The application of Multi Attribute Decision Methods (MADM) on prioritizing Iranian fisheries research projects

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Abstract

The ultimate goal of an agriculture research system is on-time, correct and clear response to the problems and expectations of agriculture household and stakeholders. In this respect, though, due to variation and frequency of the problems and expectations and as well as many limitations such as financial deficit, short time and shortage in work force and equipments etc, the system cannot be thoroughly responsive. Therefore, the necessity for optimizing the system to response through prioritizing the research projects has been a major challenge before the responsible managers and authorities. In this paper, the Analytical Hierarchical Process (AHP) has been introduced as a well known Multi Attribute Decision Methods (MADM) that combines qualitative and quantitative criteria for prioritizing the research projects of the Iranian Fisheries Research Organization. For implementation of the mentioned principles and methods of prioritizing the research projects have been studied and then by determining the final decision making criteria, the priority of the projects in the Institute have been determined by drawing decision hierarchy tree. Required data was gathered through pair wise comparison questionnaires filled by the experts and researchers. In the next step, Expert Choice software used to analyze and determine the priorities. Based on results criteria of research possibility, scientific development, economic development, and stability development with respective weight .377, .263, .187, and .173 are the most important criteria for the institute in the south area of Caspian Sea. Finally, according to the produced results, the priorities of the six studied research programs determined.

Keywords: Fisheries Research Priority setting, Multi Attribute Decision Methods (MADM), Analytic Hierarchy Process (AHP)

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Introduction

Recent century has witnessed an economy system based on science and technology emerging in global relations as a new phenomenon, so that an economy is measured in terms of its nature and potential through knowledge-orientation; thus, a decisive role of knowledge and consciousness in economic growth and development has approved. An integrated, dynamic and sustainable development is mainly based on technological development which in turn has its origin in the creativity, innovation and scientific development achieved through study and research. So, obviously, many countries tend to pay specific attentions to making investments in their national research systems, and in the agricultural studies in particular; so that until mid-ninetieth, annual expenditures on agricultural research and development in various countries were totally estimated about $ 33.2 billions of which developing countries shared $ 12.2 billions (Pardy, 1998).

Fisheries as a sub-sector of Agriculture consists of all the activities carried out to culture and produce various types of aquatic animals and sea products aiming at economic exploitation. These activities generally include fishing or farming aquatic creatures of ocean, sea and interior waters like rivers and natural and/or artificial pools. Fisheries management takes charge of coordinating all the activities including fishing, aquaculture, market adjustment, creating infra-structures as well as undertaking supportive activities for fishing and aquaculture and managing reservoirs, by observing environmental and technological considerations and with due respect to socio-economic considerations of stakeholders.

Activities and efforts within a fisheries research system would lead to success when the system may respond to issues, problems and expectations of operators and other beneficiary groups. However, one should bear in mind that their wholly comprehensive responding is not feasible in effect while these and other demands in fisheries sector appear to be so broad, diversified, numerous and complicated as well as there are certain limitations in time, facilities and equipments, financial and monitory resources, and human force. Therefore, in search for a wise and rational remedy, there is no way out unless resources and facilities are optimally allocated to research priorities. Hence, it is obvious that setting research priorities within fisheries research system would be a major concern and challenge.

Research activities might be determined and defined within a rational and structured relation, as shown in Figure 1. As Figure 1 illustrates, it is crystal clear that setting research priorities is definitely implied at different levels of research plans, programs, and projects. Besides, it should be always noticed that if results from priority setting is neglected, the expected impact and efficiency will be hardly achieved. Figure 2 indicates the relation among the above three main categories. As shown, priority setting is an introduction to planning. In fact, results from priority setting specify the limit and

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framework governing on fisheries research planning. Similarly, the content of research planning will in turn effect as the framework and principles governing on budgeting and allocating resources. Results from resource allocation provide feedback to the prioritizing stage and reveal relevancy or irrelevancy of selected priorities and how to expend resources. In detailed case, for the purpose of effective implementation of the above cycle, the steps shown in Figure 3 should be followed towards research prioritization. As shown in Figure 4, only a limited number of research themes can be evaluated in a priority- setting exercise. This set of potential themes is derived from the intersection of the needs of agricultural technology users and the technical problems that can be addressed effectively by agricultural research (Mills, 1998, P.42).

