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Cost Sharing and Water Pricing to Improve River Water Quality

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Abstract *— When the water is polluted, it can be improved by diluting the degradated water with the higher quality water. Supply of water dilution trigger several costs, as the cost to build reservoir for water discharge. The clasification of project in river basin is appropriate with the benefit, there are single purpose and multi purposes project, so in relation to water discharge as dilution, it needs cost sharing with other beneficiaries. The cost sharing of BJP-SDA with the case study on Brantas River basin is determined with Analytic Hierarchy Process (AHP) with Expert Choice 2000. The charge percentage of BJP-SDA toward the cost is recovered with three criteria, those are the raw water (domestic and industry) 28.4% ; hydropower 28.8% ; irrigation 27.9% ; flood control 12.5% and to improve the water quality 2.3%. The charge percentage of BJD-SDA toward the cost is recovered with four criterias, they are: the raw water 26.10%; hydropower 32.7%; irrigation 27.7% ; flood control 11,3% and to improvement of the water quality 2.2%. With the allocation of river water for dilution is 7.5 m^3 /sec during three months on dry season, BJP-SDA charge to improve the water quality in Brantas River has the lowest, that is, 2.2 – 2.3% from the cost which will be covered. Under the O and M cost, the percentage of the BJP-SDA charge is 0.8% and under the benefit value of the user is 1.7% from the cost which will be covered. The water pricing of BJP-SDA for the beneficiaries of the river water quality improvement is the water allocation for dilution divides with the cost which will be covered. For the O and M cost recovery, the water price is Rp. 112 until Rp. 117 per m^3, and for the full cost recovery is Rp. 126 until Rp. 132 per m^3.*

Keywords *— Cost sharing; Dilution; Analytical Hieratchy Process*

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I. INTRODUCTION

The nature provides continuous water flow in the rivers and lakes, and as long as the condition of nature is not disturbed, human cannot claim the availability cost of water. But as soon as we wish to change either quantity, the quality, the location or the dependability of natural water resources, the water cost will occur (Kuiper, 1971).

To improve the river flow quantity, perhaps a river must be moved to another river, and if the river water quality wanted to be changed, perhaps a waste treatment needs to be made. Similiarly to changing the water location, perhaps a system of water pump and water channel have to be made and also if the dependability of water flow is to improve, perhaps the upstream reservoir must be build. In every case, the cost is required to change the availability of nature water to the condition needed , so that water has a cost.

On the case of polluted waters, it can be improved by the method of water diluting which is degradated with the higher quality water. The supply of this dilution water brings up several costs. Such as the cost to build resevoir for the release of water as dilution. It is posibble in the other cost that there is benenefit from another alternative utilizing which is lost, such as the water for hydropower, irrigation, municipal or industrial purposes. Gray and Young (1974) in Young (1996) adapt Merrit and Mar method who are developing the basic approach of assessing the dilution of waste charge with the case study on river basin. They have calculated the water dilution value of many river basins in the United States and focus

on dilution charge of BOD, although this model can be used for another pollutant.

To establish the water resources sustainably, the principle of water beneficaries must cover the management cost. In the concept of integrated water resources management, the water pricing policy instrument to encourage the cost recovery needs to be developed.

The principle of cost recovery water management recommended by World Water Commission, 2000) is a full cost recovery, Roger et al (1998) defines that full cost recovery for water service consists of operational cost, maintenance cost, capital charge (include shrinkage cost and the interest), opportunity cost, economic externalities and environment externalities. Whereas the water pricing policy is the fee or price that needs to be charged for water service, to sustain the water resources management. If it is viewed from the water service provider, water pricing is the price for the given service, wheareas if it is viewed from the beneficaries point of view, the price is the cost that must be paid for the service which has been received.

Base on regulated in the Act Number 7 year of 2004 (Undang-Undang Nomor 7, 2004), the service cost of water resources management, (Biaya jasa Pengelolaan Sumber daya Air, BJP-SDA) is the cost recovery policy of water resources management in Indonesia. BJP-SDA is the cost that is levied from the water beneficiaries for management so that the water resources can be used sustainbly, with the BJD-SDA's unit price is determined for every utilation unit such as per kWh rupiah or per m^3 rupiah.

