Irrigation Maintenance Priority Analysis (Case Study: Irrigation Areas in Salatiga City)

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Abstract. The absence of a standard reference and limited funds for determining the classification of irrigation maintenance and rehabilitation activities in the Salatiga become an important research nowadays. Budget funds for 14 irrigation areas come different sources. Those funds are limited only to support the maintenance activities, while the rehabilitation activities rely on funds from the provincial and central governments that are not easily to be approved. Therefore, it is necessary to analyse the classification and the priority of irrigation activities. In this research, the grouping analysis employs two assessment criterias, namely; physical condition of irrigation networks and irrigation performance indices. Assessment of irrigation performance indices according to PU Minister's Regulation Number 32/PRT/M/2007 is for technical irrigation status, therefore it is necessary to identify adjustments to existing conditions. The priority analysis of irrigation maintenance activities in this research uses Analytical Network Process (ANP) method. The criterias that are investigated are irrigation performance indices, area width, irrigation status, estimated cost and distance of warehouse to intake. In this research, 4 groups of identifying the classification of irrigation status, i.e. i) technical irrigation, ii) semi-technical irrigation with weir main building, iii) semi-technical irrigation with spring pond main building and iv) simple irrigation, are used. The results of the grouping analysis showed that 11 irrigation areas are included in irrigation maintenance activities. The results of the priority analysis of irrigation maintenance activities from the first to the last priority are; Kedungkopyah, Cengek, Kedawung, Andong, Banyuputih, Siluwing, Sijamban, Bonorejo, Siandran, Sijambe, and Plampeyan. By determining the priority of irrigation maintenance, the budget allocation will be more targetted.

1. Background and Objectives

1.1. Background

The calculation of irrigation maintenance activities in Salatiga city faces troubles each year. The irrigation maintenance with the fund of APBD is still limited by the location selections for irrigation
areas based on the damage level. Large calculation depends on the funding uncertainty from the government of Middle Java and central government. The devription of maintenance calculation is limited causes inequality in the field. The maintenance inequality in large area will cause it to receive more fund even though the irrigation maintenance less than the smaller are, and vice versa [1].

This maintenance is very important since it keeps the condition of water in balance. Another problem is there is not any standard in grouping the irrigation maintenance and the rehabilitation activities. The grouping in this case based on 2 benchmarks, i.e., physical condition of irrigation network and the working index of the irrigation [2].

In order to support the development of agriculture, the development of irrigation infrastructure and facilities is needed so that the availability of water is sufficient [3].

One of the basic criteria in this research is the rule of the minister of public works No.32/PRT/M/2007 that speaks about operation guidelines and upgared Irrigation network maintenance.

Water consumption in Salatiga is focused in the river and the water sources. Irrigation network is a main building of a dam and a fountain. Hence, the working assessment needs to be identified and suited on sub criteria of a physic infrastructure’s aspect.

Objectives of this study are as follows:
a. Analyzing the determination of maintenance and irrigation rehabilitation activities in Salatiga city.
b. Analyzing the criteria which can be used to determine the priority of irrigation maintenance in Salatiga City.
c. Determining the priority of irrigation maintenance areas in Salatiga City.

2. Research Methods

2.1. The Research Location

The research location is in Salatiga City, Central Java Province, which is administratively surrounded by the district of Semarang, among others; Pabelan District, Tuntang District, Getasan District, and Tengaran District. The objects of this research are 14 irrigation areas which are the authority of Salatiga City. The research locations can be seen in Figure 1 [4].

![Research location](image-url)
2.2. Stages of Research
Stages of Research can be seen in Figure 2.

![Figure 2. Stages of research](image)

2.3. Assessment of Physical Conditions of Irrigation Networks
The Weight of each component based on material Training in Job Training, Operation and Irrigation Maintenance held by Water Resources Department of Central Java Province, (2014) [5] as in Table 1.

| Group Descriptions        | Weight of Value | Value Achievement | Weighted Value (%) |
|---------------------------|-----------------|-------------------|-------------------|
|                           | 1               | 2                 | 3                 | 4 = (2x3)          |
| Retrieval Building        | 12              |                   |                   |                   |
| Drainage Building         | 6               |                   |                   |                   |
| Weir Body                 | 10              |                   |                   |                   |
| Wings                     | 4               |                   |                   |                   |
| Complementary building Weir | 3          |                   |                   |                   |