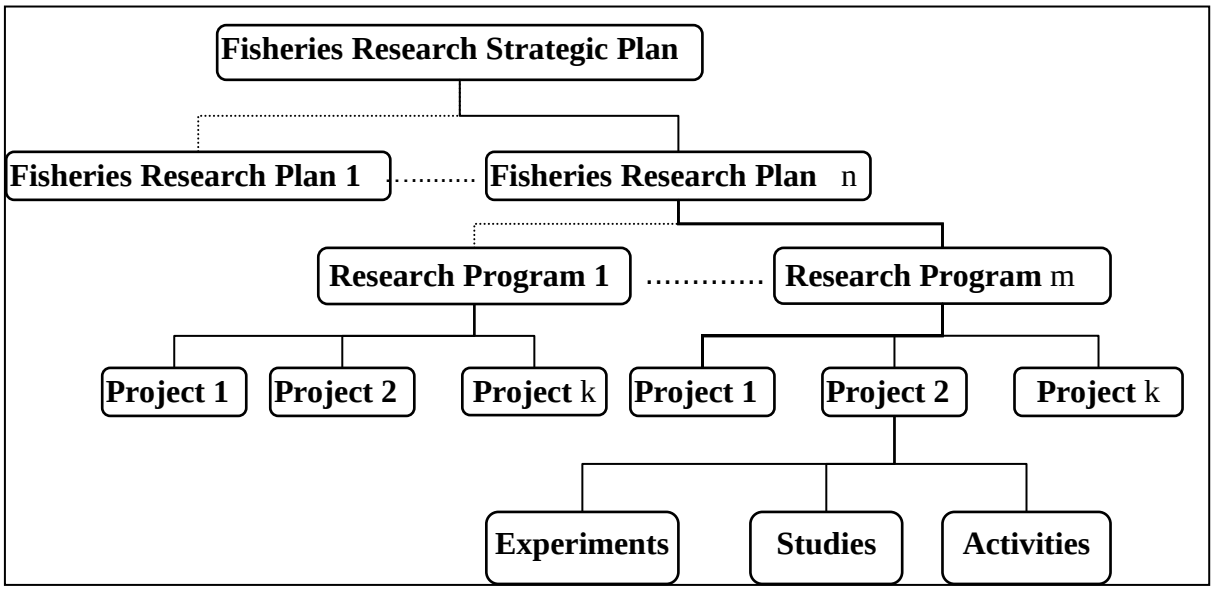

Figure 1: Research Plan Hierarchy

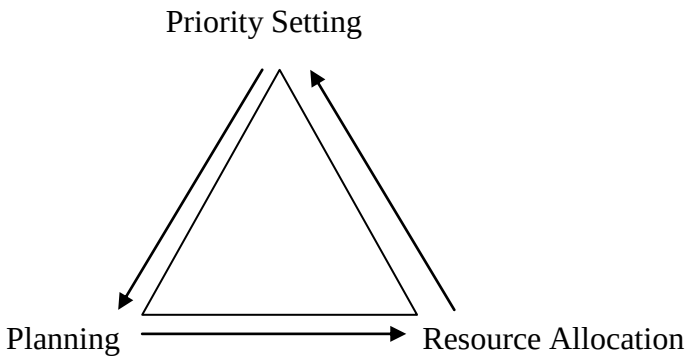

Figure 2: Linkages between priority setting, planning, and resource allocation (Mills, 1998, P.6)

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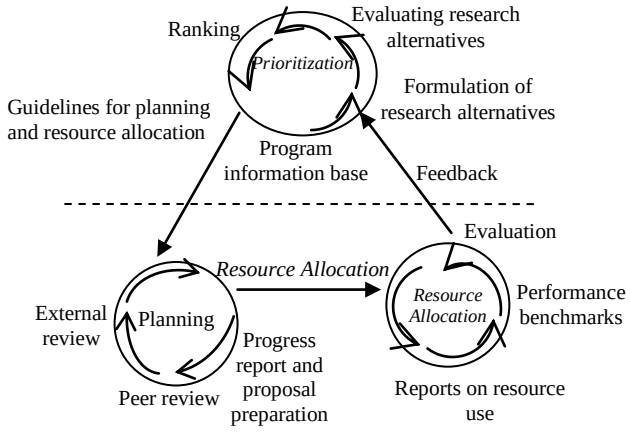

Figure 3: Disaggregated linkages between priority setting, planning, and resource allocation (Mills, 1998, P.6)

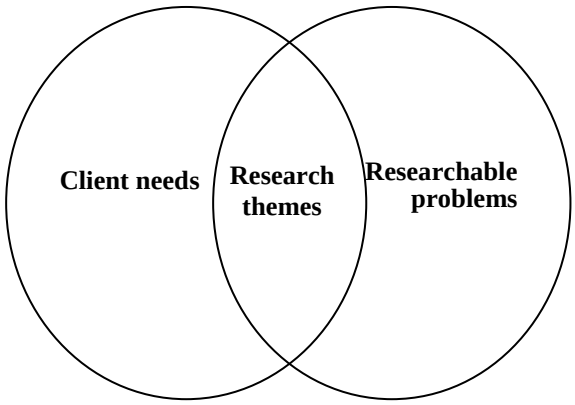

Figure 4: Research themes are the intersection of client needs and researchable problems (Mills, 1998, P.42)