On the *river basin*, there are single purpose and multi-purposes projects, then in relation to the reservoir project of water release as dilution, it needs cost sharing with the other beneficaries. The determination of water pricing depends on kinds of the water cost that will be recovered, so the factors which affect the charge of the cost recovery on river basin are : (1) infrastructure of water service and (2) water value.

II. MATERIALS AND METHODS

The water resources has a social function, it means that the natural water resourses for public interest is prioritized over individual interest. The water resources has enviromental function meaning that it is become a part of ecosystem. And also the water resources has economic function which means that the water resourses can be utilized to support businnes activity.

With those many functions, come few players and key roles who are involved in the water resource management. The policy of BJP-SDA is levied from the water beneficaries, relates to multi complexities, as it has many dimentions, sectors, criteria, and science dicipline. So the principle and regulations for BJP-SDA is basically related to decision-making.

The cost sharing from BJP-SDA is determined by *Analytic Hierarchy Process (AHP)* which is the multi-criteria decision making method considers from two factors objective and subjective criteria in the best of alternative selection, with the case study on Brantas River Basin.

The model of AHP is built following the mind set that is developed by Saaty (1998) , with the steps are:

1) The first step is arrange the elements hierarchy that needs to be considered in the cost sharing of BJP-SDA on the river basin.
2) With the bases on the structure hierarchy, pair wise matrices are made to consider the importance relative of all elements.
   - Every cel pair wise matrice one alternative element on certain criteria toward another alternative element, it is filled with the result analysis of data allocation characteristic BJP-SDA towards the users and water beneficaries.
   - Every cel pair wise matrice one criteria element toward another criteria element is filled with the result analysis of water resources experts assesment.
3) The priority weight between the elements and the global weight are calculated using *Expert Choice 2000.*

To investigate how sensitive it is the alternative level towards the change of the important criteria, *expert choice* supply sensitivity analysis facility. The facility choice which can be used are five sensitivity analysis graphs: *performance sensitivity graph, dynamic sensitivity graph, gradient sensitivity graph, two-dimensional sensitivity graph, and difference sensitivity graph.*

III. RESULTS AND DISCUSSIONS

The hierarchy structure of the model of BJP-SDA's cost sharing on the river basin consist of three levels. The first level is the aim, the second level is the criteria of achievement and the third is the alternative from the final action. As the aim is BJP-SDA, which must be charged to the water service beneficiaries.

The criteria elements on the first hierarchy structure are :

- The benefits of water usage
- The operational and maintenance cost
- The amount of the primary buildings (head works)

The criteria elemens on the second hierarchy structure are:

- The benefits of water usage
- The maintenance and operational cost
- The asset values
- The amount of the primary buildings (head works)

The alternative element on the hierarchy structure of the users and the beneficiary groups on Brantas River basin, consist of:

- The users group of irrigation
- The users group of raw water for consumption and industry
- The users group of energy power
- The beneficiaries group of flood control
- The beneficiaries group of water quality control

The characteristics of five groups of the water service recipients are analyzed based on benefit value, maintenance and operational cost (O and M), asset value and number of the headwork. The characteristics of every beneficaries group are showed in Table 1.

The respondent (water resources experts) assessment towards the importance level of inter-criteria is variated. It shows that there are understandable diversity and importance on respondance groups (Managers, Users, Academicians). The results of the fixed calculation of respondance groups are showed in Table 2.

The pair wise matrices based on the data from repondences perseption is showed on Table 3. The pair wise matrices based on the quantitative data of every criteria is showed on Table 4, Table 5, and Table 6.

The relative priority charge of BJP-SDA is calculated using *Expert Choice 2000* software. The percentage of BJP-SDA charges are presented in on Figure 1 and Figure 2.

