2}) + 16.76x5_{2}(u_{i2}) + 0.2153x6_{2}(u_{i2}) - 0.06522x7_{2}(u_{i2}) + 0.5508x8_{2}(u_{i2}) + 0.2347x9_{2}(u_{i2}) - 0.0366x10_{2}(u_{i2}) + 0.08113x11_{2}(u_{i2}) - 0.00436x12_{2}(u_{i2}) + 0.2805x13_{2}(u_{i2}) - 4.93x14_{2}(u_{i2}))]$$

The model above showed that the first component consisting of 14 grids or segments with smaller contribution to the model,

namely 0.05132 or 5.132%. While the second component consisting of 33 segments contributing 0.9487 or 94.87%.

In the first component, all variables have a positive coefficients except patch damage and no damage variables that have a negative coefficient in the model. The negative sign on the variable of the Poisson regression model shows that the variable has a smaller probability contribution the positive one as the cause of the number of road damage at that location. This is because the Poisson regression model uses the log function link to its intensity. While in the second component, there five variables that has negative sign, i.e. length of road damage, variable type of bumpy damage, crocodile crack variable, edge crack variable, and no damage variable which negatively affects the amount of road damage.

B. Pavement Condition Index (PCI) Method

The PCI count is based on a deduction value (DV), which has a high value from 0 to 100. These deductions determine any damage when using or increasing the pavement. A deduction value of 0 proves that damage does not have a bad influence on pavement performance, whereas a value of 100 indicates serious damage to pavement [8]. Table 2 shows the recapitulation of the PCI calculation results.

The recapitulation results from the calculation of the PCI indicate the level or condition of the existing Regency Highway in Karang Penang Sub-District. Jl. Raya Blu'uran is categorized as excellent, Jl. Raya Tlambah is categorized as fair, but along the kilometer of 500-1000 km and 1000-1500, the road conditions are very poor. Jl. Raya Gelidigen is categorized as poor. While along Jl. Raya Karang Penang is categorized as excellent, because of the overall good road conditions. Jl. Raya Robatal - Palengaan is categorized as good road, but along the kilometer i.e. 1000-1500 km, 1500-2000 km, and 2000-2500 km are in very poor conditions. Jl. Raya Karang Penang - Sokobanah overall in the category as very good road, except along the kilometer i.e. 2500-3000 km and 3000-2500 km have fair categories. While the overall condition of Jl. Tlambah 2 in the category is very good, but at km 500-1000 it is classified in the fair category. Jl. Sumber Anom as a whole the road conditions included in the category are very good with the condition only along 0-500 km classify as fair condition. **All these highly qualitative PCI results can be explained quantitatively complete with an explanation of the location and type of damage explained by the results of the SPPP analysis.**

IV. CONCLUSION

In general, qualitatively, the level or condition of the existing Regency Highway in Karang Penang District is included in the category is excellent on Jl. Raya Blu'uran and Jl. Raya Karang Penang, Jl. Raya Robatal - Palengaan and Jl. Anom Resources in the category is good, Jl. Raya Karang Penang - Sokobanah and Jl. Add 2 in the category is very good, Jl. Raya Tlambah in the category is fair, and Jl. Raya Gelidigen in the category is poor. However, some parts of the road are damage. These damaged roads can be explained by SPPP. The pattern of the amount of damage to the road can be explained properly by SPPP. The results of the SPPP analysis of the distribution of damage points in district roads show that the pattern of distribution of road damage is a non-homogeneous point process. Based on the parameter estimation results, the first component has smaller number of location (smaller contribution in the mixture model, 0.05132), but it tend to have higher intensity due to its bigger estimated parameter for each variables than the second component. In this group of road, the number of road damage events is affected by the width of the damage, the length of the damage, into the damage, the width of the road, the type of path damage, the type of damage collapsed, type of corrugated damage, type of surface peel / thirsty damage, type of crocodile crack damage, elongated damage type, edge cracking type, patch damage type, with the highest significant type of crocodile crack damage and elongated crack damage. The second component has bigger contribution, i.e. 0.9487, which shows as bigger number of road location fall in this group. In this group, the number of road damage events is affected by the width of the damage, into the damage, the width of the road, the type of damage to the groove, the type of damage to the ablaze, the type of surface peeling / thirsty damage, the type of crocodile crack damage and the type of damage Cracked edges with the highest significant type of groove damage.

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