Priority Determination of Repairing Embankment Dam using Analytical Hierarchy Process (AHP), Case Studies: Saguling Dam and Djuanda Dam

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Abstract. Damage to the body of the dam requires fast handling, so it is necessary to repair the damage. But with a lot of damage and limited funds, a priority is needed to improve the damage to be repaired first. The research objective is to identify damages to the body of the dam based on visual and instrumentation inspection, make an assessment using the Condition Index method, and determine repair priorities by using the Analytical Hierarchy Process (AHP) method and assisted by the Expert Choice program. The study was conducted at the Saguling Dam and Djuanda Dam. The results showed that the condition index of the body of the Saguling Dam is 4.044 while in the body of the Djuanda Dam is 4.149. The priority for damage repair in the Saguling Dam is sedimentation, while the Djuanda Dam is seepage.

Keywords: repairing, embankment dam, AHP, priority

1. Introduction
A dam is a building in the form of soil, stone, or concrete which is constructed to hold and hold water [1]. The damage occurred on Dam will affect its function and performance. Structural damage is one of the damage that most influences the function and performance of a building [2,3]. In order to maintain the security of the dam and maintain its performance and function, there must be a repairmen actions of the damage to the body of the dam structure [4,5,6]. The number of damages that occur in the body of the dam that needs to be repaired so that it requires a large cost [7,8,9,10], therefore a priority repair system must be carried out to find out which damage can be done first. Based on this, it is necessary to conduct an assessment and prioritize improvement before repairs are made. This paper will show visual inspection of the body of the dam, an assessment of the condition of the body of the dam, and priority on the damage that occurs to the body of the dam.

The case study in this study was at Saguling Dam and Djuanda Dam. The objectives of this study are as follows: (1) identify structural damage that occurs in the body of the dam; (2) determine the assessment of structural damage to the body of the dam; (3) determine the priority of repairs to structural damage to the body of the dam.

2. Research Methods
The methodology in this research is a descriptive qualitative method because the researcher wants to describe the condition of the body of the dam to the structural damage that occurs in each component
of the body of the dam and then an assessment is made to set priorities for repairs to these damages. The flow chart in this study in Figure 1 is as follows

![Flow Chart](image)

**Figure 1.** Research flow chart

3. **Results and Discussion**

3.1. **Visual Inspection on the Body of the Saguling Dam**

Inspection is carried out on the body of the dam, which is the top of the dam, upstream slope, downstream slope, reservoir area, downstream area, right footing, and left footing. Following are the results of a visual inspection carried out at the Saguling Dam.

![Inspection Image](image)

**Figure 2.** Dam Peak Condition of Saguling Dam
Based on the results of a visual inspection of the Saguling Dam, it can be seen that the dam peak is covered with asphalt pavement, and there is a parapet on both sides of the dam's peak. At the top of the dam's surface layer coated with asphalt pavement, there is a crack located in the middle at the top of the dam. In the parapet at the top of the dam, there are cracks. In the parapet on the downstream side of the dam, there is also a crack and also a decrease.

The condition of the upstream slope of the dam is neatly arranged. The surface of the upstream slope is in a flat condition, maintained, and there are no visible damages. The upstream slope surface is coated with rip-rap material. Rip-rap material on the upstream slope consists of igneous rock. The condition of rip-rap material as a whole is in good condition, but some appear to be weathered but only 0.1% of all rip-rap lining the upstream slope.

The conditions of the downstream slope of the dam are neatly arranged. The downstream slope surface is flat, maintained, and there are no visible damages. The downstream slope surface is coated with rip-rap material. Just like on the upstream slope, rip-rap material consists of igneous rock and overall is in good condition but there are some that are weathered.

The condition of the reservoir area is the fish cage aquaculture with a large number scattered in the inundation area of the Saguling Reservoir. There are water hyacinth plants at some point inundated area of the Saguling Reservoir. There are avalanches at various locations on the slopes of the periphery of the inundation area of the Saguling Reservoir. The condition of the downstream area of Saguling Dam, there are no damages that affect the safety of the dam. There are no cracks, nor seepage in the downstream area. There is no instrumentation such as a sliding pole so that it cannot be
measured if there is a decrease or movement in the downstream area of the Saguling Dam. Buildings found in the downstream region are also in good condition and are displaced.