TABLE I
THE CHARACTERISTICS OF BENEFICARIES ON BRANTAS RIVER BASIN

Beneficaries Groups	Benefit (Rp. 10^6)	O and M (Rp. 10^6)	Asset (Rp. 10^6)	Headwork (pieces)
Irrigations	565,885	88,438	2,925424	17
Raw water	1,397,888	41,223	1,823,284	8
Hydropower	692,154	144,963	5,335,123	9
Flood	14,471	20,793	677,113	11
Water Quality	49,105	2,263	189,134	2

Source : PJT I, analyzed

TABLE II
THE IMPORTANCE VALUE OF INTER CRITERIA ELEMENTS

Criteria	Importance Value inter criteria elements								Criteria
	Manager		User		Academician		Stakeholders		
	RA	RG	RA	RG	RA	RG	RA	RG	
To determine the allocation of the water resources management cost for users which are more important among:									
O and M cost	1.7	0.5	2.18	0.8	2.,68	1.1	2.12	0.76	Amount of the head works
O and M cost	0.85	0.3	1.82	0.9	1.76	1.0	1.91	0.67	Benefit
Amount of the head works	1.16	0.4	1.85	1.1	3.29	2.8	2.21	0.93	Benefit

Remark :
RA = arithmetic mean
RG = geometric mean

TABLE III
THE PAIR WISE MATRICES INTER-CRITERIA

Criteria	O and M cost	Amount of the head works	Benefit value
O and M cost	1,00	0,76	0,67
Head Work		1.00	0,93
Benefit			1,00

TABLE IV
THE PAIR WISE MATRICES ALTERNATIVE ELEMENT ON MAINTENANCE AND OPERATIONAL CRITERIA

Maintenance and operational cost	Irrigation	Raw water	Hydropower	Flood	Water quality
Irrigation	1.00	2.15	0.61	4.25	39.07
Raw water		1.00	0.28	1.98	18.21
Hydropower			1.00	6.97	64.03
Flood				1.00	9.19
Water quality					1.00

TABLE V
THE PAIR WISE MATRICES ALTERNATIVE ELEMENT ON BENEFIT CRITERIA

Benefit	Irrigation	Raw water	Hydropower	Flood	Water quality
Irrigation	1.00	0.40	0.82	4.00	11.52
Raw water		1.00	2.02	9.88	28.47
Hydropower			1.00	4.89	14.10
Flood				1.00	2.88
Water quality					1.00

TABLE VI
THE PAIR WISE MATRICES ALTERNATIVE ELEMENT ON CRITERIA OF AMOUNT OF HEAD WORK

Amount of the primary building	Irrigation	Raw Water	Hydropower	Flood	Water Quality
Irrigation	1.00	2.13	1.89	1.42	8.50
Raw water		1.00	0.89	0.67	4.00
Hydropower			1.00	0.75	4.50
Flood				1.00	6.00
Water quality					1.00

