BUDGETING STRATEGY AND SENSITIVITY ANALYSIS

FOR IRRIGATION INFRASTRUTURE MAINTENANCE

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Abstract

Maintenance of irrigation infrastructure is essential related to the degradation of the function of irrigation systems especially in order to meet budget allocations. In developing countries such as Indonesia, annual operations and maintenance costs are very limited and follow the government policy within annual variation in budget allocations. The objective of this study is to develop a budgeting model to assist decision makers to make equitable budget allocations at operational levels. In Indonesia, it is common to allocate the budget based on rupiahs per hectare in which every region has the same budget in term of unit cost per hectare without considering the irrigation characteristic such as the length of the canal and the number of hydraulic structures in each region. This study proposes other approach of fair budgeting allocation for irrigation maintenance using multicriteria analysis and its sensitivity if there is limited budget for the maintenance. The case study will focus on five irrigation regions in the province of West Java in Indonesia.
Keywords: Analytic Hierarchy Process, Budgeting Sensitivity Analysis, Budgeting Strategy

Background

Irrigation infrastructure in Indonesia is commonly constructed in order to meet the local demand for rice and to improve the economy of farmers since the majority of communities in Indonesia still rely heavily on agriculture as their main livelihood. Operation and Maintenance (OM) activities are crucial in order to prevent the acceleration of the degradation of the function of infrastructure facilities. Therefore, the formulation of a meticulous pricing strategy (budget planning) to maintain the irrigation infrastructure system is vital to ensure the sustainability of rural irrigation and community development especially in developing countries such as Indonesia.

However, for some reason the budget allocation for maintaining the system is inequitable since emphasis is given to the development of new infrastructures rather than on increasing OM activities. The available budget can only barely meet OM costs in each irrigation region and the government does not have the resources to constantly provide and maintain the fixed budget for each year. Furthermore, the assumption for OM budget allocation is normally calculated based on the total area of the irrigation region without considering the density of its hydraulic structures and the length of canal in each irrigation region. Consequently, the amount of money received by each regional authority to maintain its irrigation system

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would only depend on the total area of the irrigation network. In other words, the Water Resources Agency will dole out identical budget allocations for each irrigation region in rupiahs per hectare. When in fact, water delivery in longer distribution systems (canal) should have greater budget allocations compared to water delivery in shorter canals (Hadihardaja, 2005).

The situation becomes worthy of attention because after so many years and even until today there has been no remedial measures or evaluation carried out to address these OM budgeting issues that have been raised by the regional irrigation authority. This study is intended to close the existing gap by determining an equitable budgeting strategy for optimal OM budget allocation for each irrigation region. This is important as budget allocation will adjust to fluctuations from year to year based on the physical characteristics and the number of infrastructure assets of each region.

In order to solve the problem mentioned above, Analytic Hierarchy Process (AHP) will be adopted to reach optimal decision for an equitable budgeting strategy for the selected (five) irrigation regions in the West Java province in Indonesia. Sensitivity analysis due to budget allocation is also introduced in this study in order to evaluate the possible variation of OM budget.

Financial management is implmented by using tools such as financial planning, budgeting, accounting, reporting and auditing. It is the link between planning, operating, and controlling. One of the significant financial tools for providing the whole management process is budget allocation (Grigg, 1988). In Indonesia, the budget allocation for irrigation maintenance is established in rupiahs per hectare. This is used in order to provide the budgeting needs as the easiest method, however, it lacks the accuracy as it fails to consider the number of assets of each irrigation region. In fact, the level of maintenance usually varies from one irrigation region to another. In addition, the average budget should differ among irrigation regions as it depends on previous maintenance activities carried out and irrigation infrastructure condition.