The Value of Physical Condition assessment based on Water Resources Department of Central Java Province is still qualitative so that the quantitative value of physical building in the field is calculated by approaching the percentage of building area/ building volume to the area/ volume of damage. The categories of results from physical condition assessment of the irrigation network can be seen in Table 2.

| Damage Rate (%) | Value of Irrigation Network Physical Condition (%) | Category                  |
|-----------------|---------------------------------------------------|---------------------------|
| <10             | > 90 - 100                                         | Good Condition            |
| 10 - 20         | 80 - 90                                            | Minor Damaged Conditions  |
| 21 - 40         | 60 - 79                                            | Moderate Damaged Conditions|
| > 40            | <60                                                | Major Damaged Conditions  |
2.4. Irrigation System Performance Evaluation

Performance evaluation system irrigation based on Indonesia’s Minister of Public Works number 32/PRT/M/2007 [6] with aspects and weights of assessment can be seen in Table 3.

| Table 3. Weight rating of the irrigation system performance indices for technical irrigation network |
|:--------------------------------------------------|:-----------------|:-----------------|
| Aspects of                                        | Total        | Weight |
| Aspect Condition of Physical Infrastructure       | 45           | 45    |
| Aspects of Planting Productivity                  | 15           | 15    |
| Aspects of Supporting Facilities                  | 10           | 10    |
| Aspects of Personnel Organizations                 | 15           | 15    |
| Aspects of Documentation                           | 5            | 5     |
| Aspects of Water User Association                  | 10           | 10    |

Categories of results from the assessment of irrigation system performance indices can be seen in Table 4.

| Table 4. Assessment category of irrigation system performance indices |
|:---------------------------------------------------------------------|
| Value of Irrigation System Performance Indices (%)                  | Category     |
| >80                                                                  | Great Performance |
| 70 - 79                                                              | Good Performance |
| 55 - 69                                                              | Less Performance |
| <55                                                                  | Bad Performance |

2.5. Determination of Program Handling

Program handling based on the value of physical conditions irrigation networks and irrigation system performance indices can be seen in the matrix in Table 5.

| Table 5. Matrix program for handling irrigation areas |
|:-----------------------------------------------------|
| Value Physical Conditions Irrigation Network        |
| Good Condition (90% - 100%)                          |
| Minor Damaged Conditions (80% - 90%)                 |
| Moderate Damaged Conditions (60% - 79%)              |
| Major Damaged Conditions (<60%)                      |
| Performance Indices                                  |
| Great Performance (80% -100%)                        |
| Good Performance (70% -79%)                          |
| Less Performance (55% -69%)                          |
| Bad Performance (<55%)                              |
| Maintenance                                        |
| Maintenance                                        |
| Maintenance                                        |
| Maintenance                                        |
| Rehabilitation                                     |
| Rehabilitation                                     |
| Rehabilitation                                     |
| Rehabilitation                                     |

2.6. The Methods and Criteria for Determining the Priority of Maintenance and Irrigation Activities

Some research methods that have been used in determining the priority of irrigation maintenance are as follows:

a. The study conducted by Padmadya Olvi et al., [7] used an irrigation performance indices assessment method according to Indonesia’s Minister of Public Works regulation number
The results of this study are; comparison of the level of water adequacy in each irrigation network, the value of irrigation system performance of each irrigation network and the priority scale of irrigation networks by considering the physical aspects of the performance assessment of irrigation systems with the order of the smallest value being the top priority.

b. The research conducted by Rahajeng, (2012) [8] using the assessment method of Indonesia’s Minister of Public Works number 32/PRT/M/2007 by adding an assessment of the Water Distribution Implementation Plan (WDIP) in the sub-cropping productivity sub-criteria. The results of this study are; comparing the results of the irrigation system performance without additional components of the WDIP with the addition of WDIP components and simulations with an increase in every aspect of the irrigation system performance component.

c. The research conducted by Nurcahyo, (2012) [9], the criteria used in determining priorities are estimated costs, channel length, service area and level of damage. The method used in determining priorities is with the Analytic Network Process (ANP) with the help of Super Decision software. The results of this study are; knowing the existence of irrigation network area condition, obtaining the level of damage to the irrigation area network and obtaining a priority scale for handling damage to the irrigation area network with the ANP method.