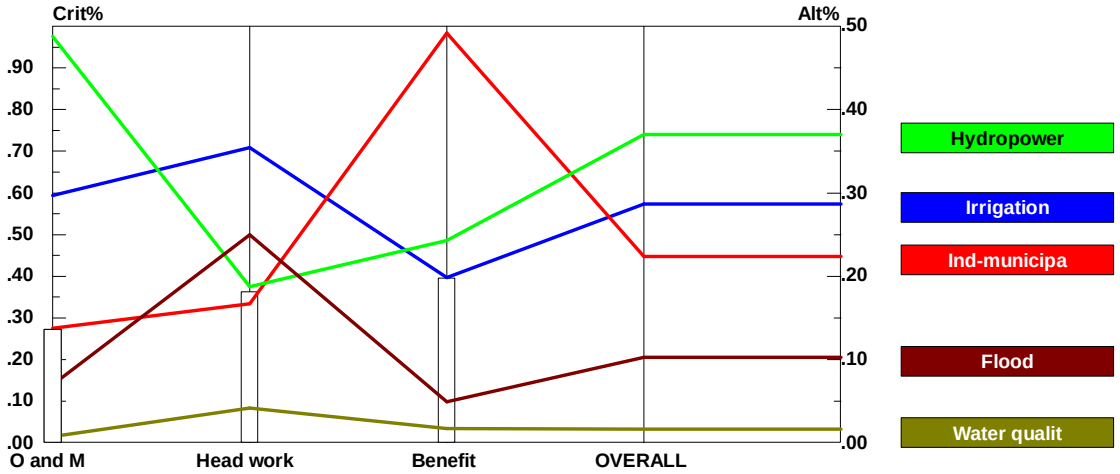


Fig. 1 The graph of BJP-SDA charges with three criteria

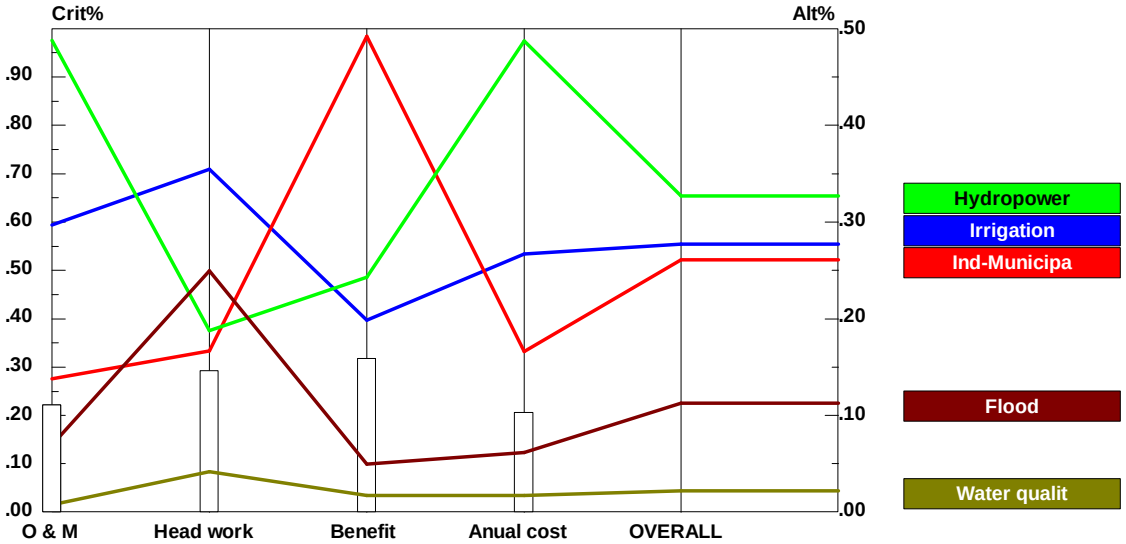


Fig. 2 The graph of BJP-SDA charges with four criteria

The importance rank of inter-element hierarchy that is determined based on the characteristics of users and beneficaries, is able to produce weight of elements priority and global weight with consistent ratio 0.0. Thereby the assessment of the importance rank of inter-element hierarchy which has been subjective can be reduced or avoided.

The global weight priority constitutes from the percentage of BJP-SDA charges to the group of water service users and beneficaries. The charge of BJP-SDA to beneficaries with three criterias are showed on Table 7, and The charge of BJP-SDA to beneficaries with four criterias are showed on Table 8.

TABLE VII
THE CHARGE OF BJP-SDA TO BENEFICARIES WITH THREE CRITERIAS

Beneficaries Group	Global weight toward criteria			Global weight
	O and M	Head Work	Benefit	
	0.263	0.352	0.385	
Irrigation	0.297	0.355	0.198	0.279
Raw water	0.138	0.167	0.492	0.284
Hydropower	0.488	0.187	0.243	0.288
Flood	0.070	0.250	0.050	0.125
Water quality	0.008	0.042	0.017	0.023
total	1.000	1.000	1.000	1.000
inconsistency	0.00	0.00	0.00	0.00

TABLE VIII
THE CHARGE BJP-SDA TO THE BENEFICARIES WITH FOUR CRITERIAS

O and M	Global Weight toward critera				Benefit
	O and M	Head Work	Benefit	Asset	
	0.212	0.283	0.308	0.196	
Irrigation	0.297	0.355	0.198	0.267	0.277
Raw water	0.138	0.167	0.492	0.166	0.261
Hydropower	0.488	0.187	0.243	0.487	0.327
Flood	0.070	0.250	0.050	0.062	0.113
Water quality	0.008	0.042	0.017	0.017	0.022
Total	1.000	1.000	1.000	1.00	1.00
inconsistency	0.00	0.00	0.00	0.00	0.00