The conditions of the right footing of the Saguling Dam are neatly arranged and in a flat condition, there are no symptoms that harm the body of the dam such as cracks, seepage, and avalanches. The right surface of the upstream part is walled with rock pile protection. The right surface of the downstream is protected by shotcrete protection. The condition of the left footing of the Saguling Dam is neatly arranged and is in flat condition, there are no symptoms that harm the body of the dam such as cracks, seepage, and landslides. The upper and lower right side surfaces are walled with shotcrete protection.

3.2. Assessment of the Saguling Dam Body Condition
Assessment of the condition of the Saguling Dam using the condition index method. Assessment is carried out on the body of the Saguling Dam. The components contained in the body of the Saguling Dam which are the object of assessment are the dam peak, upstream slope, downstream slope, reservoir area, downstream area, right footing, and left footing. In this study condition index criteria are given a 1-5 scale which is determined based on the type of damage consisting of five categories which can be seen in Figure 7.

| No | Component           | Component Weight | Component Condition Index | Condition Index Total |
|----|---------------------|------------------|----------------------------|-----------------------|
| 1  | Dam Peak            | 0.247            | 4                          | 0.988                 |
| 2  | Upstream Slope      | 0.247            | 4                          | 0.988                 |
| 3  | Downstream Slope    | 0.247            | 4                          | 0.988                 |
| 4  | Reservoir Area      | 0.105            | 3                          | 0.315                 |
| 5  | Downstream Area     | 0.067            | 5                          | 0.335                 |
| 6  | Left Footing        | 0.043            | 5                          | 0.215                 |
| 7  | Right Footing       | 0.043            | 5                          | 0.215                 |
|    | Condition Value     | 4.044            |                             |                       |

Table 1 shows the result of an assessment of the condition of the Saguling Dam.

Based on the results of the above calculations, the index value of the body condition of the Saguling Dam has a value of 4.044. With the value of the conditions obtained, the body of the Saguling Dam is in the good condition category, but there are some damages including minor damage and moderate damage.
3.3. **Priority for Improving the Structural Damage of the Saguling Dam**

To determine the priority of damage repair, the initial assessment has been carried out through visual inspection and the results of instrumentation readings. From the two results, then it was discovered what damage was identified on the body of the Saguling Dam which has the potential to disrupt the safety of the dam. Based on the AHP structure and Paired Comparison Matrix, the matrix is created to determine the importance of an alternative to other alternatives. The interest intensity scale can be seen in the following table.

| Intensity of Importance | Definition | Explanation |
|-------------------------|------------|-------------|
| 1                       | Equal importance | Two activities contribute equally to the objective |
| 3                       | Moderate importance | Experience and judgement strongly favor one activity over another |
| 5                       | Strong importance | Experience and judgment strongly favor one activity over another |
| 7                       | Very strong or demonstrated importance | An activity is favoured very strongly over another; its dominance demonstrated in practice |
| 9                       | Extreme importance | The evidence favoring one activity over another is of the highest possible order of affirmation |
| 2, 4, 6, 8              | Values between two close consideration values | This value is given if there are two compromises between two choices |
| Reverse                 | If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i |

Based on the pairwise comparison rating scale, then put into pairwise comparison matrix for each alternative. To determine the priority of repairs to the damages that occur in the body of the Saguling Dam, scoring of each damage is carried out to determine the intensity of the importance of one damage to the other damage. Scoring is based on visual inspection data and secondary data. The following are the results of the priority improvement of structural damage to the Saguling Dam using the AHP method and assisted by the Expert Choice program.

![Figure 8. Priority Results for Improving Structural Damage to the Body of the Saguling Dam](image-url)
Based on the results obtained from the analysis carried out by using the Expert Choice program that was displayed on the Sensitive Graph, the results showed that the priority for repairing damage to the Saguling Dam was sedimentation. Sedimentation is at the top of the analysis.

3.4. Visual Inspection on the Body of the Djuanda Dam

Inspection is carried out on the body of the dam, which is the dam peak, upstream slope, downstream slope, reservoir area, downstream area, right footing, and left footing. Following are the results of a visual inspection carried out at the Djuanda Dam.