Secondly, since it is impossible to undertake all researches simultaneously, due to existing limitations, there should be prepared a preliminary list of the potential subjects to be studied known as priority setting options according to the information gathered from the above database. Thirdly, the potential impacts and results of each research option have to be estimated, assuming their conduction and implementation of the results. Then, as the fourth step, existing options are to be prioritized by means of an appropriate method. In the fifth step, according to the results from priority setting, guidelines to include priorities into the research planning should be formulated.Assessing options and setting their priorities are influenced by factors like indexes of decision and key decision makers' viewpoints as well as inclusion of organizational conditions, implying a sort of complicated decision making. These indexes might be in their nature considered as either quantitative or qualitative and/or both types of indexes, indicating the

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complexity of making decisions on them, particularly when options are assessed to be favorable by some indexes while being unfavorable by some others. In addition, since such decisions are often made in a group, it is of a great challenge to combine views so that it would lead to a decision with the agreement and consent of all the group members, which would be of due consideration in reducing resistance and enhancing cooperation morality. Such a decision making environment tends to conform to capabilities of Multi-Attribute Decision Making (MADM) method.

Materials and methods

This article illustrates how to use Analytical Hierarchy Process (AHP) as a well-known Multi-Attribute Decision Making (MADM) method, and also how to combine qualitative and quantitative indexes for priority setting of research programs in Research Programs on South Basin of Caspian Sea in Fisheries Research Institute.

For this purpose, basics of priority setting for studies were reviewed and followed by a comparative study. An initial list of indexes and sub indexes was specified for decision making, which has subsequently been finalized by holding a professional poll. Then, through a decision subject modeling, research programs were determined within the AHP model, representing a decision hierarchy tree. Required data were gathered through a paired comparison questionnaire formulated by the concerned experts and researchers. In different stages of estimation, 'Expert Choice' software was applied and, eventually priority setting results were determined.

A Review on the Most Common Methods of Setting Research Priority:

Several qualitative and quantitative methods are available to assist agricultural research priority setting. The simplest methods are Rule of Thumb and Checklist. The two most common methods are scoring and economic surplus. Two other methods, mathematical programming and simulation have been used for selecting the research projects. A more recent method is the analytic hierarchy process (AHP).

As 'rule of thumb' requires minimal data, it is one of the simplest methods of priority setting. The rule of thumb method is categorized into two types including 'precedence' and 'congruency' (Anderson and Parton, 1983). In a precedence approach, budget of preceding year is a basis of budget allocation for current year; and variations in budget and other resources are divided by an equal proportion for every research activity.

Checklist:

In checklist method, a checklist of assessing criteria and indexes is initially made by decision makers who are then trying to assess research programs and projects by proposing certain related questions. According to the answers resulted, priority of programs and projects are set by personal and expertise views and judgments. Some of the criteria used in this method include result acceptability, research project's role in providing food security, export growth (import decline), and resource and facility requirements.

Scoring:

In fact, scoring is a more complicated version of the checklist method; it has

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been applied to priority setting of researches more than any other methods. In scoring method, in the first place, assessment indexes and criteria are identified and their weight coefficients determined. Then, the research program or project is assessed and measured in terms of the concerned indexes and criteria. Finally weighted score of each program or project is calculated by multiplying the index weighted coefficients by the assessment values. Applications in agricultural research of this method are found in many studies all over the world (Norton, 1993).

Cost-Benefit:

This is a quantitative method of priority setting, in which all the study results and implications are presented as costs and benefits in monitory terms of values. Thus, for the purpose of method application, first of all, costs and benefits of the options should be identified and then measured by a monitory value.

Economic Surplus:

This is in effect a transformed model of the cost-benefit method, based on economic efficiency as well, to assess and prioritize the research projects; however, the economic surplus method is particularly varied in that it illustrates all the study results and implications within their impact on supply curve of the product and then, the impacts of changed supply curve on market equilibrium are determined and total gains from the study estimated according to the economic welfare theory. There are many examples of this approach in the economic literature on specific research commodities or production constraints (Falconi, 1993).

Domestic Resource Cost:

This method is based on domestic resource costs of the product in a country, relative to global market. When there is a comparative advantage of a product, the study might be invested in that product; otherwise, it would be preferred to disregard domestic production of the product and as a result, to make investments on its research.

