Interdisciplinary Research Review
Volume 18, Number 6, Pages 9 – 16

Participatory Multi Criteria Decision Making for Irrigation Management Chiang Rai Province, Thailand

Pattana Kayachai[1*] and Chanchai Sangchyoswat[2]
[1,2] **Center for Agricultural Resource System Research (CARSR), Faculty of Agriculture, Chiang Mai University, Chiang Mai 50200, Thailand**

Abstract

This study aimed to investigate alternative options for irrigation management in the dry season by participatory multicriteria decision making and to reveal attitudes of relevant stakeholders in irrigation management at the Mae Lao irrigation scheme (MLIS), Chiang Rai province. In the past, the Royal Irrigation Department used the Participatory Irrigation Management (PIM) to collaborate with stakeholder irrigation management. In order to determine the appropriate irrigation during dry season, the Participatory Multi Criteria Decision-Making (PMCDM) tool, based on the analytical hierarchy process (AHP), was applied in this study. All appropriate irrigation management options were assigned scores by the PMCDM procedure through two workshops. In the Workshop, all relevant key stakeholders (11 government officials and 22 water users) participated in a focus group with an expert facilitator using participatory methods. In the PMCDM procedure, relevant multiple criteria (technique, irrigated agriculture, institution and budget criteria) were generated and evaluated in the criterion weighting procedure. Then, relevant solution options of irrigation management were prioritized by these stakeholders. The results show that financial budget criterion has the highest weighted criteria score. Establishing the local irrigation budget and reforming irrigation institution are the first and the second ranking of alternative solution options. Moreover, two criteria (institutional transparency and financial budget) got high sensitivity scores. These criteria influenced attitude of participants who then changed alternative option scores. Participants attitudes toward alternative options for irrigation management showed that their status, roles, responsibilities and irrigation knowledge have influence whether their views become positive or negative towards alternative solution for participatory irrigation management in the study area.

Keywords: Participatory multi-criteria decision making (PMCDM), analytical hierarchy process (AHP), irrigation, participatory method

Article history: Received 21 April 2023, Revised 03 June 2023, Accepted 17 July 2023

1. Introduction

The Left Main Canal scheme (LMC scheme) is a sub-irrigation schemes and managed by the Mae Lao irrigation scheme (MLIS) in Chiang Rai province. Generally, water scarcity is the main problem for paddy rice in the dry season. The problem is not only caused by the over-cultivation and inefficient hydraulic structures [1], but also aggravated by ineffective water conveyance system of the LMC and secondary canals to the irrigation area. So, irrigation management in the LMC scheme needs to determine appropriate alternative options for irrigation management through a suitable decision- making (DM). Such a DM process, two major stakeholders (the government sector and the water user group), who responded to manage irrigation in the LMC scheme, had a play role according to the principle of irrigation management, namely, the Participatory Irrigation Management (PIM), has been promoted by the Thai Royal Irrigation Department (RID) since year 2005 in order to implement a bottom-up approach based on stakeholders' participation in planning and decision making between them [22]. According to the policy, it was stated that the Thai rice-based irrigation system should be changed and adapted irrigation to be effective management in some terms that 1) increasing time of a canal maintenance, 2) changing the management of irrigation supply from continuous flow to rotation flow, 3) decreasing inequitable sharing of water among head-end and tailed-end water users and 4) gaining complaints and disputes from water users [23].

To determine an optimal resolution of irrigation management under the constraints of relevant obstacles in a dry season, relevant obstacles due to the irrigation management in the dry season, the participatory multi-criteria decision-making (PMCDM) based on the analytical hierarchy process (AHP) was used as a tool to increase participation in the DM process. PMCDM was a suitable tool for deal with this obstacle because it was able to handle complex situations in many dimensions, such as, socio-economic, physical, environmental, etc. dimensions, namely, unstruc-

*Corresponding author; email: Woody@gmail.com

tured or semi-structured problems in irrigation management [6]. Moreover, characteristics of the DM process in Thai irrigation management were a top-down decision- making. This DM's characteristics will increase uncertainties for the DM process that were characterized in the systematic problems as unstructured and semi-structured problems [10].