d. The research conducted by Putri et al. (2014) [10] used an assessment of irrigation performance indices according to Indonesia’s Minister of Public Works regulation number 32/PRT/M/2007 by calculating need discharge requirements (water availability) in advance with the SRI method. The priority of the method used is the Analytical Hierarchy Process (AHP). The results of this study are; calculate the debit of water availability and discharge of water requirements without the SRI method and use the SRI method, assess the performance of the irrigation system and determine the priority scale using the AHP method for irrigation network components.

e. The research conducted by Supriyono et al. (2013) [11] used an irrigation performance indices assessment method according to Indonesia’s Minister of Public Works regulation number 32/PRT/M/2007 by calculating balance discharge first. The results of this study are; Handling priorities are based on the value of factor K for each irrigation area, the value of aspects of physical infrastructure, the value of irrigation performance and the value of irrigation performance with the smallest value being the top priority.

f. Research conducted by Zamroni et al. (2016) [12] using the Analytical Hierarchy Process (AHP) method by first determining the weighting of the performance indices for irrigation network systems for semi-technical irrigation and simple irrigation with the guideline Public Work and Public Housing number 12/PRT/M/PU. The criteria used for irrigation maintenance are; performance indices, area, irrigation status and distance from the Unified Service Unit.

### 2.7. Analytical Network Process (ANP)

Many decision problems cannot be built as a hierarchy because of dependencies (inner/outer) and influences between and within clusters (criteria, alternatives). The ANP is very useful for solving these kinds of problems. It provides a general framework to deal with decisions without making assumptions about the independence of higher-level elements from lower level elements, or about the independence of the elements within a level. In fact, ANP uses a network without the need to specify levels as in a hierarchy [13].

There are three super matrices associated with ANP. The unweighted super matrix includes the local priorities which are extracted from the pairwise comparisons. The weighted super matrix is presented by multiplying all elements in a component of the unweighted super matrix by the corresponding cluster weight matrix, so that the sum of numbers in each column is 1. The column vectors of the cluster weight matrix could be specified by the eigenvectors of the pairwise comparison of clusters. The limit super matrix is achieved by multiplying the weighted super matrix by itself. When the numbers of columns become the same for each column, the limit matrix will be reached and the matrix multiplication process will be stopped [14].
Both the AHP and ANP models are based on a comparative judgment of the alternatives and criteria. Since ANP dismisses the hierarchical structure associated with AHP it allows criteria to interact with each other [15].

Basically, the stages in the ANP method are as follows:

a. Defining clusters objectives, cluster criteria, and cluster alternatives.

b. Creating a Network Structure.

c. Making a structured network which has a function to determine the influence or interdependence between both elements, criteria and alternatives. The network structure can be seen in Figure 3 [16]

d. The clusters weighting by respondents.

e. Making a Pairwise Comparison Matrix with the formula which used in AHP.

f. Calculating the genvalues and their consistency values with the same stages as the AHP method.

g. Calculating the Super Unweighted.

Makes it unweighted super by entering all eigenvalue vectors matrix obtained from the pairwise comparison matrix between elements. If it is assumed that a system has an N cluster where the elements in each I interact or have an influence on some or all of clusters the existing. If the cluster is denoted by C_h, where h = 1, 2, 3, ..., N. With as many elements as nh that are notated with e_h1, e_h2, ..., e_hnh. The influence of a set of elements in a cluster on another element in a system can be represented by a ratio-scale priority vector drawn from pairwise comparisons based on the weight value of the pairwise comparison matrix. A value of 0 (zero) indicates that there is no relationship between clusters. The basic matrix format can be seen in Figure 4 [17].

h. Calculating of the weighted supermatrix by multiplying the unweighted supermatrix with the corresponding value so that the value in each column becomes 1 (one)

i. Calculating of the supermatrix limit by multiplying the weighted supermatrix continuously until the values on one row are equal.
j. The alternate ranking is calculated from the process generated from each weight node's limit of Supermatrix each cluster is divided by the total of each cluster where the node is located.