The water delivery of a longer distribution/canal may require more budget than a shorter one although the field rice is smaller (especially in hilly land). In addition, a higher number of the infrastructure hydraulic structure will entail a larger budget allocation than a lower one, although the field rice is relatively smaller. These must be considered in order to ensure a fair budgeting strategy for appropriate cost allocation for each irrigation region. If the budget allocation is based on rupiahs per hectare, then, a larger area of field rice will need a larger budget allocation. Therefore, a fair budgeting system is considered to be one that quantify the characteristic of irrigation infrastructure due to the density of the hydraulic structure and length of canal per area of the irrigation region.

Case study

The issue of budget allocation becomes important when the available funds are in limited supply. In that case, operational and especially maintenance activities cannot be carried out appropriately and their sustainability cannot be maintained. This condition will encourage the degradation of the function of the irrigation infrastructure in the future and cause more damage, thus the need for additional budget for rehabilitation or reconstruction before the termination period of the infrastructure. If there is unlimited budget for maintenance that is sustainable, then the degradation process will have a mild gradient compared to a limited budget for maintenance that may accelerate a steeper gradient and eventually arrive at an immediate failed infrastructure. An illustration of the acceleration of a first-rate infrastructure quality due to good maintenance in comparison to an inferior infrastructure quality because of imperfect maintenance is presented in Figure 1.

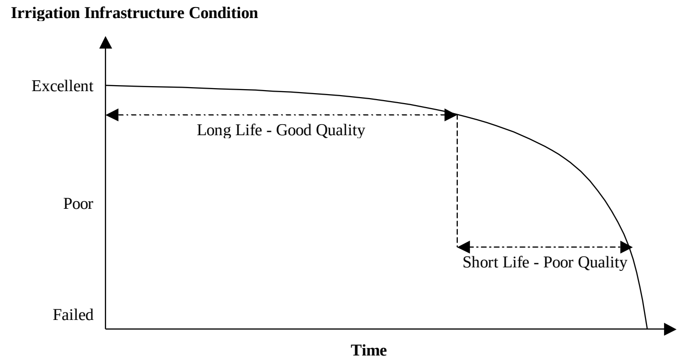

Figure 1. Life-cycle Curve of Irrigation Infrastructure

It is important to determine fair budgeting strategy when the budget allocation is very limited to ensure the sustainability of the irrigation system. On the other hand, a uniform allocation of budget based on rupiah per hectare for irrigation maintenance is unjust considering that each irrigation region has a different infrastructure density, length of canal and or the number of hydraulic structure per hectare. Therefore, budget constraints need to be modified when an assessment has been carried out in order to improve sustainability through the making of prudent decisions concerning budget allocations for the irrigation system.

Five irrigation regions have been selected for this study where they are located either in hilly, transition or plain areas. The characteristic of the area will be evaluated based on the density of its hydraulic structure, length of the canal and other supporting facilities. The five irrigation regions are South Lakbok (SL), West Lutung (WL), Cihea (Ch), Ciletuh (Ct) and Ranggon (Rgn) and the characteristics of each irrigation region are presented in Table 1.

Table 1. Characteristic Of Selected Irrigation Regions in The Province of West Java, Indonesia (Water Resources Agency - West Java Province, 2006)

Irrigation Region	South Lakbok (SL)	West Lutung (WL)	Cihea (Ch)	Ciletuh (Ct)	Ranggon (Rgn)
Area (Ha)	4,537	3,503	5,484	3,378	8,843
Total Length of Canal (m)	49,390	76,193	30,691	71,070	123,130
Number of Hydraulic Structure	288	81	147	327	400

In Table 1, mean of the total length of the channel is the total amount of primary channels and secondary channels without entering tertiary canals. A longer line indicates the location of hilly, and while the channel is shorter with the same area indicated broad flat location of irrigation region. On a hilly location problems such as sedimentation and turn the channel to make the necessary compared with flat region. So does the number of hydraulic structures, when the number is large it is indicated hilly region and small number of hydraulics structures indicated flat regions.