The PMCDM process consists of the goal or set of goals of the decision maker or group of decision-makers along with their understanding of related concepts with criteria, a set of evaluation criteria (objectives and/or attributes) based on alternative options, and a set of decision alternatives ([17];[13]; [11];[12], [15]). Moreover, the application of AHP is favorable in the DM process for water resource management. [2] studied the application of participation methods for investigating the perspectives of involved stakeholders for prioritizing irrigation management in Spain, using the decision rule by the AHP. Moreover, [18] reviewed relevant applications of AHP for the scope of water resource management in Thailand from 2009 to 2013, i.e., water resources planning, groundwater management, watershed management, flood management, water quality, irrigation planning, and wetland management. For the literature reviews of AHP for water resources issues [2] studied appropriate irrigation management options by participation methods in Spain, integrated by the AHP method. Moreover, [18] reviewed relevant studies in Thailand from 2009 to 2013 in water resources issues, which used the AHP in these studies, i.e., water resources planning, groundwater management, watershed management, flood management, water quality, irrigation planning, and wetland management.

The objectives of the study were as follows: (1), to identify an optimal alternative-solution for irrigation management by PMCDM based on AHP and (2), to investigate attitude of stakeholders for alternative solutions by the PMCDM process.

1.1 Study Area

The study area is the LMC irrigation area of Mae Lao Irrigation Scheme (MILS) in Chiang Rai.It supplies irrigation for rice paddies in irrigation service area (Fig.1). The LMC irrigation area is divided into five irrigation zones. During the dry season, LMC is able to convey irrigated water into Zone 2 (43 ha), Zone 3 (450 ha), Zone 4 (890 ha), and Zone 5 (537 ha) respectively. The LMC scheme has two major stakeholders, namely, the government sectors and water user groups.

2. Framework methodology

2.1 Methodology

The study methodology of the PMCDM, based on the AHP, composed of 4 stages, namely, (1) Irrigated agriculture system investigation, (2) Participant workshop, (3) Multi criteria decision making (MCDM) process and (4) Attitude towards alternative solutions, was proceeded according to the study methodology. Starting from the first stage (Irrigated agriculture system investigation), it involved investigation of an agricultural system under four domains of irrigated agricultural system (technical, irrigated agricultural, institutional and financial domains) in order to study characteristics of irrigation system in the study area both dry and wet season in the **workshop I**. Next, the second stage (participant workshop) was set to generate the problem statement of irrigation management in the LMC scheme of both dry and wet season. For the third stage (multi criteria decision making (MCDM) process), criterion weighting and alternative option prioritizing process for multicriteria decision making process was generated by problem statement. And the last stage (attitude towards alternative solutions), all prioritized alternative solutions were presented and requested an opinion of an agreement and disagreement by all participants (government sector and water user groups) in the **workshop II**.

Stage 1. Irrigated agriculture system investigation

The purpose of this stage purposed to investigate the characteristics of the study area according to the framework by [16]. Irrigation management context described in four domains as shown in Table 1 and discussed to relevant stake holders. Relevant key stakeholders of irrigation management in the LMC scheme were selected by their status, their roles and their responsibilities of the water user groups. Two major groups of key relevant stake holders (government sector: 11 persons; 2 irrigation engineers and 9 operation staffs and water user groups: 22 persons; 4 head of villagers, 5 irrigation volunteers and 13 general water user members from zone 5 to zone 2) were invited as participants and were interviewed by the facilitator in the morning session meeting in the workshop I. All information investigated to identify irrigation management problems by an interview checklist according to the participatory rural appraisal techniques described by [4].

