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Fair Budgeting Formulation for O&M of Irrigation Using Multi-Criteria Decision Analysis: WA and AHP Methods

Edy Anto Soentoro

Water Resources Engineering Research Group, Faculty of Civil and Environmental Engineering (FCEE), Institut Teknologi Bandung (ITB), Indonesia, E-mail: edyas209@gmail.com, edy_as@ftsl.itb.ac.id

Faizal I.W. Rohmat

Center for Water Resources Development, Institut Teknologi Bandung, Indonesia

Vitta Vurnamawati

Graduate Student of Master Program in Water Resources Management, FCEE, ITB, Indonesia

Abstract

Operation and Maintenance (O&M) budget provided by the Government of Indonesia for irrigation, so far, is based on the size of irrigated area only. Meanwhile, the actual O&M costs of an irrigation area also depend on the topographic terrain, canal density/length, irrigation structure density, and infrastructure damages that influence to the proper function of irrigation system. Thus, the O&M budget does not represent the actual cost needed. The purpose of this study is to find method for fair budgeting O&M irrigations based on Multi-Criteria Decision Analysis (MCDA): Weighted Average (WA) and Analytic Hierarchy Process (AHP) methods. As case study, the methods are applied on nine irrigation areas with various topographical conditions. The results are then compared with the conventional O&M budget. Four criteria are used to assess the irrigation areas above: canal density/length (m/ha), structure density (per hectare), infrastructure damages (%), and size of the irrigation area. The result shows that O&M budgeting using WA and AHP methods gives more fairness and closer to the actual budget needed, compared with the government budgeting that based on the size of irrigation area only. While in general, result using AHP method tends to be more sensitive than that using WA method.

Keywords: *Fair Budgeting, Irrigation O&M, MCDA, AHP.*

Abstrak

Anggaran untuk Operasi dan Pemeliharaan (O&P) daerah irigasi dari pemerintah Indonesia, saat ini, hanya berdasarkan pada luas daerah irigasi saja. Pada kenyataannya, biaya O&P dari suatu daerah irigasi juga tergantung pada kondisi topografi, panjang/kerapatan saluran, kepadatan bangunan irigasi, dan kerusakan infrastruktur yang berpengaruh terhadap berfungsinya system irigasi dengan benar. Jadi, anggaran O&P pada saat ini tidak mewakili biaya yang sebenarnya dibutuhkan. Tujuan dari penelitian ini adalah mencari cara yang lebih tepat dalam menentukan penganggaran O&P daerah irigasi berdasarkan Multi-Criteria Decision Analysis (MCDA): *metoda* Weighted Average (WA) *dan* Analytic Hierarchy Process (AHP). *Sebagai studi kasus, kedua metoda tersebut diterapkan pada 9 daerah irigasi dengan berbagai kondisi topografi. Hasilnya kemudian dibandingkan dengan anggaran O&P yang ada. Empat kriteria digunakan dalam menilai 9 daerah irigasi tersebut, yaitu: panjang/kerapatan saluran (m/ha), kepadatan bangunan air (per ha), kerusakan infrastruktur (%),dan luas daerah irigasi. Hasil penelitian menunjukkan bahwa menentukan anggaran O&P dengan metoda WA dan AHP memberikan hasil yang lebih adil dan lebih dekat dengan biaya yang dibutuhkan, dibandingkan dengan anggaran saat ini yang hanya berdasarkan pada luas daerah irigasi saja. Secara umum, hasil menggunakan metode AHP cenderung lebih sensitif dibandingkan dengan metode WA.*

Kata-kata Kunci: *Penganggaran yang adil, O&P Irigasi, MCDA, AHP.*

1. Introduction

Global climate change, food crisis, and energy crisis, are few of several strategic issues the today's world faces. Food security issue becomes the most concerned issue as the world intensifies on ensuring equitable access to a safe, sufficient, and healthy food. This effort comes as a consequence of the global population increases to around 9 billion people at around 2040s (Global Food Security, 2013). Since the global crisis also happens in Indonesia, Indonesia must be able to ensure food production for its people. Therefore, promoting food security is one of Indonesia's development priorities (Presiden Republik Indonesia, 2010).

Rice is the primary food for Indonesian, dated back to the 8th century where historical evidence record Indonesia's first cultivation activity on rice production, where evidence of wild rice consumption recorded by 3,000 B.C.E. and connected with Southeast Asia and Asia rice cultivation history (Taylor, 2003; Barker & Molle, 2004). The expansion and cultivation of rice over fifteen hundred years have shaped Indonesia's food production system. As in present days, one of the major roadmap of Indonesia's effort on food security priority is the 10 tons rice surplus targeted in 2014 by the Ministry of Agriculture of the Republic of Indonesia (Ministry of Agriculture of Republic of Indonesia, 2013). The implementation of the priority are through (1) productivity escalation, (2) agriculture area enlargement, (3) rice consumption reduction in terms of primary food diversification and community food security, and (4) management excellence through policy and regulation support, technical management excellence, and development administration excellence (Ministry of Agriculture of Republic of Indonesia, 2013).