![Figure 9. Dam Peak Condition of Djuanda Dam](image)

![Figure 10. Upstream Slope Condition of Djuanda Dam](image)

![Figure 11. Downstream Condition of Djuanda Dam](image)

Based on the results of visual inspection at the Djuanda Dam, it can be seen that the dam peak is covered with asphalt pavement, and there is a parapet on both sides of the crest dam. Crest condition is in good condition, flat, and there are no damages. In the asphalt pavement layer and on the road parapet there is no crack. The condition of the upstream slope of the dam is neatly arranged. The surface of the upstream slope is in a flat condition, maintained, and there are no visible damages. The upstream slope surface is coated with rip-rap material. The condition of rip-rap material as a whole is in good condition. Parts that have never been exposed to reservoir water, rock material becomes dark, and some experience contamination due to weather effects.

The conditions of the downstream slope of the dam are neatly arranged. The downstream slope surface is flat, maintained, and there are no visible damages. The downstream slope surface is coated with rip-rap material, and the bottom is coated with vegetation. Just like on the upstream slope, rip-rap material consists of igneous rock and overall is in good condition and vegetation conditions are also in well-maintained condition.

The condition of the reservoir area is the floating fish cage with a large number scattered in the inundation area of Jatiluhur Reservoir. There are water hyacinth plants at several points in the inundation area of the Jatiluhur Reservoir. There are avalanches in various locations on the slopes of the suburbs of the Jatiluhur Reservoir. The Conditions of the downstream area of the Djuanda Dam,
there are no damages that affect the safety of the dam. There are no cracks, nor seepage in the downstream area. There is no instrumentation such as a sliding pole so that it cannot be measured if there is a decrease or movement in the downstream area of the Djuanda Dam. Buildings found in the downstream region are also in good condition and are displaced. The conditions of the right footing of the Djuanda Dam are neatly arranged and in a flat condition, there are no symptoms that harm the body of the dam such as cracks, seepage, and avalanches. The surface of the pedestal is walled with rock pile protection. The condition of the rock dump is in good condition.

The conditions of the left footing of the Djuanda Dam are neatly arranged and in flat condition, there are no symptoms that harm the body of the dam such as cracks, seepage, and landslides. The surface of the pedestal is walled with rock pile protection. The condition of the rock dump is in good condition.

3.5. Assessment of the Djuanda Dam Body Condition

Assessment of the condition of the Djuanda Dam using the condition index method. Assessment is carried out on the body of the Djuanda Dam. The components contained in the body of the Djuanda Dam which are the object of assessment are the dam peak, upstream slope, downstream slope, reservoir area, downstream area, right footing, and left footing. In this study condition index criteria are given a 1-5 scale which is determined based on the type of damage consisting of five categories which can be seen in the previous Figure 7. Table 3 shows the result of an assessment of the condition of the Djuanda Dam.

| No | Component               | Weight | Condition Index | Total  |
|----|-------------------------|--------|-----------------|--------|
| 1  | Dam Peak                | 0.247  | 4               | 0.988  |
| 2  | Upstream Slope          | 0.247  | 4               | 0.988  |
| 3  | Downstream Slope        | 0.247  | 4               | 0.988  |
| 4  | Reservoir Area          | 0.105  | 4               | 0.42   |
| 5  | Downstream Area         | 0.067  | 5               | 0.335  |
| 6  | Left Footing            | 0.043  | 5               | 0.215  |
| 7  | Right Footing           | 0.043  | 5               | 0.215  |
|    | **Condition Value**     |        | **4.149**       |        |

Based on the results of the calculations above, the Djuanda Dam body condition index value has a value of 4.149. With the value of the conditions obtained, the body of the Saguling Dam is in the good condition category, but there are some damages that are included in minor damage.