Stage 2. Participant workshop

After the first stage, relevant problems were framed to define the problem statement in the study area in a focus group meeting, held by an experienced facilitator. Selected issues of irrigational domains were generated in order to the goal of improving irrigation management. All relevant aspects were collected by checklists and semi-structured interview by government sector and water user groups for generating obstacles or concern issues for irrigation management in a whole year (both dry and wet season). And then, more relevant concern issues were gathered and generated in terms of the problem statement in **Workshop I** that "In the wet season, the systematic problems are semi-structured problems, namely the struc-

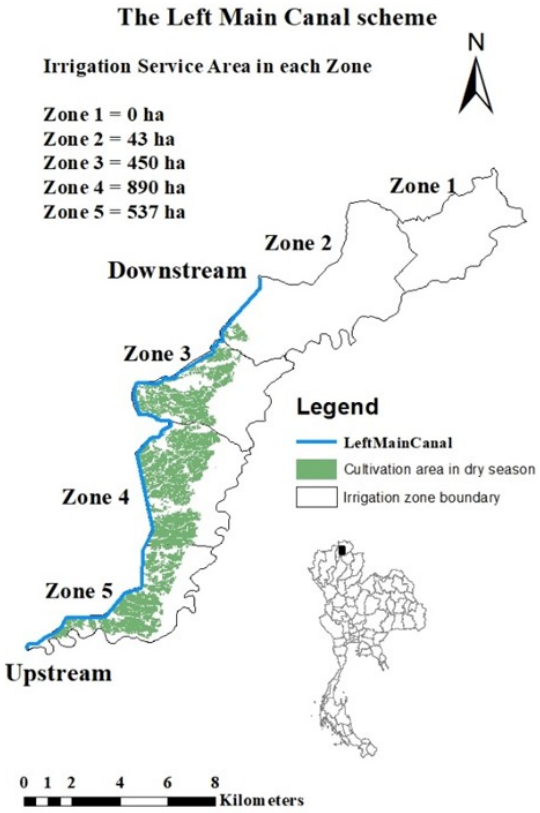

Figure 1: Map of the Left Main Canal scheme in the dry season (sourced by the LMC scheme)

Table 1. Categories of irrigation system in four domains (adapted by [15] and [16])

Domain	Irrigation system characteristics
Technical	Physical conditions (climate, water resource, etc.), physical infrastructure (irrigation canal, etc.) and operation/ maintenance
Irrigated agriculture	Field conveyance system, agricultural system, internal water storage system
Institutional	Water user groups, government sector
Budget	Budget fraction (budget for irrigation management)

tural problem of flooding caused by natural factors and an unsuitably designed main canal system. In the dry season, the unstructured problem of poor irrigation management due to weak institutions is the dominant problem. These causes lead to water scarcity, conflict among water users, breaking the rules of water usage, water theft, etc.

Stage 3. Multi criteria decision making (MCDM) process

The MCDM process was conducted with a focus group in **Workshop II** (afternoon session meeting). This stage involved to develop relevant criteria and alternative options. Criteria was developed by the problem statement in the stage 2 that water scarcity due to poor irrigation management, unsatisfied irrigation conveyance system and limitation of irrigation supply is the main issue for decision making procedure. Each of criteria was set by four domains (technique, irrigated agriculture, institution, and financial budget domains) framework. Firstly, the objective of decision-making was framed on optimization of irrigation management for cultivating paddy rice (dry season) in the LMC scheme. And secondly, relevant information of four domain criteria were determined and linked to generate relevant feasible alternative options for irrigation management in the dry season (Table 2.).

For the PMCDM procedure, all participants were provided and described all relevant objectives for decision making, criteria for achievement for decision making and definition of relevant alternative options for decision making by the experienced facilitator in the workshop II. Criterion weighting was proceeded by all participants in first round meeting and alternative options prioritizing was carried on the second round of meeting. According to the Table 2., six criteria and four alternative options in each four irrigational domains was generated, in which, represented information of all dimension in irrigation management aspects was covered on four domains. And for a set of feasible alternative options for irrigation management was grouped and defined the definition as below:

1. Improving field irrigation conveyance system:

Table 2. Criteria and alternative options in each irrigational domain

Domain	Criteria	Alternative options
Technique	1 Irrigation network performance	1 Improving field irrigation conveyance system
Irrigated agriculture	2 Irrigation practice	2 Improving the irrigation plan saving water according to the PIM policy
Institution	3 Employee	3 Reforming institution by the PIM policy
	4 Participatory water allocation	
	5 Institutional transparencies	
Budget	6 Financial budgets	4 Establishing a local irrigation budget

This irrigation management solution will be focused on rehabilitating the canal network, such as lining the canal, installing hydraulic structure to control the water level, and maintaining the canal before and after the irrigational season to increase water distribution efficiency.