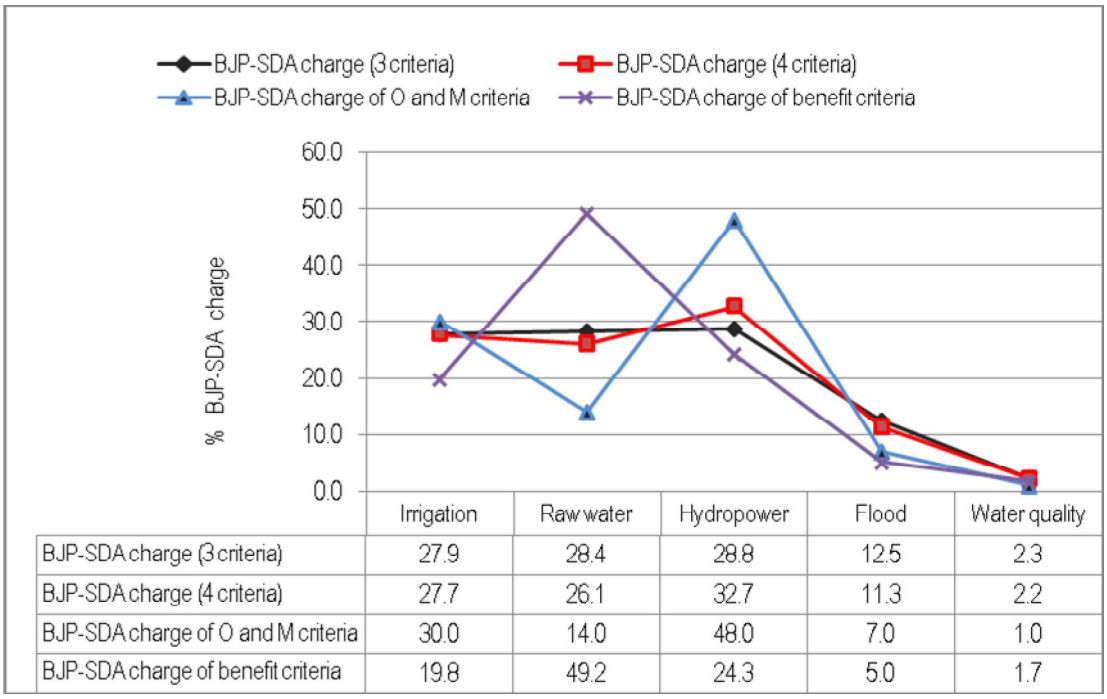
The charge of BJP-SDA to the beneficaries with three criterias, shows that the users of hydropower have the highest charge, namely 28.8% from the cost which will be covered. But if the BJP-SDA cost sharing use a criteria of benefit value, the charge of hydropower become the second highest, namely 24.3% from the cost which will be covered. Otherwise if the cost sharing BJP-SDA use a criteria of maintenace and operational, percentage of charge will become the highest, as big as 48.8% from the cost which will be recovered.

The cost sharing of BJP-SDA which is based on maintenance and operational criteria or benefit criteria or amount of headwork criteria, show the order which is varied. The highest percentage of BJP-SDA charges to the water service users on the headwork level are: (1) hydropower (48.8%) for maintenance and operational criteria, (2) irrigation (35.5%) for the amount of headwork criteria, (3) raw water (49.2%) for benefit value and (4) hydropower (28.8%) for three criterias. It shows that the percentage charge of BJP-SDA to users and beneficaries is not always proportional with the percentage of one of the criteria considered.

In compare to the cost sharing of BJP-SDA which uses three critreas, the percentage charge of BJP-SDA with four criteria has a little difference, namely on the users group of raw water, as showed in Figure 3.

