

Criteria Analysis, weight and Priority for Handling Bridges in Kudus District using AHP and Promethee II methods

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1. Introduction

Bridges are major transportation facilities that must be properly managed to avoid incurring disasters. Bridge management and rehabilitation should be conducted all year-round. Furthermore, there is a need to maintain the condition of the road network to maintain the functionality of the bridges. The performance of a bridge will decrease along with the time of service so that increasing age, the level of damaged needs more maintenance like routine maintenance, periodic maintenance and rehabilitation. The bridges are very important transportation infrastructures in Kudus District. This study was based in Kudus District Public Works Office for the 2019 bridge handling. An imbalance exists between the bridges that need to be maintained and the capacity that can be maintained. Hence, a comprehensive consideration is required to determine the priority of the bridge to be handled.

Currently, determining the priority of bridge handling is based on the condition and functionality. However, several other criteria are to be considered during bridge selection. The criteria used are: the value of conditions, Average Daily Traffic (ADT), population, number of public and social facilities, area, the length and width of the bridge. The objective of this study to analyse the ideal weight main



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criteria for the priority of selecting the weight of bridge handling and data is needed to illustrate and contrast the priority of decision-making.

By using the AHP and Promethee II method, it is considered easier, few questionnaires, applicable and it accompanies the preparation of the Bridge Handling of the Public Works Office in Kudus District for the 2019 Fiscal Year.

1.1. AHP

The Multi Criteria Decision Making (MCDM) is a strategy for making credible decisions. The best alternative I chosen from the available numbers based on several specified criteria [1]. One of the weighting techniques used in MCDM is the Analytic Hierarchy Process (AHP) The AHP method gives room for policy makers to argue, make judgments, or make measurements of inter-criteria attachments [2]. AHP is a method in the decision making system which provides space for perception, preference, experience, and intuition. Developed in the 1980s by Saaty, this method allows decision makers to model complex problems in a hierarchical structure. The structure shows the relationship between the objectives, influencing criteria, and available alternatives. The AHP method does not provide any statistical interpretation [3], so it is not limited by the sample size in the analysis. Initially, this method was created to enable a single person to make alternative decisions. The AHP not only supports decision makers by allowing them to develop complex assessment exercises, but it also allows them to combine objective and subjective considerations in the AHP decision process.

1.2. Promethee

The Promethee is a method of determining priority weights which focuses on simplicity, clarity, and stability [4]. The major criterion in the Promethee method is the value of the outranking relationship. In this method, all parameters stated here have real influence [5]. If the decision maker wants a complete solution to the problem, he should use the Promethee II throughout the ranking because it compares all emerging alternatives [6]. Promethee II presented six criteria preference functions (Brans et al., 1986), namely: usual criterion - type I, quasi criterion - type II, linear preference criterion - type III, level criterion - type IV, linear preference criterion and different areas - type V, gaussian criterion - type VI. By using the Promethee II method, much questionnaire can reduce from AHP method.

2. Research Methods

Looking for the 2018 secondary data existing condition in Kudus District that follows bridge handling and level questionnaire is the first steps for this study. The main priority for handling bridges is the assessment of the condition which is based on Attachment I of the Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia Number 33/ PRT/M/2016. This concerns the Implementation of Special Allocation Funds for Infrastructure.

The importance level questionnaire criteria for the AHP method and the preference criteria for Promethee II involves 10 respondents from several related agencies and policy makers. The criteria used are the value of conditions, Average Daily Traffic (ADT), population, number of public and social facilities, area, the length and width of the bridge.

2.1. AHP procedure steps

The AHP solution process outlines steps [7] which follow:

a. Model construction and problem structuring

The problem must be stated and entered into a rational system, such as the network format in figure 1 below:

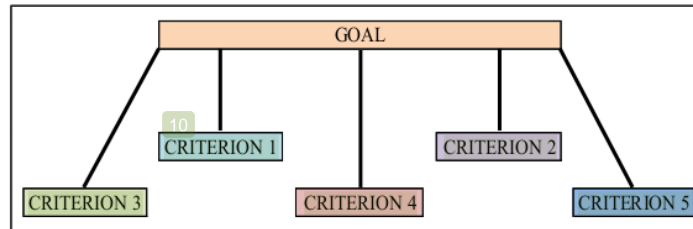


Figure 1. The network format of AHP

b. Paired comparison matrix of interrelated variables

- The correlation matrix is arranged based on ratio scale 1-9. The paired comparisons scale and perception information [8] can be seen in table 1 below :

