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Analysis on the Implementation of Analytic Hierarchy Process and Decision Tree C4.5 to Support Priority Determination in the Maintenance of Bridge in Lumajang

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Abstract

According to the data provided by the Department of Public Works and Spatial Planning of Lumajang District, there is a gap between the amounts of ideal annual bridge maintenance (8 units) and the realization of such maintenance (3 units), accordingly priorities shall be determined in bridge maintenance to enable those bridges to be used as it should. This research will integrate Machine Learning Decision Tree with AHP based upon the BMS evaluating standard to obtain the Supporting System of Priority Determination in the Maintenance of Bridge in Lumajang. The result of this study shows that the criteria of bridge within the evaluation are Bridge Condition with a value of 44%, Traffic Volume 14,72%, Policy 15,92%, Land Use with a 5,59% value, and Social 19,76%. Further, by the support of Decision Tree C4.5 process, it was obtained that the parameter of foundation in Bridge Condition criteria has the highest value.

Keywords: AHP Method; Decision Tree C4.5 Method; Priority Determination.

1. Introduction

Bridge is a construction which function is to continue the road passing through certain obstacles located in a lower position.

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These obstacles usually appear in a form of water way or normal traffic. Bridges located above traffic road is usually called viaduct [1]. Hence, bridge has an important role in maintaining the flow within the road network, and according this building structure requires a special maintenance. In 2017, Lumajang District has a Local Government Budget (APBD) as much as Rp. 2.126.022.707.107 with the cost breakdown of (1) Direct expenditure as much as Rp. 848.560.136.508 (39,91%), (2) Capital expenditure as much as Rp. 323.230.479.684 (15,20%) (3) Road, Irrigation and Network Expenditure as much as Rp. 95.016.291.000 (4,46%) [2]. Local Government Budget allocated for bridge maintenance had been used in 2 bridge construction activities and 1 bridge rehabilitation activity [3]. Meanwhile, Lumajang District has 419 units of bridge with the average building age of ± 50 years. This condition shows that the ideal amount of annual bridge maintenance shall fulfill 8 units of bridge to be maintained, both in construction and [4]. According to the data provided by the Department of Public Works and Spatial Planning of Lumajang District, there is a gap between the ideal amount of annual bridge maintenance (8 units) and the realization of such numbers (3 units), accordingly it requires a priority determination of bridge maintenance so that all bridges could be used as its functions. In determining the priority of a problem can use Analytic Hierarchy Proces (AHP) can be used to combine priorities for all levels of hierarchy including levels representing alternatives [5]. According to Thomas L. Saaty AHP can be used as a measurement to get priority scale in a problem [6]. In Saksiri Meesawad's research and his colleagues in 2019 integrated machine learning with AHP which aims to provide tools to help stakeholders make complex decisions in the industrial world[7]. Other researchers Erick Lima and his colleagues in 2019 combined machine learning (Bayesian Network) and AHP for decision making, in this study machine learning was used to bring greater reliability to the weights applied to AHP[8]. As for assessing bridge damage can be determined using bridge management system (BMS) assessment standards, as in research conducted by Asrul Nurdin and his colleagues [9], entitled "Determination of the bridge maintenance and rehabilitation priority scale in Pinrang Regency" using BMS to determine the scale of bridge maintenance and rehabilitation priorities. This research will integrate Machine Learning Decision Tree C4.5 with Analytical Hierarchy Process according to the evaluating standard of Bridge Management System (BMS) to obtain a Supporting System of Priority Determination in the Maintenance of Bridge in Lumajang. Decision Tree is a form of easily operated Machine Learning as it is using a tree as an illustration in the decision making, it is also compatible for categorical type of data according to the purpose of this research. AHP Method is used to determine the local and global value of the variables, while the Machine Learning Decision Tree C4.5 is used to classify the bridges into output class (for further action) from the priorities obtained by the AHP. Output class comprises of Routine Maintenance, Periodical Maintenance, Rehabilitation, or Replacement according to the BMS evaluating standard.