Mathematical Planning:

Mathematical techniques of decision making are most often known as ‘Research in Operation’, ‘Operational Research’, and/or ‘Quantitative Decision Making’ methods in scientific associations. Mathematical planning aims at optimizing limited resource allocations as well as adopting an optimum research combination. Its capability to define budgets at different levels of each research activity appears to be an attractive feature of this method.

Simulation Models:

These models tend to functionally estimate relations between inputs (investments in research) and outputs of research as well. So, they require an estimation of productive function to illustrate an econometric relation of productivity, on one side, with expenditures of research (and extension) and other factors, on the other side; then, its impacts on productivity of different research costs, such as introduction of technological innovations, are simulated. Finally, resulting changes in productivity are turned into a change in the supply curve,

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indicating their economic results (Braunschweig, 2000). The main disadvantage of simulation models is the large investment of resources (in data and the time of a skilled analyst) required to implement them. Data requirements are more extensive than for other economic methods, and there are few practical applications for this approach (Falconi, 1993).

Generally, in the process of prioritization, there could be found a number of key decisive elements including participation, transparency, complication rates (presence of standard measuring procedures) as well as type and extent of the required data. As subjective judgments of participants are frequently inevitable while prioritizing, it would be of importance to have the presence of knowledgeable and informed participants. In this case, research stakeholders are known as some part of the participants. Main research stakeholders include research managers, researchers, final users (such as consumers and private sector) and policy-makers in the areas like science and technology. Although participation of stakeholders is assumed to be a strength and prerequisite of a successful prioritization, it may bring along certain deficiencies as well. Some of them are hardly in a position to perceive the significance of a long-term strategic and basic research. Therefore, there should be considered a compromise between efficiency and effectiveness; that is, higher participation extent would result in increasing its effectiveness, but achieving a consensus would also lead to a declined efficiency while the number of participants were increased, and vice versa.

In addition, research transparency is linked to the extent of participation. It means that prioritization process should be so transparent that active participation of all the stakeholder groups is guaranteed. Presence of a transparent process plays a substantial role in extracting subjective judgments, resulting in more precise information and consequently, more exact priorities are achieved. Finally, complication (the extent of standard procedure) of prioritization is mainly resulted from the multi-index nature of public research decisions in which impacts of each research options should be studied and measured in respect to many criteria in different scales. Type and extent of the required data are among important considerations to choose an appropriate method of prioritization. For instance, drawing on methods like comparative advantage requires the availability of extensive information which otherwise researchers would face difficulty. In such cases, using the qualitative methods of prioritization tends to be of more importance. Table1 provides an assessment on each one of the different prioritization methods according to the above-mentioned elements.

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Table 1: Assessment of Different Prioritization Methods

Method	participation	transparency	complication	Required data
Rule of Thumb	Low	Low	Low	Low
Checklist	Low	Medium	Low	Low
Scoring	High	Medium	Low	Low
Cost-Benefit	Low	Medium	Medium	Medium
Economic Surplus	Low	High	High	High
Domestic Resource Cost	Low	High	High	High
Mathematical Planning	Low	Low	High	High
Simulation	Low	Low	High	High

Among the above-mentioned methods, 'scoring' is more relevant to the complicating requirements of decision making in research (Contant and Bottomley, 1988). Shumway and McCracken (1975), in their discussions on priority setting of agricultural research, were the first who used this method in prioritizing plans the North California Agricultural Research Station. Similarly, Franzel (1996) applied the scoring technique to priority setting of multi-purpose tree improvement. Over recent years, certain method combinations including two prioritization studies have been used, in which economic surplus model was combined with the scoring model. International Potato Center (CIP) and CGIAR have also used some combined methods. Collion and Gregory (1993) combined the scoring model with the cost-benefit analysis for CIP resource allocation. In addition a combination of the relevance (rule of thumb) method and the scoring models were applied for CGIAR by McCalla and Ryan (1992).