As one of the focus in technical excellence is the raw water use for agricultural needs, especially for the need of rice paddy field irrigation, as the complementary water supply to the paddy field in addition to natural precipitation (Stern, 1979). Report shows that the total water consumption for agricultural needs in Indonesia ranged from 70-80% (Serageldin, 1995). While FAO reported that Indonesia's raw water use reaches 85% of its total water use alongside raw water use for domestic and industrial needs (Food and Agriculture Organization of the United Nations (FAO), 2011). Currently 75% of worldwide rice production are obtained from irrigated wetland rice (Chapagain, 2009), as well as in Indonesia. In terms of promoting Indonesia's food security, raw water supply as a smaller part of water resources management aspect rises as an important issue, especially water resources allocation for irrigation.

One of important aspects in the paddy field irrigation water system is the funding for development and management. The policy of the Government of Indonesia states that the Government is responsible for the development and management of the paddy field irrigation system (The Government of Republic of Indonesia, 2006). The management stated in the regulation includes operation and management practices (O&M). The O&M practice are in the terms of water system and irrigation network management that includes water supply water distribution, water allocation, water usage, drainage, and effort to conserve irrigation network condition in order to make it well-functioning (The Ministry of Public Works of Republic of Indonesia, 2007; Kodoatie & Sjarief, 2005).

The magnitude of the raw water use and its high priority does not followed by large allocation of funding for irrigation, which indicated with the low priority and limited funding of irrigation O&M (Vermilion, 2000). The lack of irrigation O&M funding is also disproportional to what irrigation area actually needs. The standard O&M budgeting, which is based only on the size of irrigation area, do not always represents the actual need of the irrigation area O&M (Hadihardaja, Rural Infrastructure Policy Development: Irrigation and Water Resources Sector Final Report, 2005). Also, the lack of funding and improper budget allocation affect the sustainability of the irrigation system (Skutch, 1998). This improper budgeting system needs a new O&M budget formulation system.

As the regulation of the Government of Indonesia via the Regulation of Ministry of Public Works of Republic of Indonesia states that the funding for irrigation maintenance shall be managed efficiently in order to achieve desired and sustainable service level for irrigation water users and irrigation network users (The Ministry of Public Works of Republic of Indonesia, 2012). This management practice efficiency includes O&M budget efficiency. Thus, O&M budget is an important issue in the terms of enhancing irrigation technical excellence, in order to promote national food security.

The efficiency in budget use to fund alternatives are directly connected with the level of priority of the alternative, for which alternative tend to be more important relative to the other are considered prioritized for the funding. Thus, the prioritized alternative will acquire the funding first or acquire the funding more than the others, depends on the funding scheme. The study utilizes the prioritizing scheme of Multi-Criteria Decision Analysis (MCDA) method in order to acquire prioritization scheme of alternatives, i.e. the irrigation areas to be funded and transform it to a fair budgeting strategy. MCDA itself chosen as prioritizing method as it is widely used in the decision-making fields, i.e. science (Alencar & de Almeida, 2009; Athawale & Chakraborty, 2010), public affair (Bartolini, Gallerani, Raggi, & Viaggi, 2012).

This study is also a follow-up study on previous studies that have been made: the Decision Support System for Irrigation in Indonesia (Hadihardaja & Grigg, Decision Budgeting Strategy and Sensitivity Analysis for Irrigation Infrastructure Maintenance (Hadihardaja, Indrawati, Suryadi, & Soekarno, 2010). The purpose of this study, are to formulate fair budgeting of irrigation O&M using Weighted Average and Analytic Hierarchy Process method; to compare the results of fair budgeting formulation with the government budgeting, and to analyze the sensitivity of each fair budgeting criteria.

The scope of study includes the formulation of fair budgeting, comparison with the budget, and sensitivity analysis using MCDA method (Weighted Average and Analytic Hierarchy Process). The study uses nine study areas with different terrain characteristics: Ciherang, Cirasea, and Wanir (mountains); Cibutul, Cikeruh, and Cikamangi (transition); Setupatok, Ambit, and Cibacang (flat). The characteristic of irrigation area included are canal density (m/ha), structure density (ha^{-1}), and infrastructure damage (%). The size of the irrigation area (ha) is used as comparing criterion.

2. Methodology

Methodology of this study consists of several steps: identification of alternative values per criterion, normalization of alternative values per criterion, criterion weighing, Multi-Criteria Decision Analysis processes which consists of Analytical Hierarchy Process and Weighted Average methods, comparison between MCDA budgeting strategy and government's budgeting, and the sensitivity analysis of the evaluating criteria (**Figure 1**).

2.1 Data compilation (identification of alternative values and normalization)

The study was carried out using actual irrigation area data-set which derived from the West Java Water Resources Service (Dinas PSDA Jawa Barat). From more than 40 irrigation area, the study uses nine samples of irrigation areas with particular characteristic, three from the mountainous area (Ciherang, Cirasea, and Wanir), three from the plains (Setupatok, Cibacang, Ambit), and three from the transition (Cibutul, Cikeruh, and Cikamangi). The data set arranged in tabular format, with criteria column and alternative rows. The data set is using actual values, with canal density criterion derived from the ratio between total canal length and the size or irrigation area, and the structure density is derived from the ratio between total number of hydraulic structures and the size of irrigation area. While the infrastructure damage criterion derived from the total canals, hydraulic structures, and mechanical-electrical structure damages both physically and functionally.