2. Materials and Methods

2.1. Preliminary Study

The research location is in the bridge along the district road within the authority of the Department of Public Works and Spatial Planning which has a steel frame structure or composite with a minimum range of 10 meters as much as 40 units. This research is done in 2020. The bridge that is assessed is a district bridge that is the authority of the Public Works and Spatial Office of Lumajang Regency with a span of at least 10 meters and a structure in the form of a steel or composite frame and assessment of the bridge based on the condition of the structure, floor condition, backrest condition, foundation condition and condition of the head of the bridge.

2.2. Reaserch Variable

The criteria of Analytic Hierarchy Process used in this research comprises of criteria related to the background of bridge maintenance priority in Lumajang District. The criteria of this research will further be formulated in a form of hierarchy after obtaining the secondary data. In this research, the organization of hierarchy levels used in the Analytical Hierarchy Process (AHP) comprises of 4 (four) levels, namely:

- Level I (purpose) is to determine the priority of bridge which requires maintenance by routine, periodical, rehabilitation as well as construction of bridge (replacement).
- Level II (criteria) comprises of several criteria in determining the priority of bridge. The chosen criteria are the parameters referring to the Sustainable Development Goals (SDGs). This program is United Nation's program which has been concluded by over 130 states to combat poverty, health issues, elevate the standard of education and other goals [10]. SDGs program is supported by economic, social, and environment pillars. Those criteria are: Bridge Condition Factors (A) which is considered as technical factor, Traffic Volume Factor (B) which is included in economic pillar, Land Use Factor (C) which is considered as environment pillar, Policy Factors (D) and Social Factor (total population and public facilities) (E) which is included in the social pillar.
- Level III (Expansion from the Level II, which will further be addressed as sub-criteria).

Bridge Condition Factor (A), which is the evaluation based on Level 2 of Bridge Management System Level 2 aktor Kondisi Jembatan (A), yaitu penilaian berdasarkan Bridge Management System Level 2 [11,12]:

- Main Girder
- Abutment
- Pillars
- Deck
- Bridge Bearing
- Pedestal
- Bridge Wing Wall
- Bridge Back Wall
- Girder
- Joint
- Surface Layer
- Sidewalk

Traffic Volume Factors (B), this factor is chosen based upon the possible velocity of the passing vehicles [12]:

- <50 pcu/hour
- 51-200 pcu/hour
- 201-500 pcu/hour
- >500 pcu/hour

Land Use Factor (C) this factor is chosen based upon the consideration of preservation area stipulated in the Regional Spatial Plans of Lumajang District 2012-2032 [13]:

- Agricultural Area
- Designated Mining Area
- Designated Industrial Area
- Designated Tourism Area

Policy Factor (D), policy factor is chosen based upon the Strategic Plan and Work Plan 2014 – 2019 of the East Java Public Works Department and based upon the Act No. 25 of 2004 on the National Development Planning System[14,15]:

- District Musrenbang
- Advices of the Regional Apparatus Organization
- Council's Aspirationusrenbang Kecamatan

Social Factor (E), is a factor chosen based upon the total amount of people who obtain benefits from the existing bridge, or direct impact by the people [16]:

- Number of People Served
- Number of Public Facilities
- Level IV (alternative), is the bridges in the district road within the authority of Public Works and Spatial Planning Department with a steel frame structure or composite with a minimum range of 10 meters. This type of bridge is considered as high risk in experiencing damage and therefore requires continuous monitoring. In Lumajang District, there are 40 units of bridges within these criteria.

The organization of hierarchy level which comprises of 4 (four) levels will be shown in Figure 1.