3. Results and Discussion

3.1. Research Results

3.1.1. Identification of Physical Infrastructure Component Aspects of Irrigation System Performance Indices.

The results of physical infrastructure identification aspect components adapted to the conditions of the irrigation network in Salatiga city can be grouped into the following irrigation status.

a. Technical Irrigation.

b. Semi-Technical Irrigation with Weir Main Building.

c. Semi-Technical Irrigation with Spring Pond Main Building.

d. Simple Irrigation.

3.1.2. Determination of the Handling Program

Based on Hendarto's thesis, (2018) [18] recommendations for treatment programs contained 11 irrigation areas including irrigation maintenance activities. The full recommendation program handling table can be seen in Table 6.

| The Name of Irrigation Area | Physical Conditions Network (%) | Performance Indices (%) | Recommended Program Handling |
|----------------------------|---------------------------------|--------------------------|-----------------------------|
| Cengek                     | 83.69                           | 53.56                    | Maintenance                 |
| Bonorejo                   | 80.88                           | 51.07                    | Maintenance                 |
| Andong                     | 94.37                           | 56.13                    | Maintenance                 |
| Kedawung                   | 83.59                           | 54.84                    | Maintenance                 |
| Siluwing                   | 83.82                           | 50.96                    | Maintenance                 |
| Tambakboyo                 | 68.64                           | 47.34                    | Rehabilitation              |
| Tengah                     | 73.20                           | 50.17                    | Rehabilitation              |
| Kedungkopyah               | 81.33                           | 56.36                    | Maintenance                 |
| Banyuputih                 | 89.81                           | 59.73                    | Maintenance                 |
| Siandran                   | 82.27                           | 60.89                    | Maintenance                 |
| Sidali                     | 75.28                           | 55.92                    | Rehabilitation              |
| Sijambe                    | 96.42                           | 56.03                    | Maintenance                 |
| Sijamban                   | 84.89                           | 56.98                    | Maintenance                 |
| Plampeyan                  | 96.02                           | 63.74                    | Maintenance                 |

3.1.3. The Methods and Criteria of Priority

The used criteria are the irrigation performance indices, estimated costs, area, irrigation status and distance of the office warehouse with the intake. While the method used in this study is by Analytical Network Process (ANP).

Data on the priority of irrigation maintenance criteria can be seen in Table 7.
Table 7. Assessment data criteria for priority determination

| The Name of Irrigation Area | Building Physical Condition (%) | Irrigation System Performance Indices (%) | Estimated Repair Cost (Rp.) | Irrigation Status | Distance Intake from Warehouse (meters) |
|----------------------------|---------------------------------|------------------------------------------|----------------------------|------------------|----------------------------------------|
| Cengek                     | 83,69                           | 53,56                                    | 631.330.000,00             | Technical (weir’s intake) | 6528                                   |
| Bonorejo                   | 80,88                           | 52,24                                    | 88.550.000,00              | Technical (weir’s intake) | 7533                                   |
| Andong                     | 94,37                           | 55,83                                    | 275.180.000,00             | Technical (weir’s intake) | 2131                                   |
| Kedawung                   | 83,59                           | 54,84                                    | 1.248.550.000,00           | Technical (weir’s intake) | 3585                                   |
| Siluwing                   | 83,82                           | 50,81                                    | 127.770.000,00             | Technical (weir’s intake) | 5470                                   |
| Banyuputih                 | 89,81                           | 59,73                                    | 663.350.000,00             | Semi-Technical (weir’s intake) | 4303                                   |
| Siandran                   | 82,27                           | 55,74                                    | 108.330.000,00             | Semi-Technical (weir’s intake) | 4975                                   |
| Kedungkopyah               | 81,33                           | 56,36                                    | 1.161.350.000,00           | Technical (weir’s intake) | 2330                                   |
| Sijambe                    | 96,42                           | 55,88                                    | 6.420.000,00               | Semi-Technical (weir’s intake) | 5541                                   |
| Sijamban                   | 82,97                           | 57,68                                    | 363.540.000,00             | Semi-Technical (spring pond’s intake) | 5325                                   |
| Plampeyan                  | 96,02                           | 63,74                                    | 8.050.000,00               | Simple (spring pond’s intake) | 5985                                   |

3.1.4. Determination of Priority for Irrigation Maintenance with ANP Method.

a. Network Structure

The structure of the irrigation maintenance network with the ANP method can be seen in Figure 5.
b. Supermatrix Table.