2.2 Criterion weight

Since MCDA method involves criterion in the decision making process, criterion weight become a vital element in the analysis. The criterion weight represents the relative importance among each criterion. Criterion weight in this study is determined based on questionnaire which is distributed to 17 respondents who professionally work in the field related to O & M of irrigation, including staffs who work in budget planning and implementing the budget. There are: 6 staffs from Ministry of Public Works, 5 staffs from Provincial Government, 4 university professors, and 1 person from private sector. The questionnaire consists of questions about the relative importance among each criterion. The criterion weight is determined based on the average result of the questionnaires. If the number of respondents is being increased, the criterion weights will not be exactly the same with those in this study. The discrepancy, however, it will not affect a lot to the conclusion of this study, as long as the respondents are professionally work in the field related to O&M of irrigation.

2.3 Multi criteria decision analysis

Multi Criteria Decision Analysis (MCDA) is a study of identification, alternative selection and analysis, which is based on the value and the preference of the decision maker (Harris, 2012). The goal of MCDA is to find the best answer or alternative solution, among many alternatives based on the preference of the decision-maker under evaluation of more than one evaluating criteria. The result of the MCDA process is the comparative value between each alternative (Baker, et al., 2001). In this study, the MCDA method being used is the Weighted Average and the Analytic Hierarchy Process.

The Weighted Average method is one of the simplest MCDA techniques which also mostly used. The technique consists of only two steps: criterion weight and inter-alternatives rating. The criterion weight derived from the previous step is used as the criterion weight to calculate inter-alternative rating, derived from the actual value of the alternatives, and resulted inter-alternative rating which shows the relative importance between each alternative.

The second method, Analytic Hierarchy Process (AHP), is the MCDA method formulated by Thomas L. Saaty in 1970 (Haas & Meixner). The AHP analysis technique started with outlining structure of the problem. The structure itself consists of three levels: goal, criteria, and alternatives. The inter-alternative relationship quantized using the Saaty Scale ranged from 1 to 9. The result of the method is the inter-alternative rating which shows alternative's relative importance.

The results of both MCDA methods then converted onto fair budgeting, which then compared with the Government-standard budgeting, which based only on the size of the irrigation area. The final part of the study is the sensitivity analysis of MCDA result, in order to determine the sensitivity of both methods. The study itself uses assumption that there is no addition/ reduction in the size of irrigation area, the total length of canal, and the number of hydraulic structures. So that the characteristics of the irrigation area remain the same since the irrigation area is constructed. On the other hand, the infrastructure damage used in the study is the temporally static value.

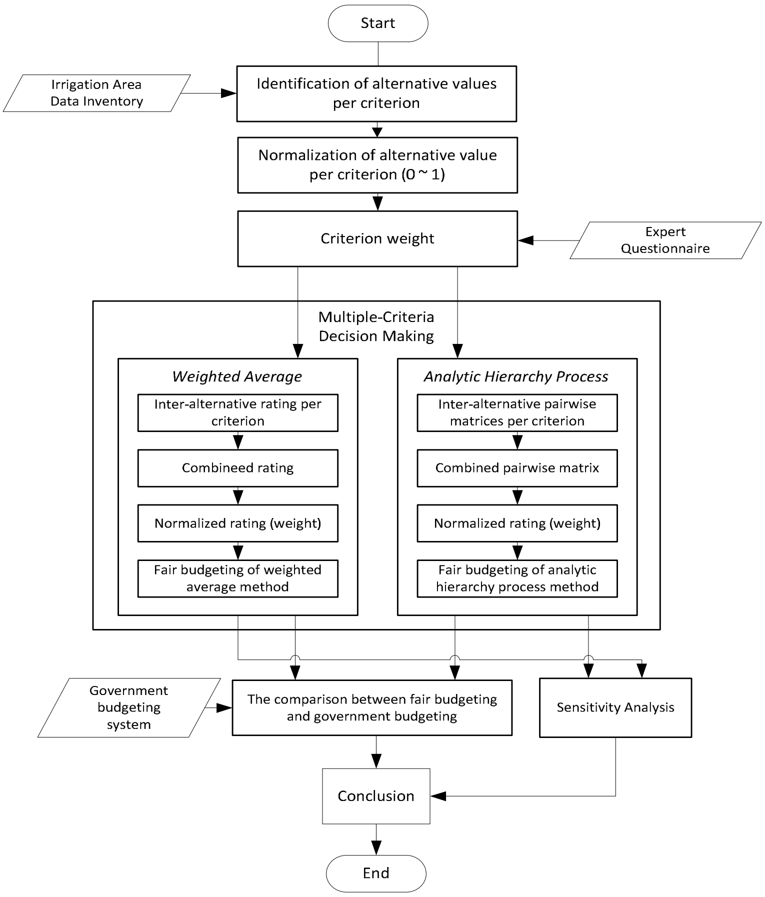

Figure 1. Study flowchart

3. Analysis

As it has been stated earlier, the study used nine irrigation area and three criteria. For MCDA analysis reason, the nine irrigation area recognized as the alternatives of MCDA analysis. The values of each alternative per criterion are presented below (**Table 1**), alongside with the normalized value of each alternative per criterion (**Table 3** and **Figure 2**). The value for each irrigation area by three evaluating criteria plus the criteria of the size of irrigation area (**Table 1**) are based on the actual irrigation area inventory report of West Java Water Resources Management Service (West Java Water Resources Management Service, 2010).