Fair budgeting strategy using multicriteria analysis

AHP has been extensively used in economics and planning, energy policy, conflict resolution, project selection and resource allocation. AHP is one of multicriteria Decision-making technique and based on hierarchical additive weighting, utilizing the pair-wise assessment method to evaluate the alternatives using quantitative or qualitative decision weights (Dzemydiene et al., 2008). Thomas Saaty in the middle 70s introduced a multicriteria decision making technique that involves concerns of two aspects that are objective and subjective in order to obtain the best alternative. This technique applies an procedure to obtain the cardinal ranking of alternative scale-ratio associated with Multiatribute decision-making problems (Saaty, 1980).

In this technique, Saaty gives scale of interest ordinary from (1) to the best important (9) without decimal value (integer). Once the alternative options are ranked, the decision-maker can easily choose the most suitable alternative for the decision needs (Saaty, 1980). In this study, the decision weights are determined in order to obtain the justified weight for each alternative, i.e. each irrigation region. Therefore, the justified weights are the new weights and they are called, then, the budgeting indexes.

The five irrigation regions are used as the case study and the alternatives in the AHP model. In addition, three criteria are used to evaluate the five alternatives such as the length of the irrigation canal, the area of irrigation region, and the number of hydraulic structures. Since the weight resulted by the AHP model is totally equals to one, then, it is necessary to be adjusted to obtain the equilibrium state of the model. Therefore, it is introduced the proportional value of the decision weights by using the equation (Hadihardaja & Grigg, 2010):

$$C_w \sum W_i a_i = \overline{B} A \text{ for } i = 1, \ldots, N \quad (1)$$

in which C_w is the modified constant of decision weight, W_i is the decision weight based on global priority for the AHP solution, a_i is the area of each irrigation region. $\overline{B}$ is the budget allocated by government related to average cost for maintenance, A is the total area for all irrigation region, N is the number of the selected irrigation region (in this case N =5). In addition, the value of $C_w W_i$ can be calculated as the new budget coefficient for each irrigation region representing the justified weights, which are identical to the budgeting indexes as well.

Fair budgeting strategy is developed by applying budgeting indexes for each irrigation region and determined by using AHP method. In this case, the assumption is considered based on expert judgment for the significant level of the criteria. For each of criteria (area, length of canal and number of hydraulic structure), the assumptions provide the following interest such as:

- Length of canal is 3 times important from area, since the variation of canal is influence significantly for the cost of OM.
- Number of hydraulic structure is 2 times important from area, since more hydraulics structure will implies cost of OP more expensive.
- Consequently, the length of canal is 1.5 times important from the hydraulic structure.
- This condition is for routine maintenance excluded rehabilitation and construction.

Analysis and discussion

Based on the execution of the model using Expert Choice Software, the analysis and discussion will focus on the budgeting indexes of each irrigation region and the sensitivity analysis. The global priority, W_i ,of each irrigation region is presented in Figure 2. This indicates that Ranggon has the largest budget maintenance compared to the others. In addition, the local decision weight based on each criteria and the global decision weight as indicated by 'overall' is presented in Figure 3.