Table 1. Paired comparison scale

Interest intensity	Information
1	Both elements are equally important
3	One element is slightly more important than the other
5	One element is more important than the other
7	One element is absolutely essential to the other
9	One element is clearly more important than the other
2,4,6,8	Values between two close consideration values

- When an assessment is carried out for a pair, automatic mutual values are assigned to the opposite comparison matrix. If the number of respondents is more than one person, then the calculation of the geomean/geometric average is done. The formula used to calculate geometric averages with equation (1) as follows :

$$GM = (Z_1 \times Z_2 \times Z_3 \times \dots \times Z_n)^{1/n} \quad (1)$$

- c. The next step is to calculate the eigen value by dividing the value of each element in the geomean matrix by the total value of each column, next, the weight is calculated by adding the eigen value of each element in a row and dividing it by the number of elements, hence, the average eigen value of the equation is achieved (2) as follows:

$$Wi = \Sigma GM_n / n \quad (2)$$

- d. In the assessment process, problems occur in the consistency of paired comparisons. Hence, consistency ratios are calculated using the following steps:

- The first step is the division of the value of the result of the matrix multiplication with the eigen value in equation (3) as follows :

$$X_i = \frac{(w_i)}{(\Sigma w_i)} \quad (3)$$

- The second step averages the results achieved in the first step which is called the consistency vector value (λ). As in equation (4) as follows :

$$\lambda_{maks} = \Sigma a_{ij} \times X_i \quad (4)$$

- After achieving the consistency vector value, the consistency index calculation is done with equation (5) as follows:

$$CI = ((\lambda_{maks} - n)) / ((n - 1)) \quad (5)$$

- Next is the calculation of the consistency ratio value with equation (6) as follows:

$$CR = CI / RI \quad (6)$$

RI = the average random consistency index (saaty 2006) as in table 2 below:

Tabel 2. The average random consistency index

ordo matriks(n)	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.48	1.49

If the calculated ratio is less than 0.10, then consistency is considered acceptable.

2.2. Promethee II procedure steps

a. Criteria evaluation

- Figure 2 shows the visual method [9] of determining the bridge condition on the district/city road segment.

S	STRUCTURE	DANGEROUS	1	CONDITION VALUE S + D + DG + F + I
		NOT	0	
D	DAMAGE	SEVERE	1	0 GOOD
		NOT	0	
DG	DAMAGE GROWTH	≥ 50%	1	1 MODERATE
		< 50%	0	2 DAMAGE
F	FUNCTION	NOT	1	3 SEVERE
		WORKING	0	4 CRITICAL
I	INFLUENCE	TAKE EFFECT	1	5 COLLAPSE
		NOT	0	

Figure 2. Scheme for determining bridge conditions

To determine the bridge handling programs for the district/city roads, the following regulations should be considered:

- If the value of the condition is 0 and 1 (if categorized as good condition, a routine maintenance program is needed.
 - If the value of the condition is 2 and 3 (if categorized as mildly damaged and severely damaged; a Periodic Bridge Rehabilitation / Maintenance program is required.
 - If the value of the condition is 4 and 5 (if categorized as critical and collapsed, there is a need for immediate replacement of the entire Bridge handling program.
- Average Daily Traffic (ADT) criteria value from Kudus Transportation Office.
 - Population, number of public and social facilities, area value from *Kudus Dalam Angka*.
 - The length and width of the bridge from Kudus Public Works Office.

b. preference questionnaire

Choose the maximum or minimum criteria value that has more priorities.

c. Determining the Promethee II type

This study makes use of the linear preference criteria – type III with the $H(d)$ function for the preference function presented in figure 3 below:

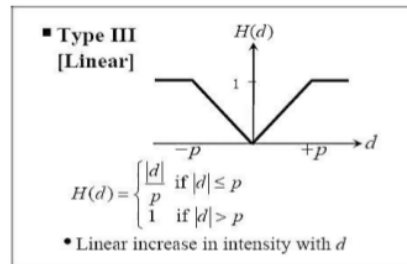


Figure 3. Linear preference criteria (type III)