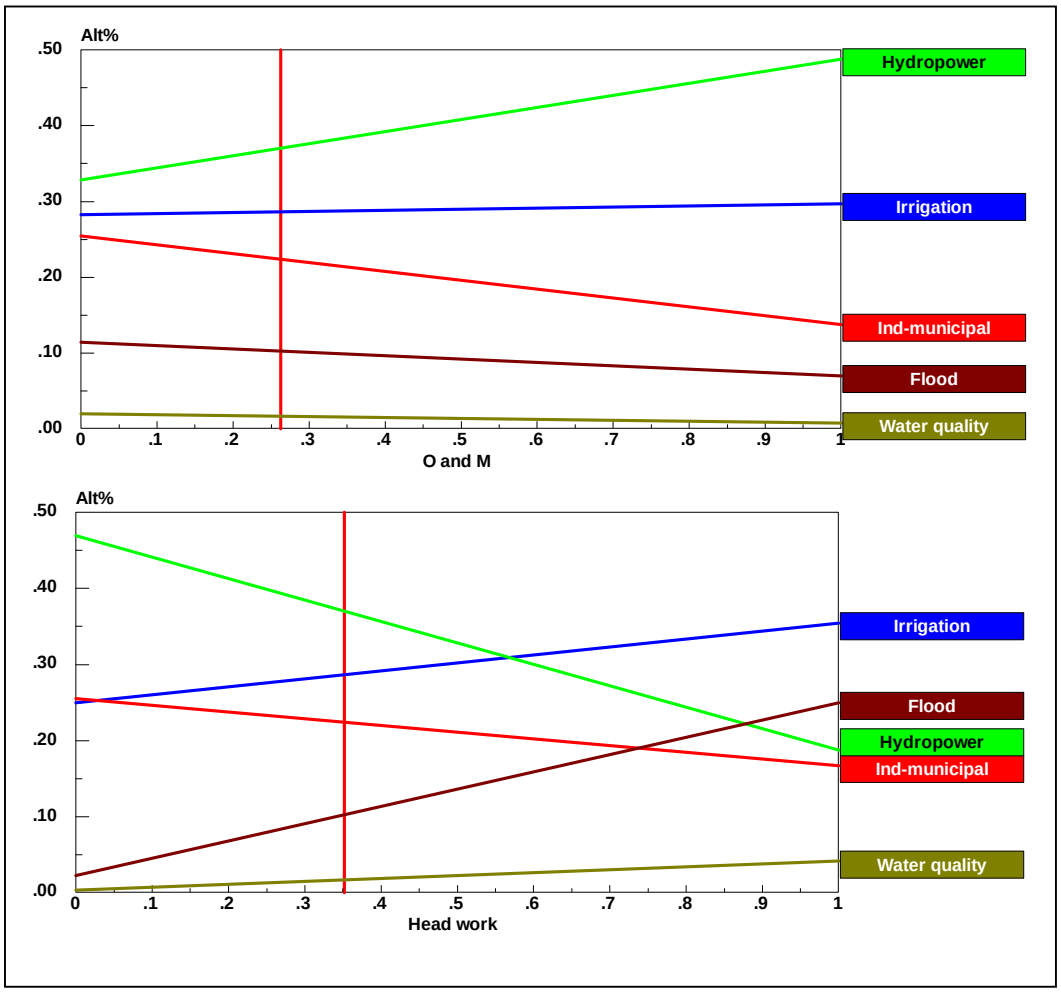
The percentage charge of the raw water users on the top two order for the counts with three criteria, is 28.4%. Whereas the counts with four criteria is 26.1% from the cost which will be covered and on the top three order. This difference shows that the amount of criteria can affect the percentage charge of BJP-SDA. The more criteria used to assess importance hierarchy element level, the more equitable the calculation of BJP-SDA allocation to users and beneficaries will be.

To investigate how sensitivite the alternative level is towards the change of the criteria's importance, can be seen on Figure 4 and Figure 5. Those figures show the *gradient sensitivity* graph, which is the declivity line of every criteria given as separate graphs. The vertical line is the priority which is appropriate to the criteria selected and the declivity line shows the alternative. The alternative priority is obtained from the crossing line point of priority criteria and the alternative one.



	Irrigation	Raw water	Hydropower	Flood	Water quality
BJP-SDA charge (3 criteria)	27.9	28.4	28.8	12.5	2.3
BJP-SDA charge (4 criteria)	27.7	26.1	32.7	11.3	2.2
BJP-SDA charge of O and M criteria	30.0	14.0	48.0	7.0	1.0
BJP-SDA charge of benefit criteria	19.8	49.2	24.3	5.0	1.7

