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Analysis of Irrigation Modernization Pillars with Fuzzy Analytical Hierarchy Process (FAHP) Approachment

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***Abstract*—** *In carrying out irrigation system management in the irrigation area of the authority of the East Java Province government, The Agency of Public Works of Water Resources of East Java Province experienced several obstacles. In an effort to overcome these obstacles, in addition to operations, maintenance and rehabilitation a comprehensive reform is needed, either managerial, institutional and technical, including human resources, known as irrigation modernization. Before carrying out irrigation modernization activities, there are needs an analysis on the pillars of irrigation modernization carried out through a survey of experts. Statistical descriptive analysis of experts understanding is conducted by Fuzzy Analytical Hierarchy Process (FAHP) to get the order of scale priority of application of irrigation modernization pillars in East Java Province, the results are as follows: i) The Increase in Reliability of Irrigation Water Supply, ii) Human resources (HR), iii) Irrigation Management System, iv) Irrigation Management Institution and v) Improvement of Irrigation Facilities and Infrastructure.*

***Keywords*—** *Modernization of irrigation, management, irrigation, Fuzzy Analytical Hierarchy Process.*

I. PRELIMINARY

The constraints on the management of irrigation systems in the irrigation area of the authority of the government of East Java Province namely the irrigation network has expired its technical age which has caused a decline in the function of the irrigation network performance, less optimal irrigation services because of lack of quantity and quality of human resources as the managers of irrigation as well as a decline in the existing water storage capacity due to sedimentation. Another obstacle namely the existence of population growth which causes an increase in the need for water use, an increase in food needs, the conversion of agricultural land into settlements and industries as well as a critical Watershed. (Regional Middle-Term Development Plan/ RPJMD of East Java Province in 2014 – 2019).

The needs of increased water use due to population growth accompanied by reduced water availability due to sedimentation in existing water storages and the critical watersheds, causing competition among water users, including users in the drinking water, irrigation, raw water and industrial sectors. The impact of the competition is the reduction of water supply for certain sectors, in this case the irrigation sector. To meet the increase in food demand due to population growth, in East Java itself is impossible to open new land. In fact, the opposite happened, namely the land conversion (East Java Province Central Bureau of Statistics/ BPS data in 2013 - 2017).

In an effort to overcome these obstacles, in addition to operations, maintenance and rehabilitation a comprehensive reform is needed, either managerial, institutional and technical, including human resources, known as irrigation modernization as mentioned in the Regulation of the Minister of Public Works and Public Housing No. 30/PRT/M/2015 on the Development and Management of Irrigation Systems.

The modernization of irrigation was first discussed at a workshop held by the United Nations dealing with the food and agriculture issues of the *Food Agriculture Organization* (FAO) in Bangkok, Thailand in 1995 (Amron, 2011). According to (FAO,1997), *Modernization of irrigation is process of technical and managerial upgrading of irrigation schemes combined with institutional reforms, if required, with the objective to improve resource utilization (labor, water, economic, environmental) and water delivery service to farms*.

Irrigation modernization in Indonesia can be defined as an effort to create a participatory irrigation management system that is oriented to meet the level of irrigation services effectively, efficiently and sustainably in order to support food and water security through the increase in reliability of water supply, infrastructure, irrigation management, management institutions, and human resources (Arif & Prabowo, 2014). Irrigation modernization will be different from conventional irrigation management. The differences lies in :

1. Conventional irrigation systems are designed and managed for rice plants, while modernization of irrigation allows farmers to choose the type of plant according to their choice.
2. Conventional irrigation systems are designed and managed with simple technology so that the management of the irrigation system is less flexible and inaccurate, while modernization of irrigation uses information and communication systems and digital technology to enable the management of the irrigation system to be more flexible, accurate, efficient and effective (real time management leads to real time expected weekly or 3 daily, *Real allocation* of water allocation based on field needs and real losses reduces losses up to 20%).

Irrigation modernization is also different from rehabilitation, which only emphasizes physical aspects. In the

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concept of irrigation modernization, in addition emphasizing the physical aspects, it also makes improvements on the aspects of management institutions and human resources, so that could provide services to farmers (Hakim, Suriadi, & Masruri, 2012).

Before carrying out irrigation modernization activities, there are needs an analysis on the pillars of irrigation modernization carried out through a survey of experts. Statistical descriptive analysis of expert understanding is conducted by Fuzzy Analytical Hierarchy Process (FAHP) (Saaty, 1993). The purpose of this study was to obtain a priority scale order for the application of the irrigation modernization pillar in East Java Province.