The values are then being rescaled by normalization, producing uniform scale (zero to one) in order to give uniform measurement (**Table 3, Figure 2**). The values are presented in bar-chart, presenting the higher value with higher bar with scale from zero to one. As shown in **Figure 2**, Cibacang irrigation area holds the highest normalized value for canal density and structure density, it means that Cibacang is the most dense irrigation area. This fact is coherent with the size of Cibacang irrigation area which appears to be the lowest (smallest irrigation area among the sample). For other criteria, Cirasea irrigation area holds the highest value for the size of irrigation area, which means Cirasea is the largest irrigation area among the sample.

Table 1. Alternative value on each criterion

Irrigation area	Size of irrigation area ha (Size)	Canal Density m/ha (Canal)	Structure Density unit/ha (Structure)	Infrastructure Damage % (Damage)
Ambit (AMB)	1558	0.95	0.04	18.21
Cibacang (CBC)	814	55.09	0.08	28.40
Cibutul (CBT)	1525	5.79	0.03	41.03
Ciherang (CHR)	2177	8.76	0.03	7.46
Cikamangi (CKM)	1899	13.94	0.05	27.68
Cikeruh (CKR)	1553	10.57	0.06	23.99
Cirasea (CRS)	2817	8.47	0.05	15.89
Setupatok (STP)	1494	9.08	0.06	7.90
Wanir (WNR)	2169	1.61	0.06	4.25

Source: West Java Water Resources Service, 2010.

For infrastructure damage criteria, Cibutul irrigation area holds highest value among sample, which means that Cibutul is the most damaged irrigation area.

The analysis continued with determination of criterion weight. As stated above, the determination based on questionnaire which distributed to 17 irrigation practitioner. The result of the questionnaire shows that the structure density weighed most, valued 0.489, followed by infrastructure damage and canal density, valued 0.308 and 0.204 respectively (**Table 2**). The criterion weight derived from the survey conducted to 17 irrigation practitioner shows that the respondent assume that the structure density criterion holds the highest weight among other criterion, which means that the structure density tends to be the most important criteria among others, so that the change of the value of alternative's structure density has the highest effect on the change of its planned budget.

3.1 Weighted average method

Weighted Average MCDA analysis begins with the inter-alternatives rating, the rating system is based on the value per criterion with the highest value gets the highest rating, which scaled one to nine (**Table 4**). The values are then being normalized as the total equals to one (**Table 5**). The rating (**Table 4**) is combined with the weight of the criterion (**Table 2**), so that the value of the weight of each alternative can be obtained (**Table 5**). The values are then presented in bar-chart forms to give more visualized comparison (**Figure 3**).

3.2 Analytic Hierarchy Process (AHP)

In this Modified Analytic Hierarchy Process method, the inter-criteria weight is also used to the evaluate alternatives (**Table 2**). The analysis continued with the determination of inter-alternative pair-wise matrix for each criterion (**Table 6**, **Table 7**, and **Table 8**). The value of pair-wise matrix is one divided by the original of each alternative value. Similar to the results found in Weighted Average method, the AHP result (**Table 9** and **Figure 5**) shows that Cibacang alternative also holds the highest weight on nearly all of the criteria, except the infrastructure damage. The pattern is also

Table 2. Criterion weight

Criterion	Weight
Canal	0.20
Structure	0.49
Damage	0.31
Total	**1.00**

Table 3. Normalized alternative value on criterion

Alt.	Size	Canal	Structure	Damage
AMB	0.55	0.02	0.56	0.44
CBC	0.29	1.00	1.00	0.69
CBT	0.54	0.11	0.32	1.00
CHR	0.77	0.16	0.35	0.18
CKM	0.67	0.25	0.59	0.67
CKR	0.55	0.19	0.71	0.58
CRS	1.00	0.15	0.58	0.39
STP	0.53	0.16	0.80	0.19
WNR	0.77	0.03	0.69	0.10

Table 4. Rating between alternatives per criterion on weighted average method

Criterion	Canal	Structure	Damage
AMB	1	3	5
CBC	9	9	8
CBT	3	1	9
CHR	5	2	2
CKM	8	5	7
CKR	7	7	6
CRS	4	4	4
STP	6	8	3
WNR	2	6	1

Table 5. Normalized alternatives' rating (Weighted Average Method)

Criterion	Canal	Structure	Damage	Total
AMB	0.02	0.07	0.11	0.07
CBC	0.20	0.20	0.18	0.19
CBT	0.07	0.02	0.20	0.09
CHR	0.11	0.04	0.04	0.06
CKM	0.18	0.11	0.16	0.14
CKR	0.16	0.16	0.13	0.15
CRS	0.09	0.09	0.09	0.09
STP	0.13	0.18	0.07	0.13
WNR	0.04	0.13	0.02	0.08
Total	1	1	1	1