Though the scoring models have been widely used, they have shown deficiencies, among which there might be mentioned their high costs and lack of a deep theoretical framework (Braunschweig, 2000). Another critic stems in its multiple considerations over various quantitative and verbal clauses (qualitative impacts as well as inclusion of different weights. However Thomas L. Saaty suggests a method called 'Analytical Hierarchy Process' (AHP) with no such deficiencies of the scoring method, in the early 1970s while presenting all the advantages of participation, transparency, and the standard procedure as well. Currently, this technique is widely used in complicated management decision makings which, among others, include: assessment relative importance of the environmental impacts of fishing (Innes and Pascoe, 2010); Project selection for oil-fields development(Amiri, 2010); Evaluation and pre-allocation of operators(Güngör Sen and Çınar, 2010); selection of intelligent building systems (Wong and Li, 2008); Assessing risk and uncertainty of projects (Zayed et al., 2008); Value chain analysis (Rabelo et al., 2007); transportation planning (Saaty, 1995); planning for energy resource allocation (Ramanathan and Ganesh, 1995); urban planning (Rose and Anandalingam, 1996); setting priority for energy and environmental research projects (Kagazyo et al., 1997); prioritization of electricity industries (Kaban, 1997); design of renewable

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energy systems (Chedid et al., 1998); identification of favorable fuels in transportation industries (Poh and Ang, 1999); and technology assessment (Herkert et al., 1996).

The most appropriate method for a particular priority setting situation depends on (1) time available for the study, (2) data availability in relation to degree of analysis, (3) analytical capacity, (4) participation in the process, and (5) transparency in the process (adapted from Norton, 1989).Figure 5, which summarizes the above factors, shows that priority setting methods such as scoring and AHP are more transparent and participatory, while mathematical programming, simulation, and economic surplus require more time, resources, and data analysis. However, the latter approaches, in particular the economic surplus, provide rigor and finer analysis of trade-offs at the cost of requiring more data and analytical skills (Falconi, 1999) .

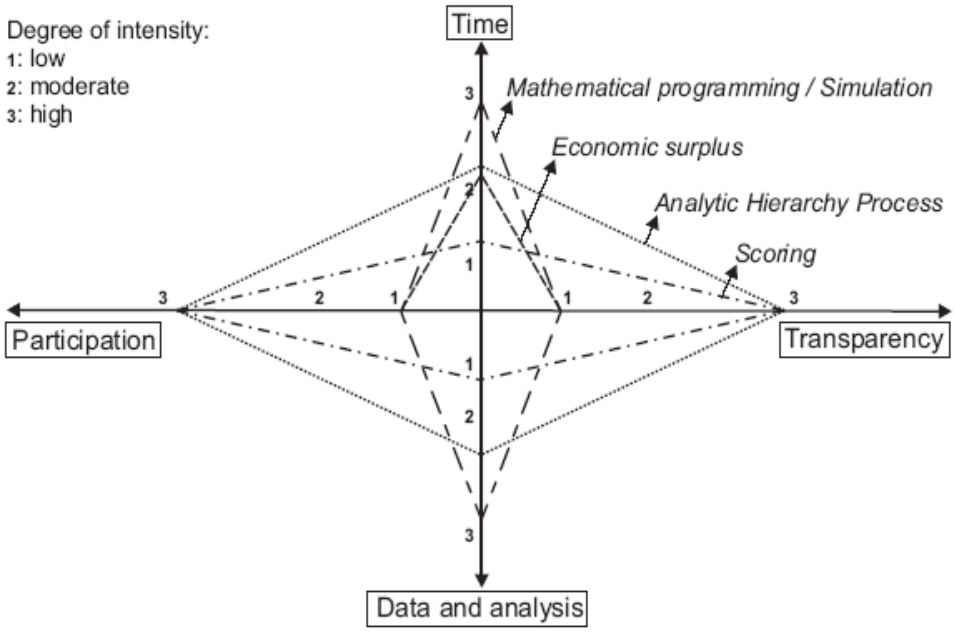

Figure 5: Priority setting methods compared (Falconi, 1999)

Based on the above five factors, the most useful methods for priority setting in agricultural research are AHP, which handles subjective judgments and allows multiple objectives, or a combination of AHP and the economic surplus approach to facilitate consistency with the economic framework. In recent years, the application of AHP method has also been common in decisions related to the agricultural and ecosystem research management. Zhang and Lu (2009) and Alphonce (1997) suggested the AHP approach to ecosystem and agricultural research. Anders and Mueller (1995) also used this technique to design long-term field experiments in International Crop Research Institute for Semi-Arid Tropical (ICRISAT). Some other researchers have also applied the AHP method to selecting either an optimum combination of research in Private sector (Libei-ator, 1989; Lockell et

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al., 1986; Manahan, 1989) or a combination basket of agricultural research in Public sector (ISNAR, 1998) and selecting an appropriate irrigation method(Karami, 2006).

Results

According to AHP approach, every decision making subjects can be explained within a hierarchical structure known as decision hierarchy tree, in which the objective is at the first level and rival options are at the last level while decision indexes are seen at the mid-level/s. Modeling decision making is initially undertaken by applying AHP and drawing a decision hierarchy tree (Azar and Zare'ei, 2002).