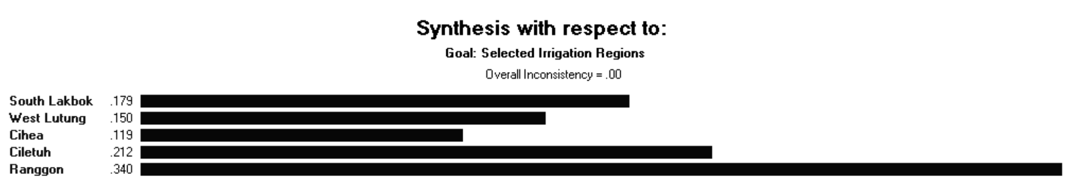

Figure 2. Global Priority of Decision Weight for Five Region of Irrigation

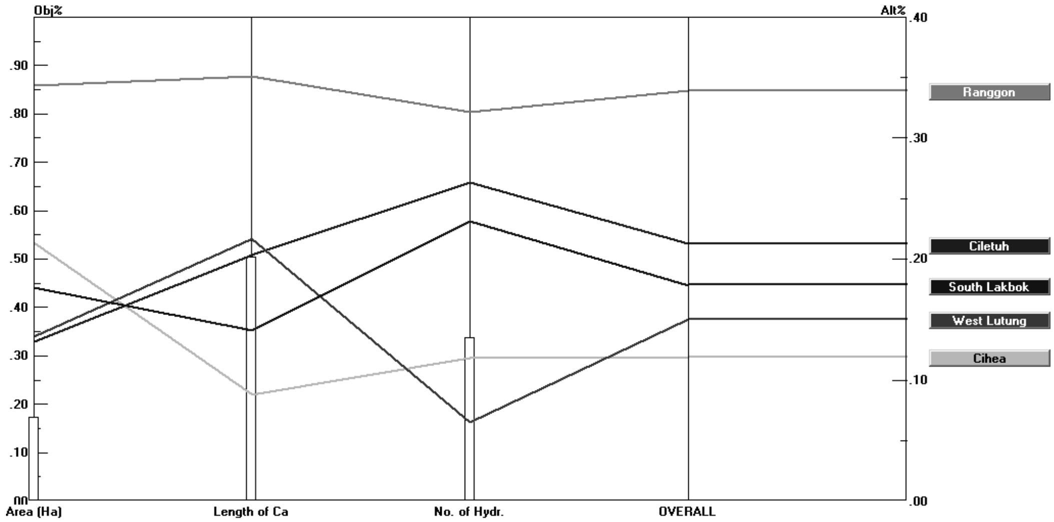

Figure 3. Local and Global Priority of Decision Weight for Five Region of Irrigation

Based on the equation (1), the value of modified constant of the decision weight for all irrigation regions, C_w, is 4.51. Therefore, the value of budgeting indexes, $C_w W_i$, of each irrigation region can computed and presented in Table 2.

Table 2. Budgeting Indexes and Budget allocation (for 200,000.00 rupiahs per Hectare) of Each Irrigation Region

No.	Irrigation Area	Budgeting Indexes $C_w W_i$	Modified Budget (Rupiahs per Hectare)
1	South Lakbok (SL)	0.807	161,458.00
2	West Lutung (WL)	0.677	135,300.00
3	Cihea (Ch)	0.537	107,338.00
4	Ciletuh (Ct)	0.956	191,224.00
5	Ranggon (Rgn)	1.533	306,680.00

The sensitivity analysis can be developed based on the measure for both global priority of each irrigation region (*y* direction) and the specific criteria (*x* direction) i.e. area, the length of canal, and the number of hydraulic structures as presented in Figure 4,5, and 6. Based on those figures, it can be examined that Ranggon has the largest budget allocation for maintenance and it is not sensitive due to the lower or higher value of each criteria (*x* direction). On the other hand, for extreme example as indicated in Figure 6, when the criteria of the number of hydraulic structure has the smallest value (equal to zero) then West Lutung is proposed the second largest budget maintenance after Ranggon. However, when the criteria of the number of hydraulic structure has the highest value (equal to one) then West Lutung is proposed the lowest budget maintenance.