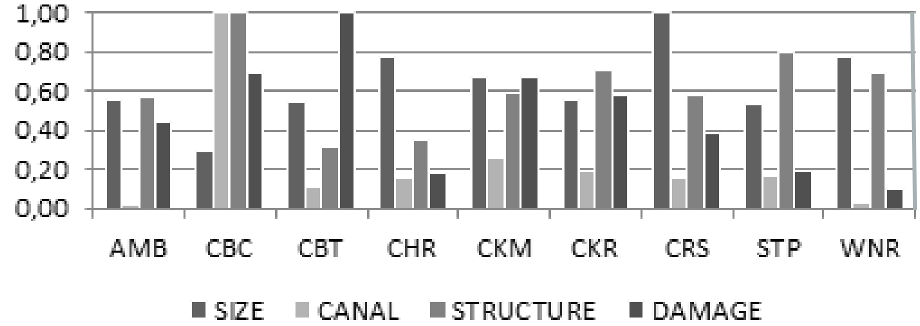

Figure 2. Normalized alternative values on each criterion

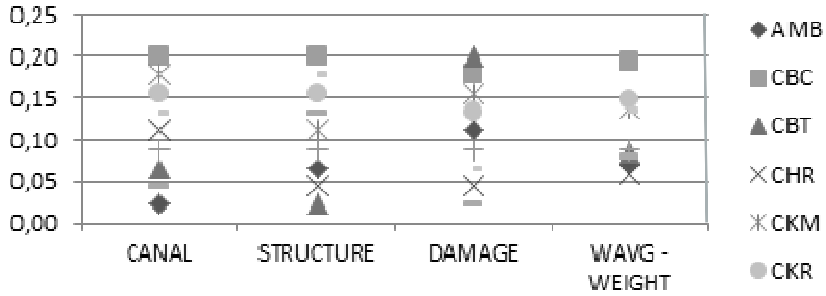

Figure 3. Summary of weight, using Weighted Average method

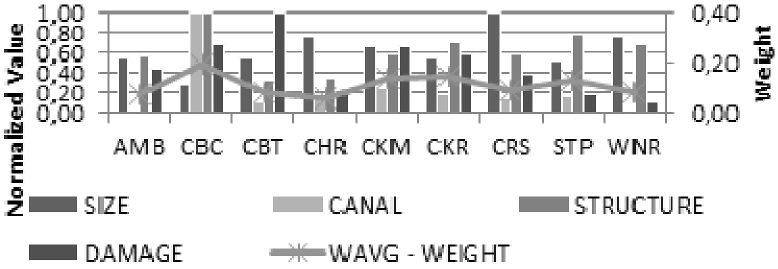

Figure 4. WAVG weight compared to normalized value

coherence with the normalized value of the alternatives (**Figure 6**). The main difference between the AHP method and the Weighted Average Method is that the result of AHP method shows broader range between the highest value and the lowest value in the canal density criteria. A broad range between maximum and the minimum value is also found in the infrastructure damage criteria. The broader range found in AHP method may cause by the pair-wise process in AHP method that compares the actual value of the alternatives, while Weighted Average weighting scale is based on natural number rating with fixed scale (one to nine). The result of AHP appears to accommodate the characteristic of the alternatives, in respect of the evaluating criteria, noted that AHP method accommodates alternative's value more.

3.3 Fair budgeting

Fair budgeting is defined as the weight of alternative multiplied by the total of government budgeting, which is Rp 4,001,500,000.00, derived from the rule of Rp 250,000.00 per ha, multiplied by the total area of 16,006 ha (of nine irrigation area). The results of fair budgeting using Weighted Average method and AHP, and its comparison with the government's budget are presented below (**Table 10**, **Figure 7,** and **Figure 8**).

Table 6. Inter-alternatives pair-wise matrix on canal density criterion

Alternatives	AMB	CBC	CBT	CHR	CKM	CKR	CRS	STP	WNR
AMB	1.00	0.02	0.16	0.11	0.07	0.09	0.11	0.10	0.59
CBC	57.95	1.00	9.52	6.29	3.95	5.21	6.50	6.06	34.15
CBT	6.09	0.11	1.00	0.66	0.41	0.55	0.68	0.64	3.59
CHR	9.21	0.16	1.51	1.00	0.63	0.83	1.03	0.96	5.43
CKM	14.67	0.25	2.41	1.59	1.00	1.32	1.65	1.54	8.64
CKR	11.12	0.19	1.83	1.21	0.76	1.00	1.25	1.16	6.55
CRS	8.91	0.15	1.46	0.97	0.61	0.80	1.00	0.93	5.25
STP	9.55	0.16	1.57	1.04	0.65	0.86	1.07	1.00	5.63
WNR	1.70	0.03	0.28	0.18	0.12	0.15	0.19	0.18	1.00