II. METHODOLOGY

This research is qualitative and uses a survey method, namely a method for obtaining data in the form of opinions or ideas from experts who interact directly with the object of research. The purpose of this method is to find out information on the general description of research objects through samples, then interpret and analyze them systematically. The sampling technique used to determine respondents was purposive sampling (Sugiyono, 2010), namely the technique of determining samples with certain considerations. The considerations used, experts are the experts on irrigation modernization and officials with the main tasks and functions related to the modernization of irrigation.

Opinions or ideas from experts are obtained through interviews and questionnaires.

TABLE 1. Sample Mapping

No.	The population of Irrigation Manager	Sample	Number of Respondents
1.	Irrigation modernization expert	Irrigation Modernization Team from the Ministry of Public Works and Public Housing	2 people
2.	Official at the Agency of Public Works of Water Resources of East Java Province	Head of Irrigation Sector, Head of Operations Section, Head of Maintenance Section, Head of Rehabilitation Section, Head of General Planning Section, Head of Operations Section of UPT PSDA in Surabaya	6 people
3.	Farmer	Farmers in Irrigation Areas of the Authority of the East Java Provincial Government	1 person
TOTAL			9 people

Determination of criteria and sub-criteria of the pillars of irrigation modernization in this study was obtained from the identification of the description of the 5 pillars of irrigation modernization in accordance with the General Guidelines for Irrigation Modernization and accompanied with the parameters on the assessment of Irrigation System Performance Index/ Indeks Kinerja Sistem Irigasi (IKSI) according to the Regulation of the Minister of Public Works and Public Housing No. 12/PRT/M/2015 and reliable literature both in the form of journals or previous research that are adjusted to the object of research through interviews with officials at the Department of Public Works, Water Resources, East Java Province.

Criteria added among others :

1. Availability of manual OP.
2. Operations, maintenance, rehabilitation and financing activities (AKNOP).
3. Quality and quantity of human resources, both government and farmers.
4. Replacing the Implementing Unit with the Provincial Public Works Agency, in this case the Agency of Public Works of Water Resources of East Java Province as the owner of the irrigation area authority.
5. Simplify the criteria for observer houses, technician, guard weirs, transportation, communication systems, offices, op equipment to become criteria for supplementary facilities.

As for the criteria and subcriteria for irrigation modernization pillars in this study can be seen in the following hierarchical model :

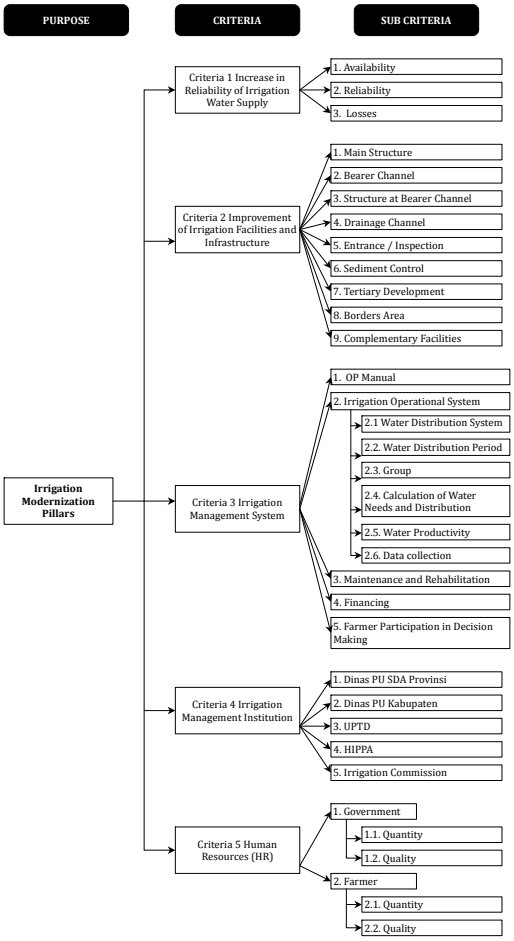

Fig. 1. Irrigation Modernization Pillar Hierarchy Model

From the hierarchical model, a paired comparison matrix questionnaire was made.

After making a hierarchical structure and questions on the questionnaire, then namely determine the weighting of the

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importance level of the criteria using the *Fuzzy Analytical Hierarchy Process* (FAHP) method. The steps are as follows :

1. Arrange the problem into a hierarchy, starting the goal, the criteria to the alternative.
2. Compile a paired comparison matrix among all criteria in the hierarchy dimension. The data used is the respondent's valuation in the form of numerical values which are then converted into TFN values (Shega, 2012).