As long as the deviation value (d) has a lower value than the p limitation, the preference $H(d)$ of the decision maker increases linearly with the d value. If the d value is greater than the value of p limitation, there is an absolute preference for $H(d)$. The procedures of the stages for the implementation of Promethee II are as follows:

- Determine the type of analysis and threshold of Promethee II.
The preference threshold (p) is the smallest or the biggest deviation that is considered sufficient to generate full preference.
- Make an evaluation table.
The results of criterion data analysis, criterion weight, threshold and Promethee II types are made in one table as in the example table 3 as follows:

Table 3. Evaluation Data

Criterion	min or max	a_1	a_2	a_3	...	a_n	criterion type	parameters
f_1	min/max	fx_1	fx_2	fx_3	...	fx_n	PIII	p
f_2	min/max	fy_1	fy_2	fy_3	...	fy_n	PIII	p
f_3	min/max	fz_1	fz_2	fz_3	...	fz_n	PIII	p
...
f_n	min/max	fv_1	fv_2	fv_3	...	fv_n	Pn	$q/p/\sigma$

Assume $w_i = \dots$

- Calculate criteria deviation between alternatives
Calculate the criteria deviation between alternatives $\{d = F(a) - F(b)\}$, its result will be used to determine the value of $H(d)$ in accordance with the provisions of Type III.
- d. Inputting the weighting scenario to the Visual Promethee Software from the result step b, c.
- e. Inputting the criterion value to the Visual Promethee Software from the result step a.
- f. Processing the calculation of priority weights with the Visual Promethee Software.
- g. Analyzing the results of the priority weight handling of the bridge.

3. Results and Discussion

This study was observed with a questionnaire and the 2018 secondary existing data for the 2019 bridge handling.

3.1 The Result of the AHP method

From the AHP method, the values are according to the stages of the study as follows:

- a. Test data consistency is done by calculating the consistency vector values in table 4 below:

Table 4. Consistency vector

	K1	K2	K3	K4	K5	K6	K7	W	M1	M1/W
K1	1.00	2.72	3.43	2.51	3.83	4.04	2.38	0.31	2.3336	7.6170
K2	0.37	1.00	0.85	3.28	3.14	3.88	1.76	0.19	1.4784	7.6614
K3	0.29	1.18	1.00	0.42	2.44	2.62	1.17	0.12	0.9142	7.4338
K4	0.40	0.30	2.40	1.00	2.89	2.45	1.40	0.15	1.0775	7.4035
K5	0.26	0.32	0.41	0.35	1.00	0.83	0.30	0.05	0.3766	7.3215
K6	0.25	0.26	0.38	0.41	1.21	1.00	0.30	0.05	0.3851	7.2792
K7	0.42	0.57	0.86	0.72	3.28	3.37	1.00	0.13	0.9226	7.2180

From the previous table the consistency index and consistency ratio calculation is as follows :

$$\lambda = \Sigma (M1/W)/7 = 7.4192$$

$$CI = \frac{(7.4192 - 7)}{(7 - 1)} = 0.0699$$

Because the number of orders is 7, the value of RI is 1.32, the value of CR = $0.0699 / 1.32 = 0.0529$. Hence, because the CR value is $0.0529 < 0.1$, it is considered consistent and acceptable.

- b. The weight criteria are highest with a value of 0.31. It can be seen in figure 4 below:

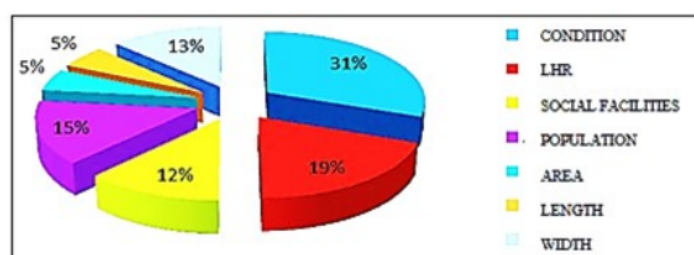


Figure 4. Priority criteria weight

3.2 Criteria evaluation

The research object was the 20 bridge proposals from the Bina Marga planning section and the Public Works Office which was projected to enter Kudus District for the 2019 Fiscal Year. The research data showed a lot of severely damaged bridges (10), lightly damaged bridges (3), mildly damaged bridges (6) and one bridge in good condition.