Table 7. Inter-alternatives pair-wise matrix on structure density criterion

Alternatives	AMB	CBC	CBT	CHR	CKM	CKR	CRS	STP	WNR
AMB	1.00	0.56	1.76	1.60	0.95	0.79	0.97	0.71	0.81
CBC	1.78	1.00	3.12	2.85	1.68	1.41	1.72	1.26	1.44
CBT	0.57	0.32	1.00	0.91	0.54	0.45	0.55	0.40	0.46
CHR	0.62	0.35	1.10	1.00	0.59	0.49	0.60	0.44	0.51
CKM	1.05	0.59	1.85	1.69	1.00	0.84	1.02	0.75	0.86
CKR	1.26	0.71	2.22	2.02	1.20	1.00	1.22	0.89	1.02
CRS	1.04	0.58	1.82	1.66	0.98	0.82	1.00	0.73	0.84
STP	1.42	0.80	2.49	2.27	1.34	1.12	1.37	1.00	1.15
WNR	1.23	0.69	2.16	1.97	1.17	0.98	1.19	0.87	1.00

Table 8. Inter-alternatives pair-wise matrix on infrastructure damage criterion

Alternatives	AMB	CBC	CBT	CHR	CKM	CKR	CRS	STP	WNR
AMB	1.00	0.64	0.44	2.44	0.66	0.76	1.15	2.31	4.29
CBC	1.56	1.00	0.69	3.80	1.03	1.18	1.79	3.59	6.68
CBT	2.25	1.44	1.00	5.50	1.48	1.71	2.58	5.19	9.66
CHR	0.41	0.26	0.18	1.00	0.27	0.31	0.47	0.94	1.76
CKM	1.52	0.97	0.67	3.71	1.00	1.15	1.74	3.50	6.52
CKR	1.32	0.84	0.58	3.21	0.87	1.00	1.51	3.04	5.65
CRS	0.87	0.56	0.39	2.13	0.57	0.66	1.00	2.01	3.74
STP	0.43	0.28	0.19	1.06	0.29	0.33	0.50	1.00	1.86
WNR	0.23	0.15	0.10	0.57	0.15	0.18	0.27	0.54	1.00

Table 9. Alternatives rating and normalized rating (weight)

Criterion	AMB	CBC	CBT	CHR	CKM	CKR	CRS	STP	WNR	Total
Canal	0.01	0.48	0.05	0.08	0.12	0.09	0.07	0.08	0.01	1.00
Structure	0.10	0.18	0.06	0.06	0.11	0.13	0.10	0.14	0.12	1.00
Damage	0.10	0.16	0.23	0.04	0.16	0.14	0.09	0.05	0.02	1.00
Weight	0.08	0.24	0.11	0.06	0.13	0.12	0.09	0.10	0.07	1.00

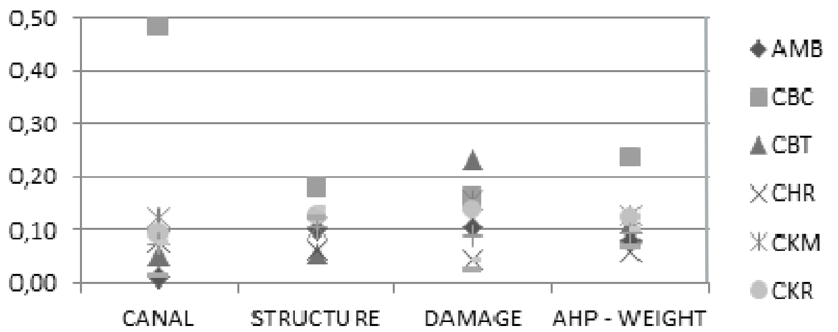

Figure 5. Summary of weight, using AHP method

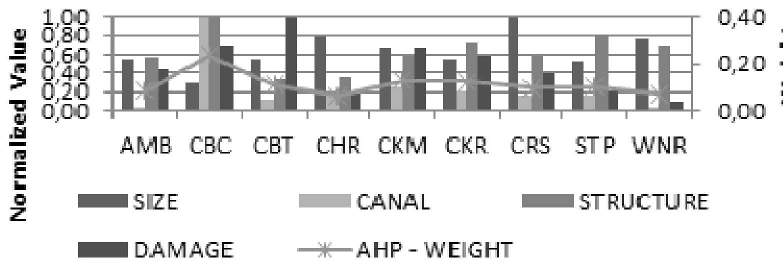

Figure 6. AHP weight compared to normalized value

As presented, fair budgeting strategy with both methods appears closely fit to the pattern of the three criteria. For example that with Cibacang holds highest value for two criteria and second highest for the other criterion, Cibacang acquires highest budget. As for Ciherang that holds relatively least criteria value, it acquires least budget. To be noted that Cibutul and Wanir irrigation area holds relatively least value for certain criteria, but also holds high value for the another criteria. This condition makes the irrigation area mentioned acquires relatively higher budget. That is, fair budgeting with the weighted average and the AHP method accommodates the canal density, density of buildings, and infrastructure damage criteria.

3.4 Sensitivity analysis

The results of sensitivity analysis (**Figure 9** to **Figure 14**) show that in general, alternatives in AHP method tends to be more sensitive than the weighted average method. As for the WAVG, the Cibacang alternative tends to dominate and insensitive to changes in criteria weights. On the other side, Cibacang alternative is very sensitive to the change of criterion weight on AHP method analysis.