TABLE 2. TFN Value Scale

Information	AHP Scale	Fuzzy Scale	Invers
Both elements are equally important	1	(1,1,1)	$(\frac{1}{1},\frac{1}{1},\frac{1}{1})$
One element is slightly more important than the other elements	3	(1,3,5)	$(\frac{1}{5},\frac{1}{3},\frac{1}{1})$
One element is more important than other elements	5	(3, 5, 7)	$(\frac{1}{7},\frac{1}{5},\frac{1}{3})$
One element is very important from the other elements	7	(5, 7, 9)	$(\frac{1}{9},\frac{1}{7},\frac{1}{5})$
One element is absolutely more important than other elements	9	(7, 9, 9)	$(\frac{1}{9},\frac{1}{9},\frac{1}{7})$
The values between two adjacent comparison values		(x-2), x, (x+2)	$(\frac{1}{(x+2)},\frac{1}{x^2},\frac{1}{(x-2)})$

3. After changing the pairwise comparison matrix data of each respondent on a fuzzy scale, then conducted data consistency test previously. The steps namely:
   a. Uniting expert opinion using the geometric mean (Saaty, 1993).
   $A_{ij} = (Z_1 \text{ x } Z_2 \text{ x } Z_3 \text{ x } \dots \text{ x } Z_n)^{1/n}$ (1)
   where :
   A_{ij} = average comparison value between A_i with A_j for n respondents
   Z_i = value of comparison between criteria A_i with A_j respondents -i
   n = number of respondents
   b. Transforming fuzzy numbers into crisp numbers (Yong, 2006).
   $$P = \frac{l + 4m + u}{6} \quad (2)$$
   c. Calculate the priority vector by adding up the values contained in one column and given the name of the total column. Then divide each matrix entry by its respective total column and add the results contained in one row.
   d. Conducting consistency tests, the values inputted and managed must produce a CR (Consistency Ratio) smaller or equal to 10%.
   $$CI = \frac{\lambda maks - n}{n - 1} \quad (3)$$
   $$CR = \frac{CI}{RI} \quad (4)$$
   where :
   n = number of criteria or sub criteria
   CI = *Consistent Index*
   CR = value of *Random Index*

TABLE 3. Value of RI *(Random Index)*

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0,58	0,9	1,12	1,24	1,32	1,41	1,45	1,49

4. After conducted consistency testing, the next step is to calculate the weight of criteria importance level. The steps are :
   a. Calculating fuzzy synthesis values (fuzzy weights) for objects -i (Corts, 2012).
   $$S_i = \sum_{j=1}^{m} M_{gi}^{j} \times \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} \quad (5)$$
   b. After the value of fuzzy synthesis (fuzzy weights) is obtained, defuzzification must be done to get the crisp value using the Centroid of Area (COA) method, namely to find the center point of the triangle curve.
   BNP = [(UR1 – LR1) + (MR1 – LR1)] / 3 + LR1 (6)
   c. Finally, normalization is carried out.

III. Result And Disscussion

The data consistency test was carried out first on the pairwise comparison matrix questionnaire before carrying out further analysis. The data used is the average of the answers of 9 respondents on 39 questions.

TABLE 4. Data Consistency Test

No.	Criteria and Sub Criteria	Number of Questions	CR (%)
1.	Irrigation Modernization	5	8
2.	Increase in The Reliability of Irrigation Water Supply	3	1
3.	Improvement of Irrigation Facilities and Infrastructure	9	8
4.	Irrigation Management System	5	4
5.	Irrigation Operational System	6	0
5.	Irrigation Management Institution	5	3
6.	Human Resources (HR)	2	0
7.	Government	2	0
8.	Farmer	2	0
TOTAL		**39**	

From the results of the analysis it is known that all questions are answered consistently because they have a CR value of <10%.

After conducting a test of consistency, the next step is to calculate fuzzy synthesis values (*fuzzy weights*). Then defuzzification was carried out to obtain crisp values using the Centroid of Area (COA) method and finally, normalization was conducted.

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TABLE 5. Recapitulation of the Weight of the Irrigation Modernization Pillar Criteria

No.	Criteria	Weight (%)	Order
I.	Increase in Reliability of Irrigation Water Supply	24,92	1
II.	Improvement of Irrigation Facilities and Infrastructure	14,76	5
III.	Irrigation Management System	20,21	3
IV.	Irrigation Management Institution	18,72	4
V.	Human Resources (HR)	21,39	2

TABLE 6. Recapitulation of the Weight of Irrigation Modernization Pillar Sub Criteria