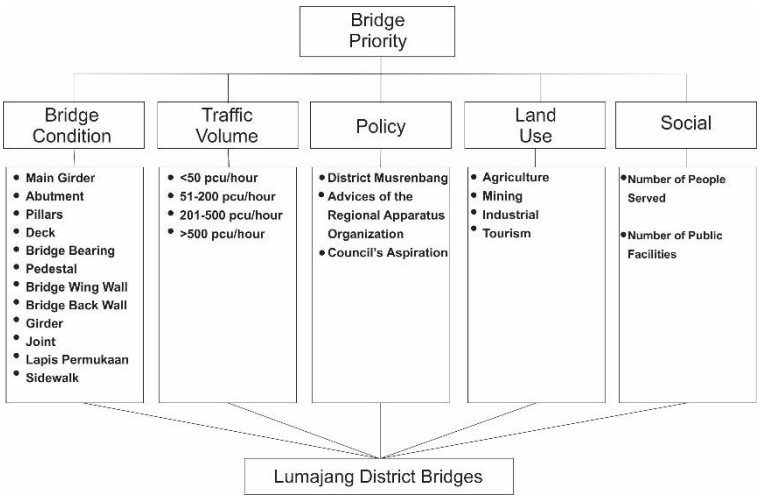


Figure 1: The organization of hierarchy level with AHP

In the Decision Tree C4.5 method, there will be bridge classification in 5 classes, which are: (1) Routine Maintenance, (2) Periodical Maintenance, (3) Rehabilitation and/or Strengthening, (4) Retrofitting or Replacement, (5) Replacement. The steps in bridge classification to support the decision making in Decision Tree C4.5 method are as follows:

- Data Preparation
- Data Preprocessing
- Decision Tree C4.5 implementation
- Entropy Value Calculation with Equation 1[17].

$$Entropy(S) = \sum_{i=1}^{c} Pi\ log_2\ Pi \qquad (1)$$

- Gain Value Calculation with Equation 2[17].

$$Gain(S, A) = Entropy(S) \sum_{v \epsilon Values(A)} \frac{|S_v|}{|S|} Entropy(S_v) \qquad (2)$$

The flow of implementation to classify further actions towards the bridges using Decision Tree C4.5 method is explained in Figure 2 as follows.

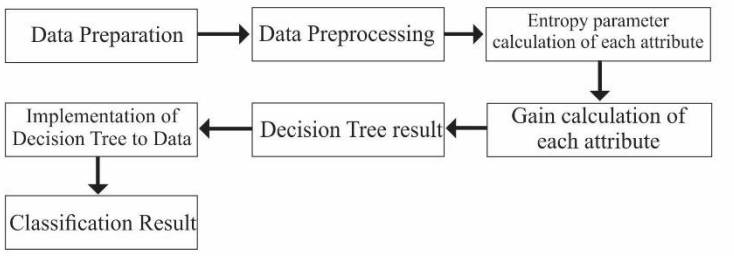
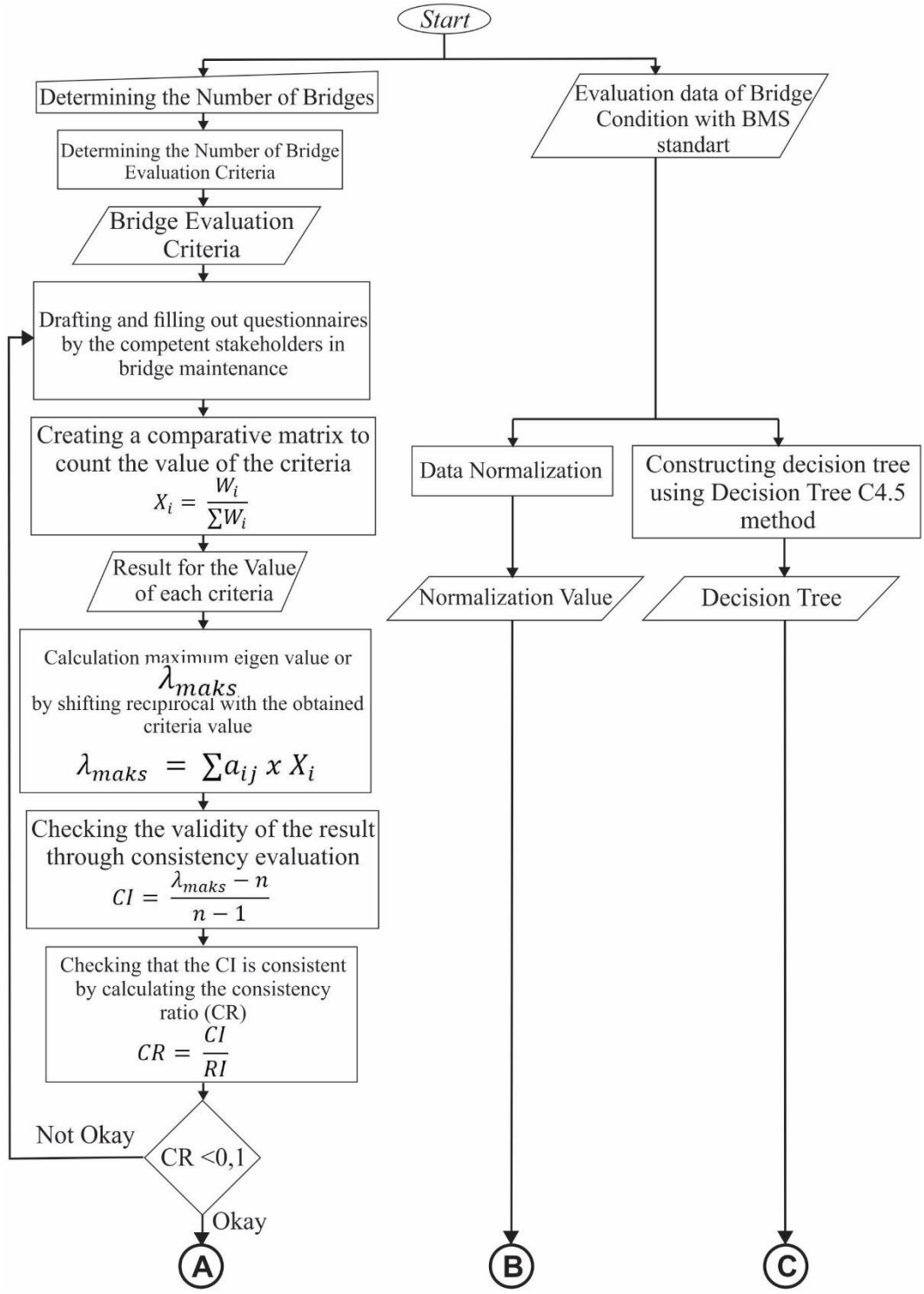