Table 10. Comparison between government budgeting, weighted average budgeting, and AHP budgeting

Alternatives	Gov-Budgeting		Wavg-Budgeting		Ahp-Budgeting	
AMB	Rp	389,500,000	Rp	285,289,836	Rp	331,291,027
CBC	Rp	203,500,000	Rp	772,942,674	Rp	941,323,367
CBT	Rp	381,250,000	Rp	343,972,315	Rp	441,884,673
CHR	Rp	544,250,000	Rp	232,131,669	Rp	237,371,215
CKM	Rp	474,750,000	Rp	553,612,988	Rp	501,274,808
CKR	Rp	388,250,000	Rp	595,098,229	Rp	491,774,908
CRS	Rp	704,250,000	Rp	355,688,889	Rp	375,418,441
STP	Rp	373,500,000	Rp	538,399,664	Rp	398,103,060
WNR	Rp	542,250,000	Rp	324,363,737	Rp	283,058,502
TOTAL	Rp	4,001,500,000	Rp	4,001,500,000	Rp	4,001,500,000

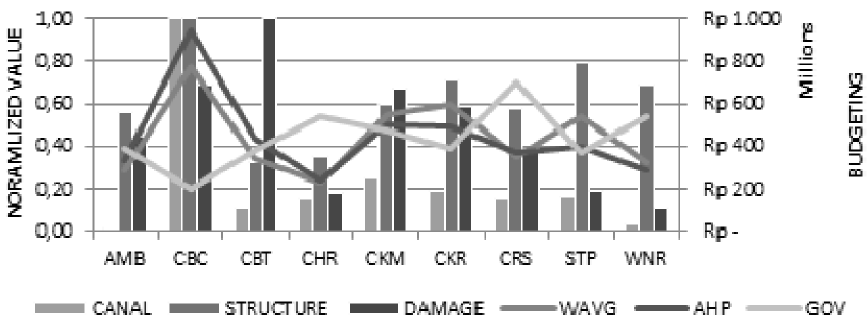

Figure 7. Comparison between government budgeting, weighted average budgeting, AHP budgeting, and normalized value of criteria per alternative

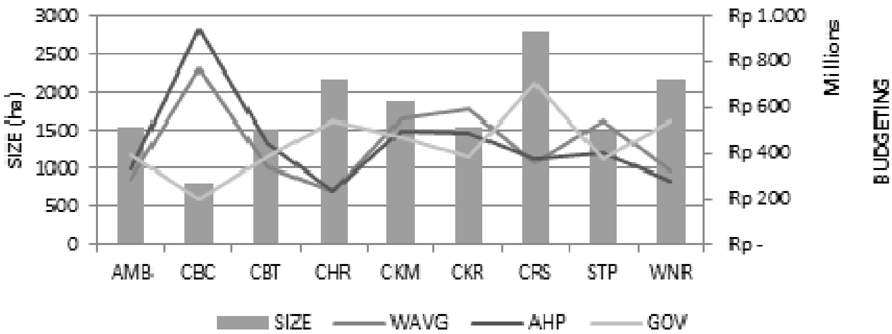

Figure 8. Comparison between government budgeting, weighted average budgeting, AHP budgeting, and the size of irrigation area criterion

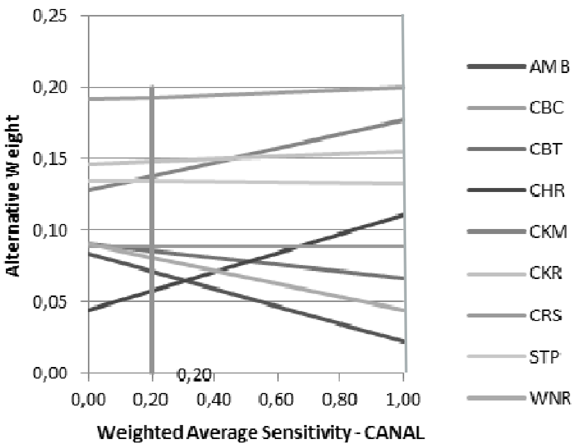

Figure 9. Sensitivity analysis for canal density criterion in Weighted Average method

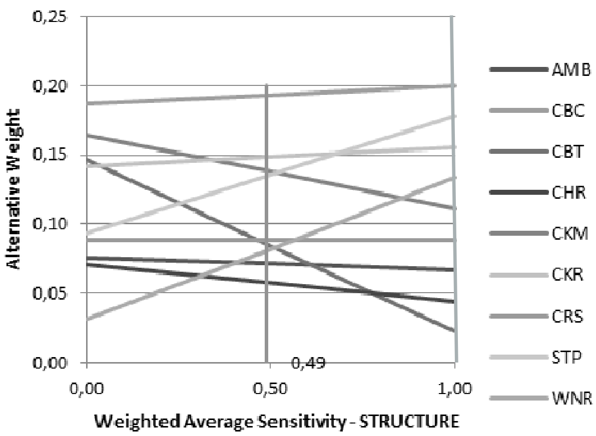

Figure 10. Sensitivity analysis for structure density criterion in Weighted Average method