Determining Indexes and Criteria of Assessment:

In general, during any priority setting process, determining and defining indexes and criteria of assessment are assumed to be an unavoidable procedure, because efficiency and effect of other priority setting stages as well as accuracy and adoption of priority setting results are greatly influenced by the assessment indexes and criteria. Therefore, though the importance of other stages of the process is frequently maintained, definition of the applied indexes and criteria is considered as an underlying and primary basis of priority setting. So, all the aspects in this regard should be taken into consideration through a comprehensive vision, so that both key and operational aspects and considerations are included, while unilateral attention to some of them and ignoring some others might be problematic in this stage.

To identify and define indexes and criteria, one may take a number of different ways the most significant of which includes conducting a comparative study and holding professional workshops with experts and associated professionals. Since research planning and priority setting are one of the serious issues in research systems across countries, a review on the experiences and results achieved in other countries is assumed as a manner of identifying and defining indexes and criteria of research assessment known as the comparative study.

Braunschweig (2000) has used the following indexes and sub indexes to set biotechnological research priority in Chile:

Objective 1: Optimal Resource Distribution of National Biotechnology Plans

- Economic indexes (net social advantages, diversification of production, direct costs of project);
- Social indexes (income distribution among social groups, health care risks); Environmental indexes (water, soil, biological diversity, bio-immunology);
- Institutional indexes (institutional capacity building, human resource capacity building);

Objective 2: Likelihood of Success

- Human resource indexes (scientific qualification, experience);
- Study feature index (technological challenges, proposal quality, rules and regulations of copyright);

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- Study environment indexes (cooperation of researchers, availability of infrastructures, project management);

Objective 3: Likelihood of Successful Adoption of Final Technology

- Final user status indexes (number, organization degree);
- Final user benefit indexes (benefits of private sector, precise and explicit demand, participation);
- Technology transfer and development indexes (maturity time, number of stages, availability of research plan, transfer system); and
- Public acceptance indexes (public attitude towards extra-genetic products and towards chemical residues).

In another research conducted by ISNAR institute for Agricultural Research Institute of Kenya, the following indexes and criteria were selected (ISNAR, 1998): Efficiency; Equity; Foreign exchange gains; Food self-sufficiency; and Sustainability. In addition, holding professional workshops with experts is a method applied to determine and define assessment indexes and criteria, in which their viewpoints could be obtained to undertake the task. For this purpose, the present study provided a preliminary list of indexes which was then finalized through holding a poll session with elites and key experts in Iranian fisheries research organization. Accordingly, decision hierarchy tree was drawn as presented in Figure 5. The indexes mentioned in Decision Tree are common and might be generally applied to any type of research prioritization in the other areas similar to fisheries. In this research, the concerned indexes were made proportionate to the case of study, i.e. Fisheries Research Institute. For this purpose, in a meeting with authorities and researchers of the institute, some of the indexes were eliminated. Finally, appropriate criteria and indexes for prioritizing the fisheries research programs consist of 18 main indexes categorized into 4 different groups. List of these indexes is presented in Decision Hierarchy Tree (Figure 6).

Calculation Stages of AHP Method

Stage 1: Paired Comparisons

Following the formation of decision hierarchy tree, present components at each level are respectively assessed from bottom-up levels relative to all the associated components at the higher levels. Therefore, the assessments of decision options are carried out in terms of the last decision indexes which are also assessed in terms of their own hierarchy. In the AHP method, when the assessment is based on quality, it is done in a paired comparison manner, where a square matrix is formed, corresponding to the number of components which are placed in rows and columns. Then, these options are compared with each other in a binary manner by decision makers and numerically scored according to Saati's standardized table (Table 2), and presented in the matrix columns. Table 3 shows an instance of paired comparisons done among different programs according to the index of "productivity improvement of production resources". Data matrix, A, is generally positive and reverse; and its components are indicated by a_{ij}. So,

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considering the reversibility property of $a_{ij} = 1/a_{ij}$, simply the comparisons by a number of n(n-1)/2 times are needed in a matrix of n.n. On the other hand, when the assessment is based on quantity, the assessed components are measured by the same basis. So, in a group decision making, each decision maker's viewpoint is obtained within the mentioned matrixes and then combined into a group matrix.