Figure 2: The flow of implementation to classify with Decision Tree C4.5

2.3. Data Analysis

The mechanism of this research starts by conducting a preliminary study to create an overview of study area, literature review, data identification, and software used. From the preliminary study, there will be an identification of issues to construct the background of the issue, formulation of the issue, purpose of the research, and scope of the issue in the research. Furthermore, there will be a collection of primary and secondary data. Primary data in this research is obtained through questionnaire or interview with competent stakeholders in bridge maintenance in Lumajang District. Meanwhile, the secondary data is obtained from the bridge condition date in Lumajang District in the fiscal year 2018 as well as Decree Number 188.45/89/427.12/2017 on the Status and Classes of Lumajang District Road. The next step is to rank the bridge maintenance with Analytical Hierarchy Process (AHP) method starting by organizing the hierarchy by determining the variables and sub-

variables. Furthermore, analysis of value in determining the bridge priority scale will be conducted with AHP method. The valuing result with AHP method will be used as the data to rank the bridge maintenance priority. Meanwhile the Decision Tree is used to classify the bridges into bridge maintenance classes according to the BMS evaluating standard. Those classifications are Routine Maintenance, Periodical Maintenance, Rehabilitation, or Replacement. The decision on priority from the AHP priority and on the bridge maintenance from the Decision Tree will be used as a reference for bridge maintenance in Lumajang District. The steps of this research are illustrated in a flow chart as shown in Figure 3.