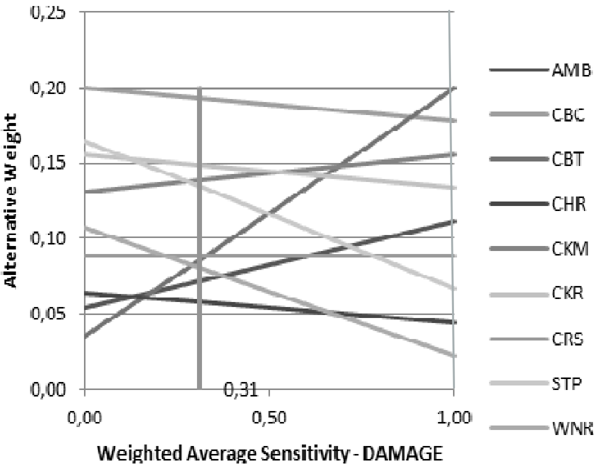

Figure 11. Sensitivity analysis for infrastructure damage criterion in Weighted Average method

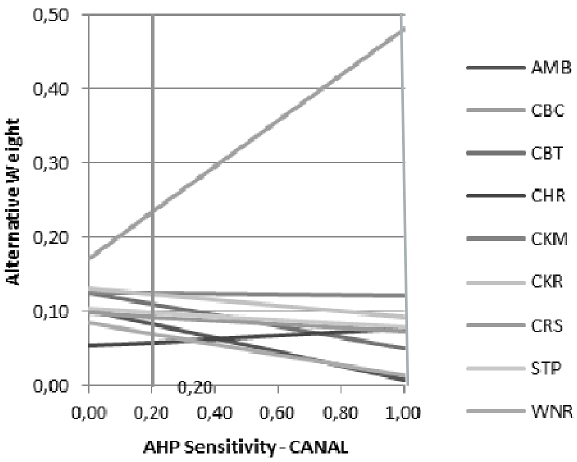

Figure 12. Sensitivity analysis for canal density criterion in AHP method

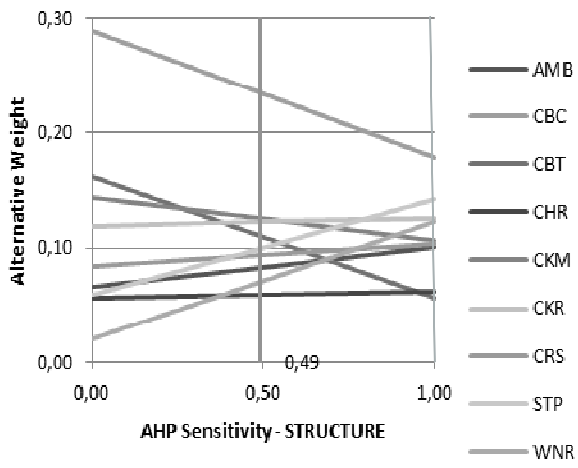

Figure 13. Sensitivity analysis for structure density criterion in AHP method

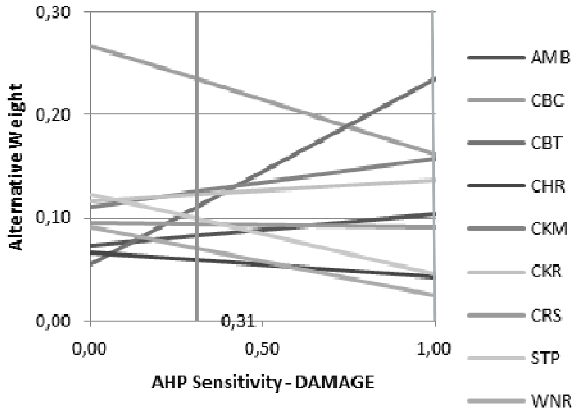

Figure 14. Sensitivity analysis for infrastructure damage criterion in AHP method

4. Conclusion

The conclusions of the study are:

1) The formulation of irrigation O&M fair budgeting can be done using the Multi-Criteria Decision Analysis (MCDA) approach: Weighted Average and Analytic Hierarchy Process method. Generally, the results of both method show similarity.
2) The irrigation area which should obtain higher priority in the context of fair budgeting is the one that holds feature of high infrastructure density (both canals and structures) and high level of damages; not only by the size of the irrigation area. Within this study it shows that Cibacang irrigation area obtain higher budget because of its high value of canal density, structure density, and infrastructure damages.
3) The result shows that O&M budgeting using WA and AHP methods give more fairness and closer to the actual budget needed, compared with the government budgeting that based on the size of irrigation area only.
4) Sensitivity analysis shows that in general the alternatives in the AHP method tends to be more sensitive than the Weighted Average method.

5. Recommendation

In this study, only nine irrigation areas are evaluated, from total 91 irrigation areas in West Java Water Resources Management Service responsible to. For further study, it is recommended to include all the 91 irrigation areas to be evaluated in order to get more comprehensive understanding on fair budgeting. It is also recommended to increase the number of samples/ respondents, targeting broader representation. In determining criteria weight, however, simple questionnaire filling and proportionally dividing the numbers of respondents who professionally work in the field related to O&M irrigation are needed to determine the valid criterion weight.

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