Table 2: Saati Spectrum to Conduct Paired Comparisons

Measure of importance in the Paired Comparisons	equal preference	equal to relative preference	Relative preference	Relative to strong preference	strong preference	strong to very strong preference	very strong preference	very strong to infinite preference	infinite preference
Numerical score	1	2	3	4	5	6	7	8	9

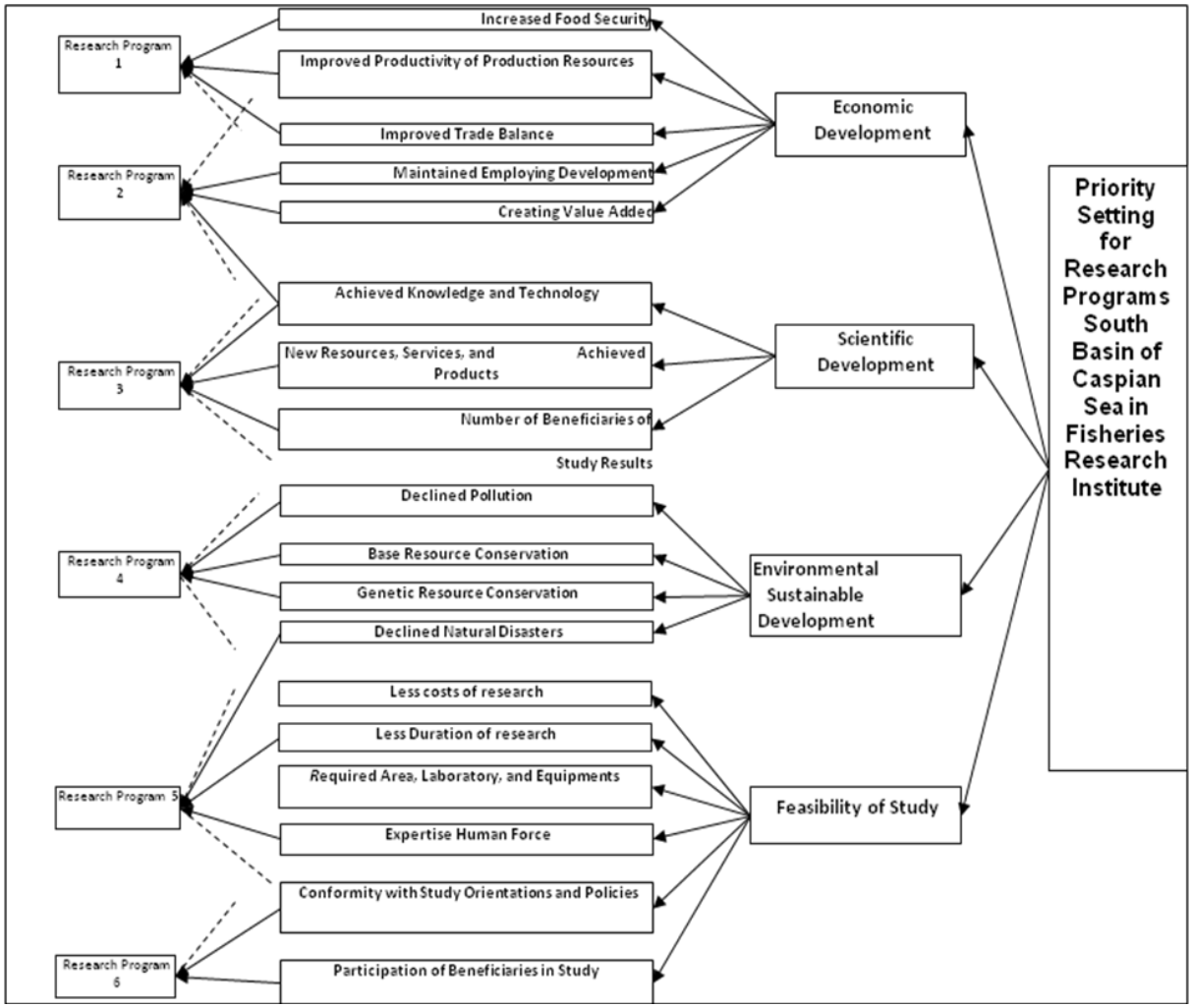

Figure 6: Decision Hierarchy Tree

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Table 3: An Instance of Paired Comparison by a Researcher according to the index of "productivity improvement of production resources"

research programs	1	2	3	4	5	6
Study of Physical and Chemical Properties of Water	1	1/3	1/4	1/5	1/5	1/6
Study of Frequency and Biomass of Phytoplankton	3	1	1/2	1/2	1/3	2
Study of Frequency and Biomass of Zeo Plankton	4	2	1	1/2	1/4	2
Study of Frequency and Biomass of Macrobenthos	5	2	2	1	1/3	2
Study of Frequency and Biomass of Mnemiopsis Leidyi	5	3	4	3	1	6
Study of Environmental Pollutions	6	1/2	1/2	1/2	1/6	1