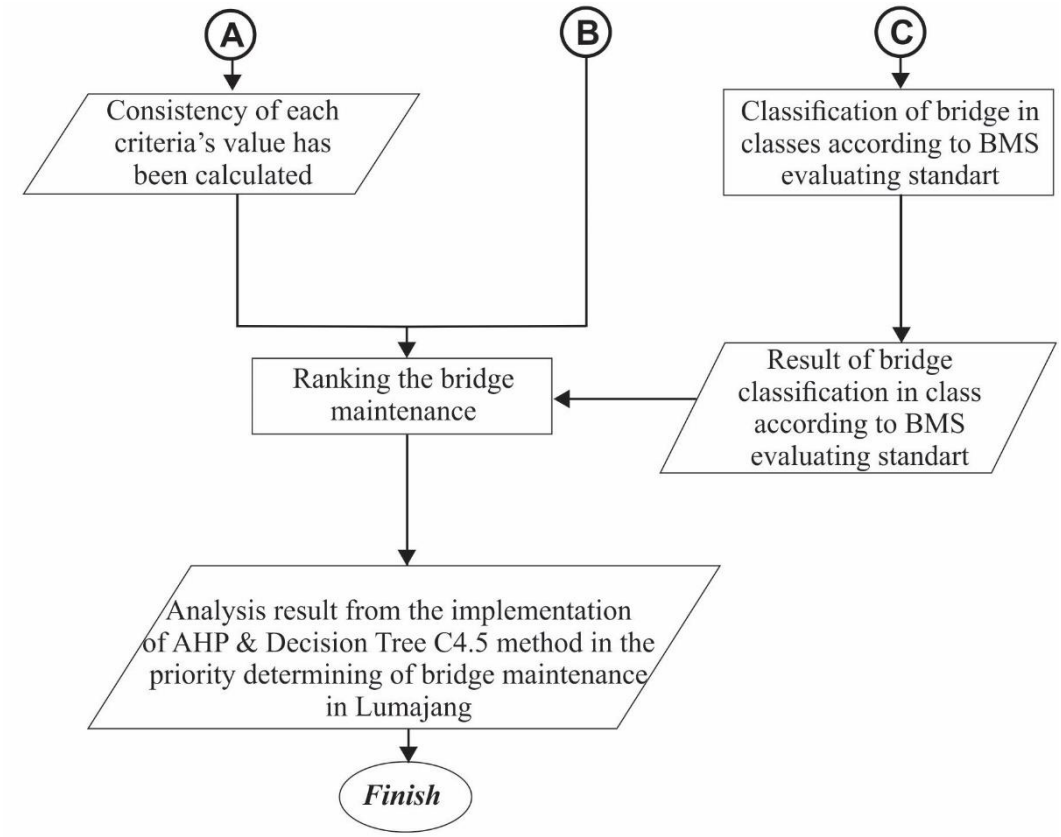


Figure 3: The steps of this research

3. Result and Discussion

3.1. Valuing analysis with AHP Method

In this research, primary data was obtained by distributing questionnaire to several sources. The distribution of questionnaires to 40 (forty) respondents was chosen purposively, which is the determination of respondent by consideration of condition that respondents must possess knowledge and competence in bridge maintenance.

3.1.1. Criteria Valuing

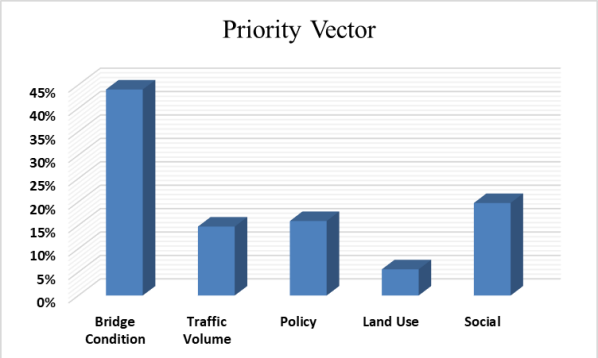


Figure 4: The valuing results from all criteria

Valuing AHP criteria based upon the questionnaire result was done by comparing the number of urgency from each Bridge Condition, Traffic Volume, Land Use, and Social. The valuing results from all 5 of those criteria are explained in Figure 4.

In Picture 4, it can be seen that the value of AHP variables result according to respondents' opinion show that Bridge Condition has bigger value compared to other variables. Bridge Condition variable has a dominating AHP ratio in the percentage of 44%, while Traffic Volume variable has 14,72%, Policy variable has 15,92%, Land Use variable has 5,59%, and Social variable has 19,76%. Through the counting of Eigen and Consistency Index, 0,0328 consistency ratio was obtained. This CR number was counted to measure the consistency rate of each respondent's evaluation. As the CR value is 0,0328 < 0,1 accordingly the CR value of "Criteria" in this research is acceptable[18].

3.1.2. Sub-Criteria Valuing

Sub-criteria are factors which affects the aforementioned criteria. The following sub-criteria also have values which were obtained from the questionnaire of the respondent. Those sub-criteria are as follows:

- Traffic Volume Factor

Priority vector of Traffic Volume < 50 pcu/ hour is 17,6%, Traffic Volume 51-200 pcu/ hour is 27,63%, Traffic Volume 201 – 500 pcu/ hour is 26,55%, and Traffic Volume > 500 pcu/ hour is 28,67%. Therefore, it can be concluded that Traffic Volume > 500 pcu/ hour is the factor with the most impact in Traffic Volume Criteria. Traffic Volume sub-criteria has a consistency ratio of 0,0082.