1) Unweighted supermatrix is based on the weight value of the pairwise comparison matrix.
2) Weighted supermatrix is made by multiplying unweighted supermatrix with the corresponding value so that the value in each column becomes 1 (one). The appropriate value is 0.5.
3) Limit supermatrix is made by multiplying the weighted supermatrix continuously until the values on one line are equal. This case each line is the same value as the 32nd rank. The limit supermatrix table can be seen in Table 8.

**Table 8. Limit Supermatrix Maintenance Irrigation**

| Objectives | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | A11 | A12 | A13 |
|------------|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|
| Performance Index | 0.0000 | 0.0980 | 0.0980 | 0.0980 | 0.0980 | 0.1414 | 0.1414 | 0.1414 | 0.1414 | 0.1414 | 0.1414 | 0.0000 | 0.0000 |
| Irrigation Status | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Irrigation Area | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Node Criteria area | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Node Kedawung | 0.0000 | 0.0980 | 0.0980 | 0.0980 | 0.0980 | 0.1414 | 0.1414 | 0.1414 | 0.1414 | 0.1414 | 0.1414 | 0.0000 | 0.0000 |
| Node Lembang | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Node Slitawang | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Node Slitandharman | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Node Slitbunyan | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Node Sijamban | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Node Sijambati | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

Description:
- P : Node Objectives of Irrigation Maintenance Priority
- K1 : Node Estimation Criteria Cost
- K2 : Node Criteria for performance Indices Irrigation
- K3 : Node Criteria Distance Warehouse Office
- K4 : Node Criteria Status Irrigation
- A1 : Node DI Kedawung
- A2 : Node DI Slitawang
- A3 : Node DI Slitandharman
- A4 : Node DI Slitbunyan
- A5 : Node DI Sijamban
- A6 : Node DI Sijambati
- A7 : Node DI Kedungkayah
- A8 : Node DI Banyuputih
- A9 : Node DI Di Santradan
- A10 : Node DI Di Sijamban
- A11 : Node DI Di Plampeyan
- A12 : Node DI Di Cengak
- A13 : Node DI Di Andong

c. Ranking of the criteria and priority

Diagram final weight and ranking of criteria and alternative priority of irrigation maintenance with ANP method can be seen in Figure 6 and Figure 7.
3.2. Discussion
The results of irrigation performance identification assessment indices for an irrigation status in Salatiga City contained an assessment of the semi-technical irrigation status of a spring pool. This was not found in previous studies by Zamroni et al., (2016) in a study case in Semarang Regency.

The results of this analysis of priority criteria have the most influence on ANP calculations with the highest weight which is 0.268

The ideal condition for the value criteria of the irrigation performance indices is influential, then the irrigation area with the lowest performance indices value is the main priority. The result that match in the analysis is only in the last order, namely DI Plampeyan with the highest irrigation system performance indices, which is 63.74%. While the results of the first order priority analysis with the highest weight is DI Kedungkopyah (ANP method = 0.125) with a performance indices value of 56.36% which is not the lowest performance indices value. This is because not all respondents consider the criteria is important in the assessment of alternative weights. In contrast to some previous studies that only use the irrigation system performance indices assessment method, the results of determining the main priority are the irrigation system performance indices in sequence from the lowest to the highest.

4. Conclusion
Based on the analysis and the results of the discussion some conclusions were drawn, which are:

a. Grouping the activities of maintenance and rehabilitation of irrigation areas in Salatiga City as follows.
   1) Irrigation areas that include irrigation maintenance activities are; Cengek, Bonorejo, Andong, Kedawung, Siluwing, Banyuputih, Kedungkoyah, Siandran, Sijamban, Sijambe, and Plampeyan.
   2) Irrigation areas that include irrigation rehabilitation activities are; Tambakboyo, Tengah, and Sidali.

b. The criteria used in determining the priority of irrigation maintenance are; irrigation performance indices, irrigation status, estimated cost, area and distance intake from office warehouse.

c. Priority of maintenance activities for irrigation areas in the City of Salatiga by using Analytical Network Process (ANP) method are; first Kedungkopyah, second Cengek, third Kedawung, fourth Andong, fifth Banyuputih, sixth Siluwing, seventh Sijamban, eighth Bonorejo, ninth Siandran, tenth Sijambe, and eleventh Plampeyan.
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