2. Establishing the local irrigation budget: This alternative solution will refer to the water user group establishing the local irrigation budget, collected water service, and penalty fees.

3. Reforming the institution by the PIM: This alternative solution will refer to reforming a major water user group from non-legal organization to an irrigation water user group.

4. Improving irrigation plan and saving water according to the PIM policy: This alternative solution will be focused on water-saving strategies to relieve the water scarcity situation due to irrigation consumption in the dry season.

For the MCDM analysis, starting the analysis process, criteria were scored by participants for weighting a score of each criterion. Each of criterion score was prioritized by the analytic hierarchy process (AHP), which was developed by [14]. This procedure was called as the criterion weighting. And next procedure was the alternative option prioritizing in equation (1), which overall score in each appropriate alternative options for irrigation management were calculated summation scores by participants for prioritizing alternative options from the best to the worst according to alternative option scores. In AHP method, consistency ratio (CR) value (less than 0.1) and consistency index (CI) value.

$$R_i = \sum_k w_k r_{ik} \tag{1}$$

where w_k is the vector of priorities associated with the k-th element of the criterion, r_{ik} is the vector of priorities comparing alternatives for each criterion, and R_i is the overall score for the i^{th} alternative. Sensitivity analysis, which was adopted by [19], will be applied to search for critical criterion values.

Stage 4. Attitude towards alternative solutions

The last stage was discussed by all alternative solutions. These solutions were presented to all participants by the facilitator to extract information regarding agreement and disagreement with solutions in practice. Effective factors, impacted on attitude toward alternative solutions, were analysed by status, role and responsibility of all participants. All attitude of participants were analysed in order to search relationship of agreement and disagreement in each sub groups according to their status, roles and responsibility of all participants.

3. Results

The first objective of this study is to find appropriate alternative solutions for irrigation management via the PMCDM process. Two main processes (criterion weighting and alternative options prioritizing) were conducted by the facilitator through relevant stake holders. Before alternative options prioritizing, criterion weighting process was scored by stakeholders. Moreover, the criterion sensitivity score was measured by changeable value for each criterion; if any criterion has a high sensitivity score, it has a high likelihood to change prioritized alternative solutions.

3.1 Criterion weighting

In the Figure 2., six criteria were weighted by all participants (government sector and water user groups). Importance of each criterion referred to score of participants' opinions, considering, in which, any criterion was more important than other criterion in decision making process. In the Figure 2, six criteria in four domains were weighted by all participants. There were classified two level groups of weighting scores. The first group had scores greater than 0.1 and the second group was less than 0.1. For the first group of criteria, the financial budget criterion was the highest score (0.35) in the financial budget domain, the employee criterion in the institutional domain was the second score (0.26), and the irrigation network performance criterion in the technical domain was the third score (0.15). And the second group, in which, weighting score had less than 0.1, the participatory water allocation in the irrigated agricultural domain was the

highest score (0.09), the institution transparency in the institutional domain and irrigation practice in the irrigated domain were scored as 0.08 and 0.06 respectively.

3.2 Alternative solution prioritizing

In the Figure 3., the x-axis shown six criteria (bar chart) and four alternative options (lined point) in each criterion. The left y-axis and right y-axis were criterion weighting scores and scores of alternative options respectively. In this graph, scores of alternative options were prioritized by ranking scores as (1) establishing the local irrigation budget (0.41), (2) reforming the institution by the PIM (0.32), (3) improving field irrigation conveyance (0.16) and (4) improving irrigation plan and saving water according to the PIM (0.11) respectively.

3.3 Sensitivity analysis of criteria

In Figure 3., slope of lined points was the sensitivity of the changeable score for each criterion. Two highly sensitive criteria occurred in the financial budget and the institutional transparency due to higher weighted criterion scores than other weighted criterion scores. High slope of lined points which was represented as high sensitivity of changeable scores occurred among four criteria, so called, (1) financial budget, (2) employee, (3) irrigation network performance and (4) participatory water allocation. Especially, pairwise criteria (financial budget criterion and employee criterion; irrigation network performance and participatory water allocation) were highly sensitive for alternative option scores as 133.98%. and 116.74% respectively.