Fig. 3 The percentage charge of BJP-SDA with variety of criteria



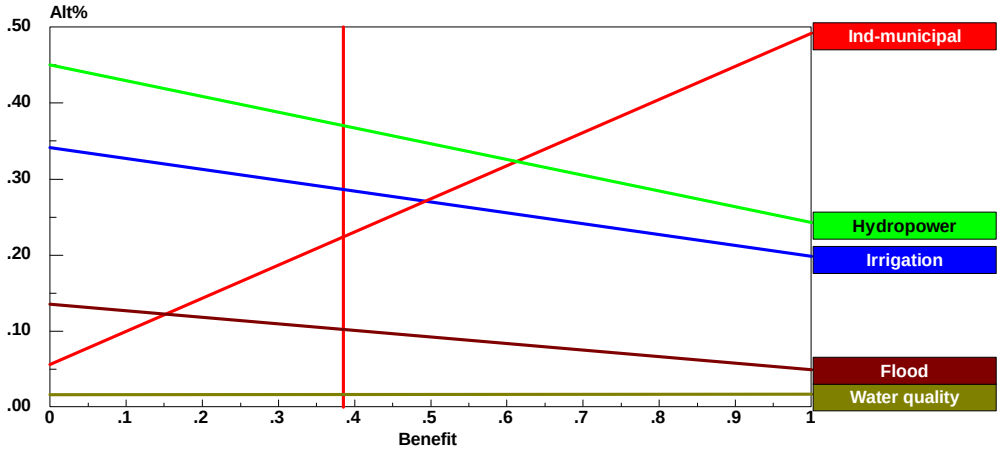
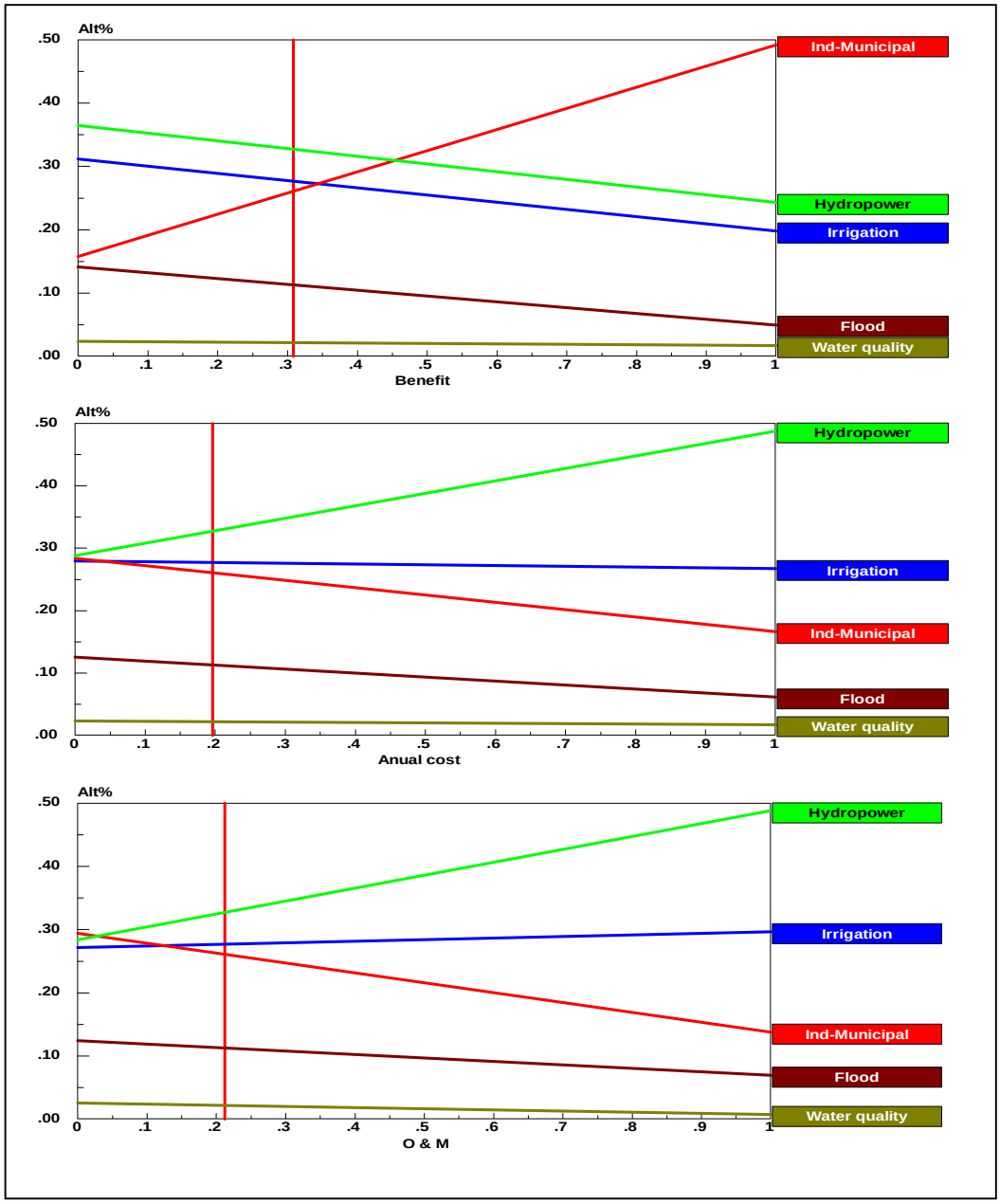