No.	Sub Criteria	Weigth (%)	Order
1.	Availability	10,33	
2.	Reliability	10,58	1
3.	Losses	4,01	
1.	Main Structure	4,25	
2.	Bearer Channel	3,15	
3.	Structure at Bearer Channel	2,75	
4.	Drainage Channel	1,08	
5.	Entrance / Inspection	0,57	5
6.	Sediment Control	0,93	
7.	Tertiary Development	0,82	
8.	Borders Area	0,55	
9.	Complementary Facilities	0,67	
1.	OP Manual	4,28	
2.	Irrigation Operational System	4,14	
	a. Water Distribution System	0,69	
	b. Water Distribution Period	0,69	
	c. Group	0,69	
	d. Calculation of Water Needs and Distribution	0,69	3
	e. Water Productivity	0,69	
	f. Data collection	0,69	
3.	Maintenance and Rehabilitation	3,85	
4.	Financing	4,75	
5.	Farmer Participation in Decision Making	3,18	
1.	Dinas PU SDA Provinsi	5,00	
2.	Dinas PU Kabupaten	2,87	
3.	UPTD	3,94	4
4.	HIPPA	3,15	
5.	Irrigation Commission	3,76	
1.	Government	11,73	
	a. Quantity	3,44	
	b. Quality	8,29	2
2.	Farmer	9,66	
	a. Quantity	2,54	
	b. Quality	7,12	

Based on the analysis above, from the criteria and sub-criteria of irrigation modernization obtained the results of the weight of importance level as follows:

1. The Increase in Reliability of Irrigation Water Supply has the highest weight namely 24.92%, because without the availability of water, irrigation activities will not be carried out.
2. The second namely Human Resources (HR) with a weight of 21,39%, because human resources are human actors in irrigation management consisting of government and farmers, which both the quantity and quality greatly influence the activities of modernization of irrigation namely in order to achieve the level of service (LoS) of reliability, adequacy of water, flexibility in division and distribution, farmer satisfaction and certainty of acceptance.
3. The third namely the Irrigation Management System with a weight of 20.21%, because it aims to regulate the amount of available water resources varies towards time and place with the amount of irrigation water needs of plants to maximize the level of productivity and intensity of certain crops in an irrigation area.
4. The Fourth namely the Irrigation Management Institution with a weight of 18,72%, includes government agencies and non-government agencies that will organize irrigation management to prevent conflicts of interest in irrigation water use either between upstream downstream users, between sectors, and between administrative areas.
5. Finally, The Improvement of Irrigation Facilities and Infrastructures which have the lowest weight namely 1,.76%. This means that it has the smallest influence on irrigation modernization activities, however, all damage and shortages in facilities and infrastructure need to be overcome by planned maintenance either planning and funding by creating a construction structure that can make the service life longer which can ultimately reduce operating and maintenance costs.
6. As for sub criteria, the sequence is as follows :
   a. On the criteria of The Increase in Reliability of Irrigation Water Supply: Reliability 10,58%, Availability 10,33% and Losses 4,01%.
   b. On the criteria for Improvement of Irrigation Facilities and Infrastructure : Main Structure 4,25%, Bearer Channel 3,15%, Structure at Bearer Channel 2,75%, Drainage Channel 1,08%, Tertiary Development 0,93%, Entrance / Inspection 0,82%, Borders Area 0,67%, Sediment Control 0,57% and Complementary Facilities 0,55%.
   c. On the criteria for Irrigation Management Systems : Financing 4,75%, OP Manual 4,28%, Irrigation Operational System 4,14%, Maintenance and Rehabilitation 3,85% and Farmer Participation in Decision Making 3,18%. Whereas for the sub criteria of the Irrigation Operational System : Water Distribution System, Water Distribution Period, Group, Calculation of Water Needs and Distribution, Water Productivity and Data Collection have the same weight namely 0,69%.
   d. On the criteria of the Irrigation Management Institution : Provincial Agency of Public Works of Water Resources/ Dinas PU SDA Provinsi 5%, UPTD 3,94%, HIPPA 3,76%, Irrigation Commission 3,15% and Regency Public Works Agency /Dinas PU Kabupaten 2,87%.
   e. On the criteria of Human Resources (HR): Government 11,73% and farmer 9,66%. While for the Government sub-criteria: Quality 8,29% and Quantity 3,44%. For farmers' sub criteria: Quality 7,12% and Quantity 2,54%.

IV. CONCLUSION

There are 5 criteria and 34 sub criteria for the pillar of

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irrigation modernization in this study. From the results of the analysis using the Fuzzy Analytical Hierarchy Process (FAHP) method obtained the weights for each criteria and sub-criteria. In this weight it can be seen that the criteria for The Increase in Reliability of Irrigation Water Supply has the highest weight, namely equal to 24,92%, which means that it has the greatest influence in the modernization of irrigation, then followed by Human Resources (HR) 21,39%, Irrigation Management System 20,21%, Irrigation Management Institution 18,72% and Improvement of the Irrigation Facilities and Infrastructure 14,76%.

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