3.4 Attitude toward alternative solutions for irrigation management

Table 3. shown attitudes toward alternative options for irrigation management as discussed by two major groups of participants (water user group members (22 persons) and the government sector (11 persons). Discussion reflects relevant participants' perception of a certain solution for irrigation management. Two alternative options (establishing a local irrigation budget and reforming the institution by the PIM) received the widest agreement among two major groups (government sector and water user groups). However, another alternative solution (improving field irrigation conveyance and improving the irrigation plan and saving water according to the PIM policy) were quite opposite between the two major groups. Particularly, improving the irrigation plan and saving water according to the PIM policy was strongly disagreed by the water user group.

4. Discussion and conclusion

4.1 Discussion

Participatory Multi Criteria Decision Making (PMCDM)

The PMCDM process was chosen in this study because it was suitable for handling the solution of unstructured problems or semi-structured problems in irrigation management [8]. In this study, three main steps for participatory procedures were applied in the study methodology, namely, first step, the problem statement was generated by key relevant stake holders, the second step, all relevant stakeholders were also addressed to weight in criterion weighting and alternative options prioritizing for irrigation management, and the third step, attitudes toward alternative options for irrigation management by two participants were investigated for positive and negative point of view on positive and negative attitudes of all alternative solution for irrigation management.

Relevant criteria and alternative options for irrigation management were developed by the concept of irrigation system in four domains [16] through the framework for defining the set of criteria [7]. It covered on settled dimensional system (technic, irrigated agricultural, institutional and financial domains) for the DM process.

For participants selection, relevant key stakeholder of irrigation management in two sections (government sector and water user group) were introduced in the meeting. Government sector, consisted of two irrigation engineer staffs and nine operation staffs, had their responsibilities for management irrigation in the main canal level. And water user group, consisted of four head of villagers, four irrigation volunteers and one the head of irrigation volunteer, had their responsibilities for management irrigation from the secondary canal to field distribution canal level. These key relevant stake holders were a key of decision in irrigation management, co-operated among government sectors and water user group through irrigation schedule plan, operation of hydraulic structures in the conveyance system, operation and maintenance process, etc.

For reducing in decision traps and the cognitive biases [9], the facilitator was selected by the level of experiences (expert facilitator by the RID) to hold the focus group meeting (team group or coalition group). Moreover, a focus group, held by a facilitator was selected in the meeting pattern because it was suitable for deal with competitive interaction contexts, caused by different attitudes of stakeholders. Other relevant responsibilities of the facilitator could control relevant decision-making issues through discourage information sharing, mediation and negotiation in decision-making process. These intended outcomes were to help mitigate or resolve stakeholder disagreements and conflicts, for instances, semi-structured or unstructured problems [20].