- Policy Factor

Priority vector of District Musrenbang is 65,73%, Advice from the Regional Apparatus Organization is 22,77%, and Council's Aspiration is 11,5%. Therefore, it can be concluded that District Musrenbanghas the highest impact in Policy criteria. Policy sub-criteria has a consistency ratio of 0,085.

- Land Use Factor

Priority vector of Agriculture is 47,3%, Mining is 21,25%, Industry is 15,08% and Tourism is 16,36%. Therefore, it can be concluded that Agriculture has the most impact in Land Use criteria. Land Use sub-criteria has a consistency ratio of 0,0824.

- Social Factor

Prirority vector from the Number of People Served is 75% and the Number of Public Facility is 25%. Therefore, it can be concluded that the number of people served has the highest impact in social criteria. Social sub-criteria has a consistency ratio of 0,00.

3.2. Implementation of Decision Tree C4.5

In this phase, the number of emerging case in each output class will be calculated. Those 5 output classes are: 1 (Routine Maintenance), 2 (Periodical Maintenance), 3 (Rehabilitation and/or Strengthening), 4 (Strengthening or Replacement) and 5 (Replacement). Output class in this phase is in accordance with the evaluation of the bridge condition based upon the existing BMS standard. Evaluation in the implementation of Decision Tree C4.5 is to determine the urgency seen from the Bridge Condition and other factors related to the Bridge Condition, namely: superstructure, substructure, deck, and foundation. Based upon the result of Decision Tree C4.5 process, this research has shown that the attribute of "Substructure" is the root of the decision tree, which is illustrated in Figure 5.

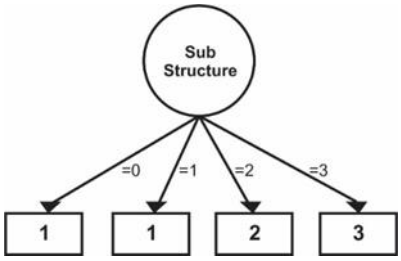


Figure 5: Ilustration of a Decision Tree C4.5

3.3. Integration of AHP and Decision Tree C4.5

The implementation of AHP model resulted in the Consistency Ratio (CR) value of 0,03 for Bridge Condition, 0,008 for Traffic Volume, 0,08 for Policy, 0,08 for Area and 0,00 for Social. This CR value is calculated to determine the consistency of the respondents' evaluation. As the CR value is < 0,1, accordingly the CR value of the "Criteria" are sufficient, equivalent to the research (Rajasekhar and his colleagues 2019) with the CR value of 0,08, it can already be considered to have a high level of consistency in each criteria. Furhtermore, after the AHP result is obtained, the Decision Tree C4.5 process is used to classify the bridges into classes of bridge maintenance according to the guidelines (Binamarga, 1993). In the implementation of Decision Tree C4.5, the researcher calculates the accuracy rate from the method by using WEKA software, with a 10 cross fold validation scenario towards 40 bridge data. The result obtained from this method has the highest level of accuracy as much as 97,5%, with a 98,3% precision and 97,5% recall. The accuracy, precision, and recall values are already sufficient to be the source of consideration in decision making [19].

The factors impacting the evaluation on the bridge are bridge condition variable, traffic volume variable, policy variable, land use variable, and social variable. The bridge evaluation result from the Analytic Hierarchy Process shows the priority vectors or values of each variable as follows:

- Bridge Condition : 44%
- Traffic Volume : 14,72%

- Policy : 15,92%
- Land Use : 5,59%
- Sosial : 19,76%

The value of each variable as presented above then resulted in a bridge preference value to determine the bridge priority. The preference values of each bridge are as presented in Table 1.