Fig. 4 Gradient sensitivity graphs charge BJP-SDA -SDA to beneficaries with three criteria



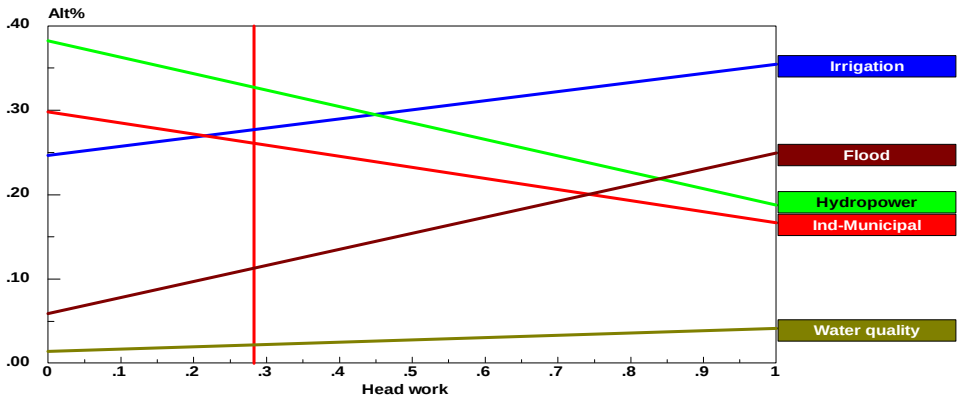


Fig. 5 The Gradient sensitivity graphs charge of BJP-SDA to beneficaries with four criteria

With the allocation of river water for dilution is 7.5 m^3 /sec during three months on dry season, BJP-SDA charge to improve the water quality in Brantas River has the lowest (Figure 3), that is, 2.2 – 2.3% from the cost which will be covered. Under the O & M cost, the percentage of the BJP-SDA charge is 0.8% and under the benefit value of the user is 1.7% from the cost which will be covered.

The water pricing of BJP-SDA for the beneficiaries of the river water quality improvement is the water allocation for dilution divides with the cost which will be covered. For the O and M cost recovery, the water price is Rp. 112 until Rp. 117 per m^3, and for the full cost recovery is Rp. 126 until Rp. 132 per $m^{3.}$

The Water charge is determined by considering many factors as ability to pay and willingness to pay. In case of the water charge to improve the water quality, it cannot be applied or it is still under the water price, so the improvement cost of the river water quality is covered by the government.

In this study , the benefit of water utilization is the most deciding factor of the BJP-SDA charges sharing. The benefit of water utilization gets the value of 0.385 compares to the value of the amount of primary building and the O and M cost, which is 0.263 for hierarchy with three variables. For the hierarchy with four variables, the benefit of water utilization's value is 0.308 compares to the value of the amount of primary building that is 0.283, the O & P cost which is 0.212 and the investment/asset gets the value of 0.196.

The decision-makers can investigate how sensitive the charge level of the beneficiary groups is towards the change of the importance of the O and M cost, the amount of head work, benefit and asset. The sensitivity analysis shows that the percentage charge of BJP-SDA for the beneficiaries of the river water improvement is 2.9 – 0,8% and 2.6 - 0.8% for the change of the O and M factors. The sensitive analysis for the amount of head work, benefit and asset is presented in Figure 3 and Figure 4.

IV. CONCLUSIONS

This study extends the model of the BJP-SDA cost sharing in the major river by considering the maintenance and the operational cost, the benefit of water utilization , the amount of head work for every beneficiary. The charge of BJP-SDA allocated based on the benefit of water utilizing can be justified by the AHP model with other factors. This model becomes one of the alternative in the calculation of the BJP-SDA charge in the major river level and as a reference for the decision-makers in planning the cost recovery in major river .

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