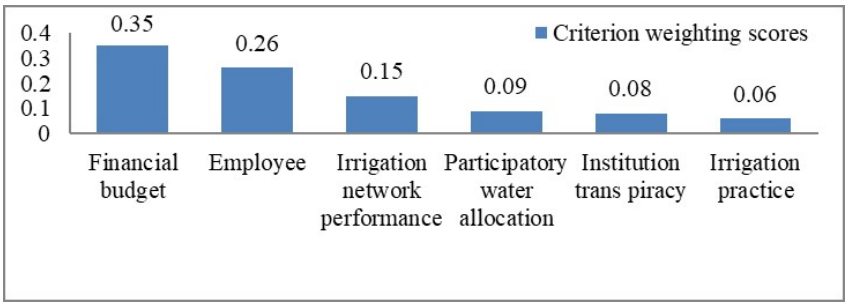

Figure 2: Criterion weighting scores

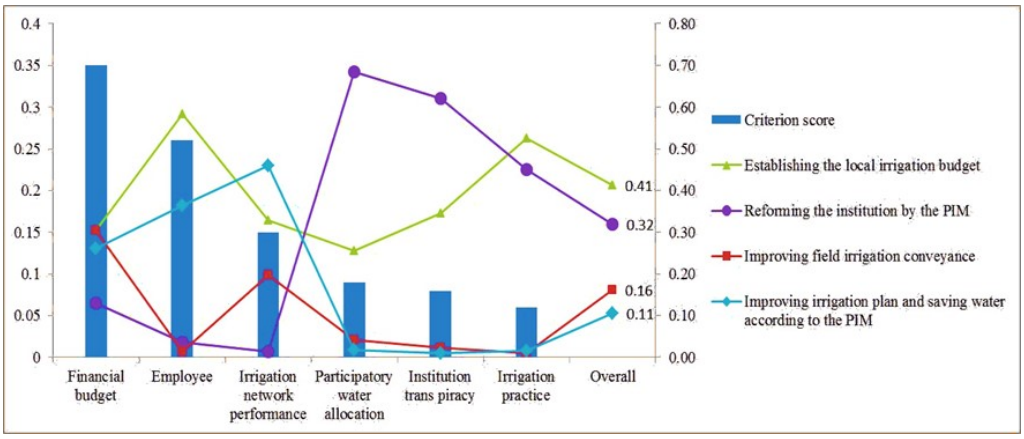

Figure 3: Prioritized criteria and criteria weighting scores

Table 1. Attitude of participants to alternative options in the dry season

Alternative Solutions	Actor Groups: Integrated Water User Group (IWUG) of the LMC scheme	
	The government sector	**Water user members**
1. Establishing a local irrigation budget	**Good:** Expenditure for irrigation management: canal maintenance, board salary, annual meeting, etc.	**Good/ Moderate:** Question for verifying the budget and not ensuring reliable water in the tail canal when paying the fees
2. Reforming the institution using the PIM policy	**Good/Moderate:** Cleary the structural organization for improving irrigation management efficiency but the not strong concept of role and law of water user groups	**Good/Moderate:** Same as the government sector
3. Improving field irrigation conveyance	**Moderate** Decrease water lost during water sending Concerning the expenditures for system upgrade Hard to operate and maintain some controllable infrastructure	**Good** Decrease water lost during water sending Fair divided water in the field conveyance system
4. Improving the irrigation plan and saving water according to the PIM policy	**Moderate** Irrigation practices (micro-sprinkler, drip water) is a good choice for water savings Alternate Wetting and Drying in paddy rice is not suitable No market for sale of products by growing plants with less water	**Bad** Irrigation practice (micro-sprinkler, drip water) for water savings is not suitable due to high expense Alternate Wetting and Drying in paddy rice is not suitable Crop calendar adjustment for water savings is hard to practice

Alternative options for irrigation management

Results of the study were discussed in two results (weighed criteria and alternative options for irrigation management). For weighted criterion, two criteria (institutional transparency and financial budget) in two domains (institutional and budget domains) have highly sensitive scores due to high weighted scores in these criteria, since these criteria have more effective for changing scores and probably affect to change priorities of alternative options scores by relevant key stakeholders. And favourite alternative options for irrigation management (establishing a local irrigation budget and reforming the institution using the PIM policy) were more important than other solutions because these alternatives focused on the improvement of the institutional domain that support the strength of the water user organization and the efficacy of the irrigation budget through the financial budget and institutional domains. This was why these options are the first choice for stakeholders' opinions.

Attitude of participants towards alternative options for irrigation management

Improving the irrigation plan and saving water according to the PIM policy was the first choice of alternative options for irrigation management in the PMCDM. This option was different attitudes among government sector and water user groups due to the status, roles and knowledge toward to agree and disagree alternative solutions. The government sector (11 persons; 2 irrigation engineers and 9 operation staffs) quite agreed on two alternative solutions (establishing a local irrigation budget and reforming the institution using the PIM policy) because these solutions involved to their roles and responsibilities for support the strength of water user depend on the PIM policy. While, the water user groups (22 persons; 4 head of villagers, 5 irrigation volunteer staffs and 13 general water user members), who responded to manage irrigation conveyance section from secondary canal to paddy rice field, insisted to disagree on some alternative solution (improving the irrigation plan and saving water according to the PIM policy), particularly, water saving issues by water saving technology (micro sprinkler, drip irrigation) was not suitable due to high expense and alternate wetting and drying technique for water saving in paddy rice was also not suitable due to hard operation in practice.