The Ngelo - Dau 10 Bridge had the highest ADT value of 611.21 skr / hour while the Cranggang Wetan - Tergo 01 Bridge which is located in the Tergo Village, Dawe Subdistrict, had the lowest ADT value of 82.04 Skr/hour. The largest number of public and social facilities recorded were 104 units in

the vicinity of Gondangmanis - Margorejo 02 Bridge and the least recorded was 12 units which were found around the Babalan - Batas Pati 02 Bridge location. The largest population that was recorded is 16,489 people and is located around the Gondangmanis -Margorejo 02 Bridge and the smallest population that was recorded is 1,020 people around the Berugenjang - Wonosoco 03 Bridge.

The largest area recorded is 1,024 Ha at the Kesambi - Bulungcangkring 07 Bridge and the smallest area recorded is 152 Ha at the Tergo location - Glagah 02 Bridge. The longest bridge is 68.50 meters, the Bae - Besito 01 (Karangsambung) Bridge and the shortest bridges recorded were 2.10 meters which are the Bonalas - Besito 01 Bridge and the Lingkar Tenggara – Gulang Bridge. The widest bridge recorded is 5.40 meters which are the Tergo - Glagah 02 Bridge and the narrowest bridge recorded is 1.80 meters which are the Dk. Karangmalang - Dk. Gambir Bridge. The values according to the criterion used secondary data is seen below in table 5:

Table 5. The criteria values of each bridge recapitulation

No.	Bridges name	Condition values	ADT (skr/hour)	Public social facilities (Unit)	Population (person)	Wide areas (Ha)	length (m)	width (m)	Handling plans
1	Cranggang Wetan - Tergo 01 Bridge	1	82.04	34	3613	341.00	10.50	4.20	Routine
2	Blolo- Nganti Bridge	3	111.93	26	5884	174.12	5.00	2.50	Rehabilitation / replacement
3	Ngembalrejo - Kemangkrompol Bridge	2	281.06	61	9398	268.27	12.80	3.20	Rehabilitation / replacement
4	Kesambi - Bulungcangkring 07 Bridge	1	153.00	46	12941	1024.00	6.00	3.60	Routine
5	Ngelo - Dau 10 Bridge	3	611.21	51	9511	502.83	50.40	4.50	Rehabilitation / replacement
6	Klaling - Tanjungrejo 05 (Merah) Bridge	3	606.85	57	11065	734.33	47.00	3.00	Rehabilitation / replacement
7	Bae - Besito 01 (Karangsambung) Bridge	3	514.66	55	8917	338.53	68.50	2.80	Rehabilitation / replacement
8	Jojo - Kesambi 01 Bridge	2	92.78	26	7933	324.69	11.40	2.10	Rehabilitation / replacement
9	Lingkar Tenggara - Kirig 02 Bridge	0	182.02	43	5402	356.00	10.25	4.40	Routine
10	Sidorekso - Kedungdowo 10 Bridge	3	544.90	30	5880	289.50	54.00	3.20	Rehabilitation / replacement
11	Besito - Karangmalang 02 Bridge	3	218.68	50	9415	262.30	6.00	3.60	Rehabilitation / replacement
12	Bae - Kadilangon (Karangdowo) Bridge	3	158.39	55	8917	338.53	3.00	3.00	Rehabilitation / replacement
13	Gondangmanis - Margorejo 02 Bridge	1	552.01	104	16489	556.59	12.00	3.30	Routine
14	Bonalas - Besito 01 Bridge	3	144.10	50	9415	262.30	2.10	2.50	Rehabilitation / replacement
15	Tergo - Glagah 02 Bridge	3	523.25	13	2049	152.00	25.00	5.40	Rehabilitation / Replacement
16	Lingkar Tenggara- Gulang Bridge	1	343.82	68	7194	515.71	2.10	3.50	Routine
17	Dk. Karangmalang - Dk. Gambir Bridge	2	153.72	50	9415	262.30	17.20	1.80	Rehabilitation / replacement
18	Karangbener - Ngelo 03 Bridge	1	86.35	55	7423	392.98	22.00	2.60	Routine
19	Babalan - Batas Pati 02 Bridge	1	244.04	12	1262	226.75	10.00	3.50	Routine
20	Berugenjang -	3	141.93	14	1020	542.42	23.50	3.10	Rehabilitation