3.6. Priority for Improving the Structural Damage of the Djuanda Dam

To determine the priority of damage repair, the initial assessment has been carried out through visual inspection and the results of instrumentation readings. From these two results, then it is known what damage is identified on the body of the Djuanda Dam which has the potential to disrupt the safety of the dam. Based on the AHP structure then a Paired Comparison Matrix matrix is created to determine the importance of an alternative to other alternatives. Interest intensity scale can be seen in Table 4.
Table 4 Pairwise Comparison Assessment Scale

| Intensity of Importance | Definition | Explanation |
|-------------------------|------------|-------------|
| 1                       | Equal importance | Two activities contribute equally to the objective |
| 3                       | Moderate importance | Experience and judgement strongly favor one activity over another |
| 5                       | Strong importance | Experience and judgment strongly favor one activity over another |
| 7                       | Very strong or demonstrated importance | An activity is favored very strongly over another; its dominance demonstrated in practice |
| 9                       | Extreme importance | The evidence favoring one activity over another is of the highest possible order of affirmation |
| 2, 4, 6, 8              | Values between two close consideration values | This value is given if there are two compromises between two choices |
| Reverse                 | If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i |

Based on the pairwise comparison rating scale, then put into a pairwise comparison matrix for each alternative. To determine the priority of repairs to the damages that occur in the body of the Djuanda Dam, scoring is carried out against each damage to determine the intensity of the importance of one damage to another damage. Scoring is based on visual inspection data and secondary data. Figure 12 shows the results of the priority improvement of structural damage to the Djuanda Dam using the AHP method and assisted with the Expert Choice program.

![Figure 12](image)

**Figure 12.** Priority Results for Improving Structural Damage to the Body of the Djuanda Dam

Based on the results obtained from the analysis carried out by using the Expert Choice program that was displayed on the Sensitive Graph, the results showed that the priority for repairing damage to the Djuanda Dam was leakage. Leaks are ranked top of the results of the analysis.

4. **Conclusion**

Damages are identified in both dams, which could potentially endanger the safety of the dam. Types of damages are leakage, erosion, cracks, vertical deformation, horizontal deformation, overtopping,
avalanches, and sedimentation. The index value of dam body condition of the Saguling Dam fall in the good category, but there are some damages including minor damage and moderate damage. As for the Djuanda Dam body, the index value is 4.149. It is still in the good category, but some minor damages have appeared. Based on the results of determining the priority of repairing damage to the body of the Saguling Dam, it was found that the priority of repairing the damage to the body of the Saguling and Djuanda Dam was sedimentation and leakage, respectively.

References

[1] Fell R, Gregor P M, Stapledon D, Bell G, Foster M Geotechnical Engineering of Dams 2nd Edition CRC Press ISBN 9781138749344
[2] Pouraminian M, Pourbakhsian S, Farsangi E N Reliability assessment and sensitivity analysis of concrete gravity dams by considering uncertainty in reservoir water levels and dam body materials Civil and Environmental Engineering Reports 30 (1) 001-017
[3] Collier M, Webb R H, Schimdt J C 1996 Dams and Rivers- A primer on the downstream effects of dams USGS Report
[4] Esmailzadeh S, Ahmadi H, Hosseini S A 2018 Damage detection of concrete gravity dams using Hilbert-method Journal of Applied Engineering Sciences 8(21) 7-16
[5] Mersianty 2015 Penilaian Kondisi Bendungan Studi Kasus Bendungan Manggar Jurnal Terknologi Terpadu No.1 Vol.3.
[6] Heryant, Y. 2014 Pengembangan Penilaian Kondisi Fisik Bendungan Untuk Penentuan Penanganan Pemeliharaan Bendungan Studi Kasus: Waduk Lodan Jurnal Teknik Sipil, Universitas Sebelas Maret, Vol 2 No.1
[7] Zare R, Kalantari B, 2018 Evaluating negative environmental impacts caused by dam construction Urban Studies and Public Administration 1(1) 42-50
[8] Juliastuti, Setyandito O 2017 Dam break analysis and flood inundation map of Krisak dam for emergency action plan AIP Conference Proceeding 1903, 100005 ); https://doi.org/10.1063/1.5011615
[9] Juliastuti, Andryan, Wulandari S, Purbasari M, Kuntjara H 2018 Effective communication using visual media to communicate emergency action plan based on dam failure model Proceedings of 1st Workshop on Environmental Science Society and Technology
[10] El Nashar W Y, Elyamany A H 2018 Managing risks of the grand Ethiopian renaissance dam on Egypt Ain Shams Engineering Journal 9(4) 2383-2388
[11] Saaty T L 1993 Experiments on ran preservation and reversal in relative measurement Math. Comput. Modelling 17(4.5) 13-18