These results will be expected to contribute effective participatory process policy that allow water users and government sectors for decision-making from irrigation planning to irrigation supply operation through the participatory or collaborative approach. Learning is a social act; communication between individuals and collective learning [21]. Moreover, stakeholders can share their concerns and perspectives, develop skills on joint problem solving [8]. And all results of this study were also expected to extend relevant details in these option for application in irrigation management under the PIM policy framework. Such two top ranking scores of alternative solutions (establishing a local irrigation budget and reforming the institution by the PIM policy), these options involved in two domains (financial budget and institutional domains). In the establishing a local irrigation budget reforming option, the local irrigation budget should be established and reformed according to the PIM approach, in order to be extensions for operation and maintenance from secondary to field distribution level, handled by relevant key water user group (local irrigation staff, local irrigation volunteers, hiring irrigation staff for watching water theft, etc.); moreover, it also used in relevant local irrigation management through irrigational activities according to the steps of PIM approach. Consequence from the first option, reforming the institution by the PIM policy option should be practiced through institutional transition from the Integrated Water User Groups (IWUGs) to be the Joint Irrigation Management for Irrigation Committee (JMC) under the PIM approach because the JMC will allow to establish a formal organization, guarantee a status of law enforcement, increase a role of financial management through driven forces of relevant water user groups and government sector in the LMC scheme in order to achieve the option's task.

However, stakeholder involvement was considered in the framework. Various groups are those where participation occurs amongst stakeholder with divergent interests and perceptions of the problem [1]; [3]. Obstacles in meeting appointment because convenient attention in the meeting had different appointed time depending on each individual participant. Suggestion in this study can be developed through activities in specific skills and knowledge in order to increase level of participatory from the participatory model level to the collaborative model level. So, expectation of the PCDM application for irrigation management was suitable for handle to semi or un structured problems in irrigation through coordination, collaboration and joint action of government sectors, who organizing team is responsible for the design and guidance of the participatory and collaborative modelling process.

4.2 Conclusion

The PMCDM process in this study was applied in the study area (LMC scheme), which is operated by the Mae Lao Irrigation project in Chiang Rai province, Thailand. appropriate participatory techniques were applied to collect information to generate relevant criteria and alternative solutions by participants (the government sector and water user members). For a decision rule, the AHP was used as a decision rule that dealt with a qualitative variable in terms of conflict in decision making for judgment in criterion weighting and alternative solution ranking processes.

Based on the results of criteria weighting and prioritized alternative solutions, it can be concluded

that six criteria (financial budget, employee, irrigation network performance, participatory water allocation, institution transparency, and irrigation practice) are weighted for prioritizing with the values 0.35, 0.26, 0.15, 0.09, 0.08, and 0.06, respectively. It meant the financial budget criteria had the most important criterion for prioritizing appropriate alternative option for irrigation management. Moreover, two criteria (institutional transparency and financial budget) in two domains (institutional and budget domains) were critical criterion value due to high sensitivity. It meant that these criteria (institutional transparency and financial budget) had the most changeable important when criterion weight scores was small change by participants' decision. The prioritized values for the four alternative solutions (establishing a local irrigation budget, institution reform using the PIM, improving field irrigation conveyance, and improving the irrigation plan and water-saving with the PIM) are prioritized in that order with the performance values 0.41, 0.32, 0.16, and 0.11, respectively.

The participants' attitudes toward alternative solutions show that relevant status, roles, their responsibilities and their knowledge can affect point of views thus making attitudes positive or negative towards alternative solution for participatory irrigation management in the study area.

References

[1] Andersen, D and G., Richardson. 1997. Scripts for group model building. Syst. Dyn. Rev. 13 (2), p. 107-129.

[2] Antunes, P., V. Karadzic, R. Santos, P. Beca and A. Osann. 2011. Participatory multi-criteria analysis of irrigation management alternatives: The Case of the Caia irrigation district, Portugal. International Journal of Agricultural Sustainability 9 (2): 334–349. 13

[3] Bots, P.W. and C.E., van Daalen. 2008. Participatory model construction and model use in natural resource management: a framework for reflection. Syst. Pract. Action Res. 21 (6), 389-407.