Wonosoco 03 Bridge

/ replacement

From the data of the criteria value, the threshold value (p) can be determined as follows:

- Condition values criterion $d = 3 - 0 = 3$ then $p = 4$ is taken
- ADT criteria $d = 611.21 - 82.04 = 529.17$ then the value of $p = 550$ is taken
- Public and social facilities criterion $d = 104 - 12 = 92$ then $p = 95$ is taken
- Population number criterion $d = 16489 - 1020 = 15469$ then $p = 15500$ is taken
- Area size criterion $d = 1024 - 152 = 872$ then the value of $p = 900$ is taken
- Bridge length criterion $d = 68.50 - 2.10 = 66.40$ then $p = 70$ is taken
- Bridge width criterion $d = 5.40 - 1.80 = 3.60$ then $p = 4$ is taken

From the data of the criteria value, the threshold value (p) can be determined from calculating the biggest difference in the value of each criterion to determine the value of H (d) in accordance with the provisions of Type III.

3.3 Results of Promethee II method

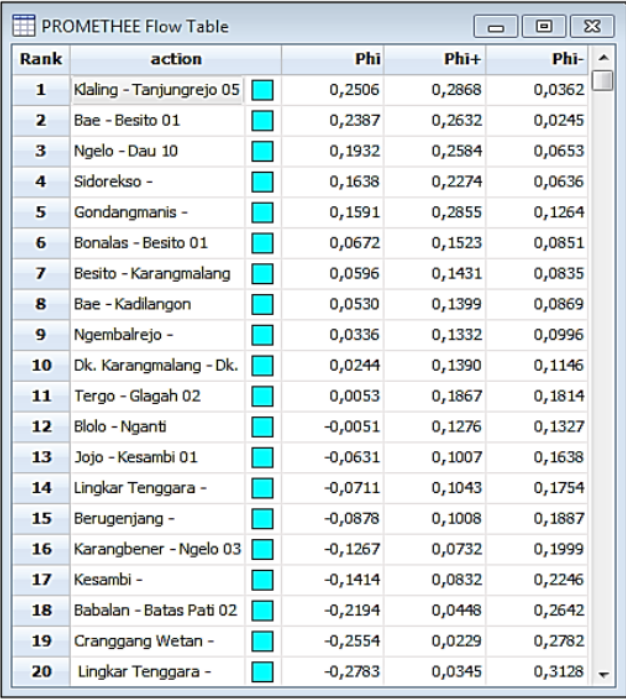
Promethee II method make the process of weighting priority more easier with only a few level questionnaire. From this case with 20 alternatives, 200 questionnaire needed to answer by using the AHP method only. By using the Promethee II method, it can 28 questionnaires needed to answer.

3.3.1. Preference scenario. According to the stages of Promethee II, it inputs data for value p. The weighting criteria and priority are applied to obtain the Maximum criteria value, Maximum LHR, Maximum Fasum-Fasos, Maximum Population Number, Minimum Area width, Maximum Bridge Length and the Minimum Bridge Width values from the Visual Promethee Software. As shown below in figure 5:

Scenario1	Nilai Kondisi	LHR	Fasumsos	Jml Penduduk	Luas Wilayah	P Jembatan	L Jembatan
Unit	skr/jam	unit	unit	jiwa	Ha	m	m
Cluster/Group							
Preferences							
Min/Max	max	max	max	max	min	max	min
Weight	0,31	0,19	0,12	0,15	0,05	0,05	0,13
Preference Fn.	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape	V-shape
Thresholds	absolute	absolute	absolute	absolute	absolute	absolute	absolute
- Q: Indifference	n/a	n/a	n/a	n/a	n/a	n/a	n/a
- P: Preference	4,00	550,00	95,00	15500,00	900,00	70,00	4,00
- S: Gaussian	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Statistics							
Minimum	0,00	82,04	12,00	1020,00	152,00	2,10	1,80
Maximum	3,00	611,21	104,00	16489,00	1024,00	68,50	4,50
Average	2,10	287,34	45,00	7657,15	393,26	18,84	3,21
Standard Dev.	0,99	189,34	21,18	3747,90	202,08	19,32	0,70