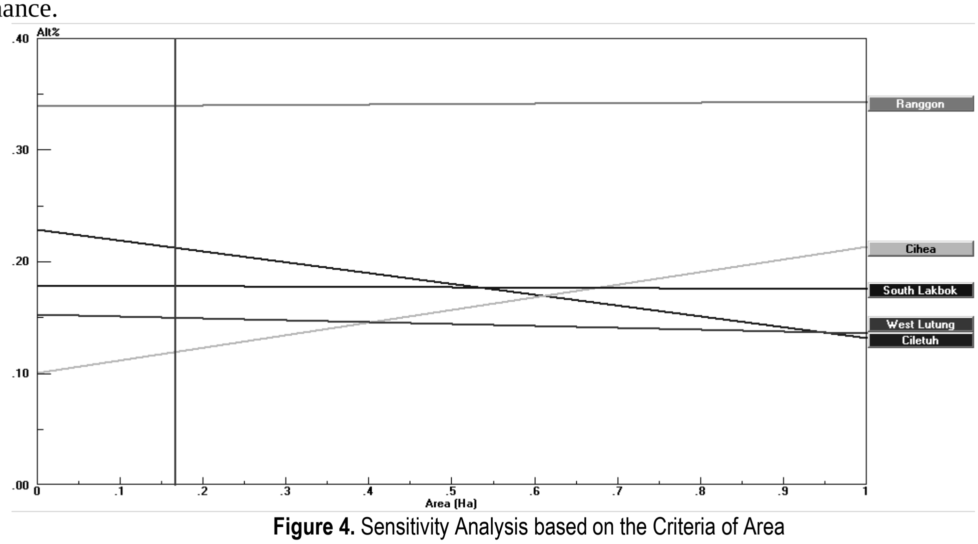

Figure 4. Sensitivity Analysis based on the Criteria of Area

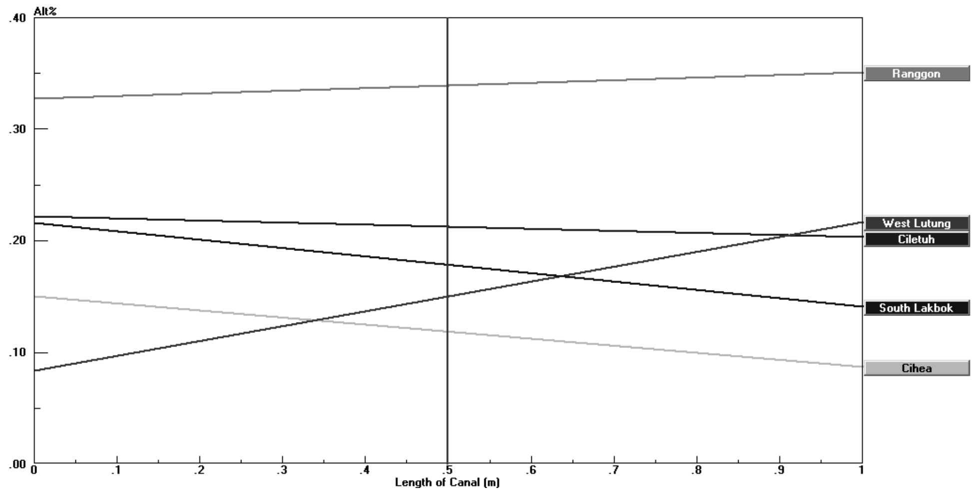

Figure 5. Sensitivity Analysis based on the Criteria of the Length of Canal

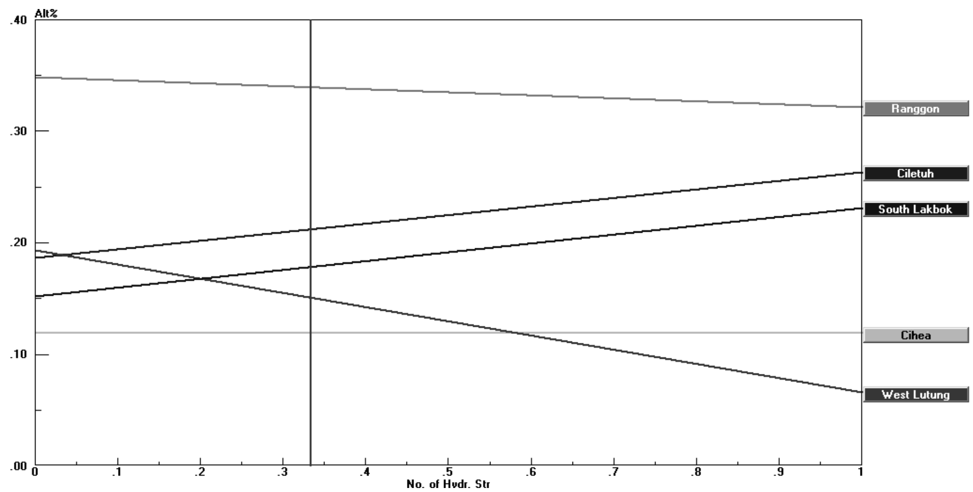

Figure 6. Sensitivity Analysis based on the Criteria of the Number of Hydraulic Structures