[4] Cavestro, L. 2003. (P.R.A) Participatory Rural Appraisal Concepts Methodologies and Techniques. M.A. Thesis. UniversitadegliStudi di Padova, Padova. 38 p.

[5] Chambers, R. 1988. Managing canal irrigation: Practical Analysis from South Asia. Cambridge University Press, 279 p.

[6] Chittaladakorn, S. 2013. Decision Support System for Water Resources Engineering Management. Kasetsart Publishing Press, Bangkok. Thailand. 503 p. (in Thai)

[7] Gamboa, G. and G. Munda. 2007. The problem of windfarm location: A social multi-criteria evaluation framework. Energy Policy. 35: 1564-1583.

[8] Hare, M. 2011. Forms of Participatory Modeling and Its Potential for Widespread Adoption in the Water Sector. Environmental Policy and Governance. 21(6): 386-402.

[9] Heuer, R.J. 1999. Psychology of Intelligence Analysis. Central Intelligence Agency, Mclean, Virginia. 184 p.

[10] Huber, G.P. 1980. Managerial Decision Making (Management Applications Series). Scott Foresman and Company, Glenview, Illinois. 229 p.

[11] Hwang, C.L. and K. Yoon. 1981. Multi attribute decision making: methods and applications. Springer-Verlag, Berlin. 269 p.

[12] Parnell, G.S., P.J. Driscoll, and D.L. Henderson. 2011. Decision Making in Systems Engineering and Management. John Wiley and Sons, Hoboken. New Jersey. 497 p.

[13] Pitz G.F. and J. McKillip. 1984. Decision Analysis for Program Evaluators. SAGE Publications, Thousand Oaks, California. 304 p.

[14] Saaty, T.L. 1980. The Analytic Hierarchy Process. McGraw-Hill, New York.

[15] Schoemaker, J.E. and P. Russo. 1989. Decision Traps: Bantam Doubleday Dell Publishing Group, New York.

[16] Small, L.E. and M. Svendsen. 1992. A Framework for Assessing Irrigation Performance. International Food Policy Research Institute, Washington, D.C. 38 p.

[17] Starr, M.K. and M. Zeleny. 1977. MCDM: State and future of the arts. pp 5-29 In: M.K. Starr, M.K. and M. Zeleny(eds.). Multi criteria Decision Making: Studies in Management Sciences. North-Holland Publishing Company. Amsterdam.

[18] Thungngern, J., S. Wijitkosum, T. Sriburi and C. Sukhsri. 2015. A review of the analytical hierarchy process (AHP): An approach to water resource management in Thailand. Applied Environmental Research 37(3):13-32.

[19] Triantaphyllou, E. and A. Sánchez. 1997. A sensitivity analysis approach for some deterministic multi-criteria decision-making methods. Decision Sciences 28(1): 151-194.

[20] Van den Belt, M. 2004. Mediated Modeling: A System Dynamics Approach to Environmental Consensus Building. Island press.

[21] Voinov, A., and E.J.B., Gaddis. 2008. Lessons for successful participatory watershed modeling: a perspectivefrom modeling practitioners. Ecol. Model. 216 (2), 197- 207.

[22] Wongprasittiporn, C. 2005.Large rice-based irrigation systems in Thailand. Country paper No.7. In: Proceedings of the Regional Workshop on the Future of Large Rice-Based Irrigation Systems in Southeast Asia. FAO Regional Office for Asia and the Pacific. Bangkok.

[23] Wongprasittiporn, C. 2007. The future of Large Rice-based Irrigation System in Southeast Asia[Large rice-based irrigation systems in Thailand]. Water Resources Development and Conservation Officer FAO Regional Office for Asia and the Pacific. Bangkok. Thailand.

[24] Wongtragoon U, Kubo N, and H. Tanji.2009. Performance diagnosis of Mae Lao Irrigation Scheme in Thailand. (I) Development of unsteady irrigation water distribution and consumption model. Paddy Water Environ, 8(1): 1-13