Figure 5. Data input of weight scenario

3.3.2. *Research Discussion.* The result from the Visual Promethee Software is shown in the order of the priority weights as shown in figure 6 below :



Rank	action	Phi	Phi+	Phi-
1	Klaling - Tanjungrejo 05	0,2506	0,2868	0,0362
2	Bae - Besito 01	0,2387	0,2632	0,0245
3	Ngelo - Dau 10	0,1932	0,2584	0,0653
4	Sidorekso -	0,1638	0,2274	0,0636
5	Gondangmanis -	0,1591	0,2855	0,1264
6	Bonalas - Besito 01	0,0672	0,1523	0,0851
7	Besito - Karangmalang	0,0596	0,1431	0,0835
8	Bae - Kadilangon	0,0530	0,1399	0,0869
9	Ngembalrejo -	0,0336	0,1332	0,0996
10	Dk. Karangmalang - Dk.	0,0244	0,1390	0,1146
11	Tergo - Glagah 02	0,0053	0,1867	0,1814
12	Blolo - Nganti	-0,0051	0,1276	0,1327
13	Jojo - Kesambi 01	-0,0631	0,1007	0,1638
14	Lingkar Tenggara -	-0,0711	0,1043	0,1754
15	Beruganjang -	-0,0878	0,1008	0,1887
16	Karangbener - Ngelo 03	-0,1267	0,0732	0,1999
17	Kesambi -	-0,1414	0,0832	0,2246
18	Babalan - Batas Pati 02	-0,2194	0,0448	0,2642
19	Cranggang Wetan -	-0,2554	0,0229	0,2782
20	Lingkar Tenggara -	-0,2783	0,0345	0,3128

Figure 6. Order of priority weights

The main priority is the 8 severely damaged bridges. The highest weight priority is Klaling – Tanjungrejo 05 Bridge. However, two severely damaged bridges were not included in the top 10 list of damaged bridges. The two bridge alternatives should still be in priority even though the value of the other criteria is not high. Studying the configuration of all criteria weights produced by the AHP method, including the condition of the bridge with 0.31 weight, it appears that the condition of the weight is less than half of the total weight of other criteria. Hence, even though having the biggest weight value is not a major factor considered because other criteria weights are also important, this could be why the 2 severely damaged bridges were not included in the top priority list. The next possible scenario is the criteria being too small which prevent the alternative bridge from receiving the absolute value for the criteria. With the existing scenario, the maximum value of the priority weight of the bridge criteria is just 0.23, while the total value of the other criteria weight is 0.67, so, these exclude the alternative bridges from inclusion into the top priority list for handling bridges in Kudus district.

From the calculation of the weight criteria, the biggest weight measured is 0.31 which is shown in the results of the paired questionnaires, and it is considered as the main weight for determining the priority weights. Other studies with the same AHP method also mentions these criteria has the greatest weight compared to others. This report received 0.3793 of the criteria weights condition, and this is the highest weight of the 3 criteria used [10]. Another report also shows a similar value with 0.491 [11]. In the study, it explains that the weight criterion condition is the highest weight of the 6 criterions and has a value of about 0.367 [12]. From the three studies, the weight of the ideal criteria is approximately 0.40. Hence, the condition criteria weight is 0.31 which is the highest weight of the 7 criterion used in

weighting the priority of the Promethee II. This research does not fully explain the condition criteria as the main factor in the priority weighting process.

4. Conclusion

The AHP method produces more consistent weighting criteria, and the result of the condition weight was 0.31, the ADT weight was 0.19, the weight of the number of public and social facilities was 0.12, the weight of the population was 0.15, the weight of the area was 0.05, the weight of the bridge length was 0.05 and the weight of the bridge width was 0.13. Furthermore, the Promethee II method makes the process of priority weighting more dynamic and easier by reducing much questionnaire from the AHP method. The main priority was the 8 severely damaged. The highest weight priority was the Klaling – Tanjungejo 05 bridge.

To achieve a ranking priority of bridge handling according to the characteristics of the bridge data, the condition criteria was used as the main factor which ranks the highest priority weight level as 0.40 and the threshold (p) value which produces an absolute value of the weight priority.

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