Table 1: The value of the weight preference

No.	Bridge Name	Preference Value from AHP Value	Decision Tree C4.5 Classification
1	BESUK SEMUT	0.8629	Routine Maintenance
2	MUJUR 1	0.7801	Routine Maintenance
3	SUDIMORO	0.9029	Routine Maintenance
4	BESUK KLOPO SAWIT 1	0.8006	Routine Maintenance
5	PONDOKAN KLOPOSAWIT 1	0.7407	Routine Maintenance
6	KALI TUGU	0.8559	Routine Maintenance
7	MANGLI	0.9221	Routine Maintenance
8	ROJOPOLO	0.8428	Routine Maintenance
9	SEMBON	0.8617	Routine Maintenance
10	JATIROTO	1.1551	Periodical Maintenance
11	JAJANG MULYO	0.1798	Routine Maintenance
12	UMPAK I	0.1743	Routine Maintenance
13	KRAJAN I	0.1743	Routine Maintenance
14	KRASAK	0.2217	Routine Maintenance
15	BONDOYUDO DAWUHAN WETAN 1	0.8159	Routine Maintenance
16	TANGKEL	1.3494	Periodical Maintenance
17	KALI CURAH MENJANGAN	0.7855	Routine Maintenance
18	BABIAN	0.8644	Routine Maintenance
19	ROJALI	0.3682	Routine Maintenance
20	DUREK PASIRIAN 2	0.3239	Routine Maintenance
21	KALI MUJUR GESANG 1	0.2896	Routine Maintenance
22	LATENG KERTOSARI 1	0.2002	Routine Maintenance
23	IRENG - IRENG SENDURO 1	0.2521	Routine Maintenance
24	KARANG ANOM	0.2322	Routine Maintenance
25	SUMBER BULUS	0.3039	Routine Maintenance
26	CAMPURAN	1.3676	Periodical Maintenance
27	KEJEMAN	0.7536	Routine Maintenance
28	WATES WETAN 2	0.7478	Routine Maintenance
29	WATES KULON	0.8166	Routine Maintenance
30	NOGOSARI	0.8499	Routine Maintenance
31	BURNO	1.4605	Periodical

No.	Bridge Name	Preference Value from AHP Value	Decision Tree C4.5 Classification
			Maintenance
32	IRENG - IRENG BURNO 1	1.9320	Rehabilitation and/or Strengthening
33	CURAH KEBO	2.1405	Rehabilitation and/or Strengthening
34	KANDANGAN 1	0.7521	Routine Maintenance
35	MENJANGAN BEDAYU TALANG 1	1.3678	Periodical Maintenance
36	URANG GANTUNG	0.7858	Routine Maintenance
37	KALI ASEM MOJOSARI 1	0.1920	Routine Maintenance
38	BULUREJO	0.1405	Routine Maintenance
39	KALI PIRI 1	0.2095	Routine Maintenance
40	SUKOSARI	0.1285	Routine Maintenance

In this research, Curah Kebo Bridge in Senduro District, Senduro – Kandangan Road, has the highest priority rate for further action. This is due to the high preference value of Curah Kebo Bridge for the "Bridge Condition" variable. In this research, "Bridge Condition" variable has the highest value of all variables as it has the most impact on the overall service functioning of the bridge, in which why this [9][20] shows that the "Bridge Condition" variable has the highest value.

4. Conclusion

a. Bridge variables used in the evaluation are Bridge Condition, Traffic Volume, Policy, Land Use and Social.
b. Evaluation of bridge variable from the Analytic Hierarchy Process has resulted in priority vector or value for each variable, which are as follows:

- Bridge Condition : 44%
- Traffic Volume :14,72%
- Policy :15,92%
- Land Use :5,59%
- Social :19,76%

Supported by Decision Tree C4.5 process by using Information Gain Ranking Filter to attribute evaluator and ranker method, it was obtained that the parameter of "Substructure" in Bridge Condition has the highest value.

c. The implementation of Analytic Hierarchy Process and Machine Learning to support the decision making has resulted in prioritizing Curah Kebo Bridge in Senduro district, Senduro – Kandangan, which has the highest preference value, which further shows that this model is applicable in supporting the priority determining of bridge maintenance in Lumajang.

5. Suggestion

The authors recognize that this research needs to be a development in order to improve this research in the future. Here's what to develop :

1. With a total of 40 bridge data and obtained the result of accuracy rate of 97.5% can be found there is 1 misclassification by decision tree method C4.5. Developers can use ensembling methods to improve accuracy.

2. Developers can build systems to predict other bridges by using weights and tree decisions from this study.

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