Based on Figure 4,5, and 6, the sensitivity analysis can be derived for each irrigation region in order to determine the range of the budgeting indexes if the important of the criteria would be changed in the next future. The range of budgeting indexes is presented in Table 3.

Table 3. Range of Budgeting Indexes, $C_w W_i$, based on each criteria for each Irrigation Region

No.	Irrigation Area	Area		Length of Canal		Number of Hydraulic Structure	
		Min (0)	Max (1)	Min (0)	Max (1)	Min (0)	Max (1)
1	South Lakbok (SL)	0.812	0.812	0.947	0.586	0.677	0.992
2	West Lutung (WL)	0.677	0.586	0.361	0.947	0.857	0.271
3	Cihea (Ch)	0.451	0.902	0.586	0.361	0.541	0.541
4	Ciletuh (Ct)	1.037	0.541	0.992	0.857	0.812	1.128
5	Ranggon (Rgn)	1.533	1.533	1.488	1.533	1.579	1.398

Based on the budgeting indexes, the comparison of total budget allocation for fixed budget (such as 200,000 Rupiahs/Hectare) and modified (fair) budget allocation for each irrigation region (for total area of the region) can be presented as dot red line and blue histogram, respectively (Figure 7). If the value of dot red line is higher than blue histogram for each irrigation region, it indicates over budget allocation.

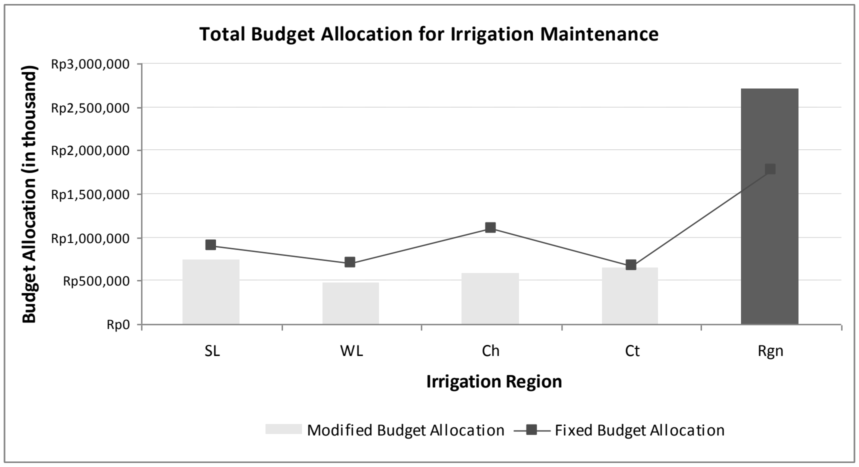

Figure 7. Fixed Budget of 200,000 Rupiahs/Hectare and Modified Budget using AHP (for Total Area of Each Irrigation Region)

Closure

The study proposes another method for fair budgeting strategy model by taking into consideration the density of infrastructure such as area, the lenth of canal, and the number of hydraulic structure and its sensitivity. The previous budgeting allocation system such as fix budgeting in term of 200,000.00 rupiahs per hectare can be justified by using budgeting indexes solving by AHP technique when the budget is limited.

The sensitivity analysis can be developed in order to evaluate the range of budget maintenance for each irrigation region when the significant level of each criteria is changed based on the policy. This modified budgeting strategy model and the sensitivity analysis is an alternative useful budgeting allocation system in the unit of rupiahs per hectare and an easier method for implementation to justify the existing system. In addition, the modified model is developed in order to assist decision makers in determining an appropriate limited budget allocation.

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