For the purpose of creating group matrixes, as shown by Saati and Aczel (Forman and Peniwati, 1998), applying geometric mean is the best method, because the reversibility property of comparisons is maintained in the geometric mean. The corresponding components in a group matrix can be found by the following formulation:

$$a'_{ij} = (\prod_{i=1}^{k} a_{ij})^{\frac{1}{k}}$$

Number of decisionmakers: i= 1, 2, …, k. If necessary, there could be given priority, W_L, to the views of decision makers according to specialization and responsibility. When it is impossible to determine W_Ls in absolute terms,AHP could be used. Nevertheless, in this case, if we have $\sum_{i=1}^{k} W_l = 1$, there is no need to the root of $\frac{1}{\sum_{i=1}^{k} W_l}$ in calculating a'_{ij};

therefore, it results: $a'_{ij} = (\prod_{i=1}^{k} a_{ij}^{w})$

Finally, it should be pointed out that all the group members are not necessarily needed to undertake all the assessments; that is, any individual's viewpoint might be taken upon his/her specialization and expertise.

Group Matrix of paired comparisons among different programs according to the index of "productivity improvement of production resources" is shown in Table 4.

Stage 2: Extracting Weight Coefficients of Matrixes

In this stage, firstly, comparison matrixes are normalized. There are many methods for this purpose, such as 'dimensionless by Euclidean norm', 'fuzzy dimensionless', and 'linear dimensionless', the last one of which is used in AHP as follows (Asgharpour, 1996):

$$r_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}, \qquad j = 1,...,m$$

OR

$$r_{ij} = \frac{a'_{ij}}{\sum_{i=1}^{n} a'_{ij}}, \qquad j = 1,2,...,m$$

Here, r_{ij} is a normalized matrix component, by which weight coefficients, Wj , can be extracted. For this purpose, there are a few methods inclding Anthropy, Linmap, Lowest Weighted Squares, and Specific Vector which might be applied (Hwang et al., 1995).

w_i indicates the weight of factor i among other factors at the same level, relative to another factor at a higher level.

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Stage 3: Calculation of Consistency Rate

Prior to analyzing data, consistency of comparisons should be ensured, since the factors were compared by decision makers in a paired series and they are likely tobe inconsistent in general. Threrfore, a strength of the AHP method refers to its use in the consistency rate to evaluate the reliability of the paired comparison matrixes. Calculating consistency rate would be possible when the comparisons were done on the basis of Saaty's scope. Consistency rate is meared by a mathematical rationale of specific vectors (Hwang, 1995). Mathematically, if components have a full consistency, we will then have:

$$a_{ij} = a_{kj} \times a_{ik}$$

$$i,j,k = 1,2,\ldots,n$$

So, if all the components of the matrix A show a full consistency, we will have:

$$a_{ij} = \frac{w_i}{w_j}$$

However, as deviations are frequently possible, the consistency rate estimation should reveal weather or not a deyiation might be acceptable. In an analysis of consistency index, if the value is less than 0.1, the consistency of comparisons will be acceptable; otherwise, they need to be revised. The presence of consistency rate could most often be considered as a weakness of AHP in large-scale decision making models; though it is rather the case for making individual decisions, the consistency rate would be strongly reduced when the decisions were made in a group of people, due to the presence of geometric mean in matrix combinations.

Table 4: Group Matrix (Combined) of Paired comparisons According to the Index of "Productivity Improvement of Production resources"

research programs	1	2	3	4	5	6
Study of Physical and Chemical Properties of Water	1	2.702	2.484	2.139	2.139	1.695
Study of Frequency and Biomass of Phytoplankton	0.37	1	2.221	1.6	1.059	0.922
Study of Frequency and Biomas s of Zeo Plankton	0.403	0.45	1	1.741	1.496	0.803
Study of Frequency and Biomass of Macrobenthos	0.467	0.625	0.574	1	1.38	0.894
Study of Frequency and Biomass of Mnemiopsis Leidyi	0.467	0.944	0.668	0.725	1	1.084
Study of Environmental Pollutions	0.59	1.084	1.246	1.118	0.922	1

Table 5: Random Indexes for Paired Comparison Matrix

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

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Table 6: Research Program Priority Results

Objective	Decision Indexes and Weight Coefficients		Total Weight	Consistency Rate	Weighted Score of Rival Options in Terms of Related Indexes					
					1	2	3	4	5	6
Assessment and Prioritization of Research Programs on South Basin of Caspian Sea in the Fisheries Research Institute	Economic Development (0.187)	Increased Food Security (0.450)	0.084	0.06	0.236	0.135	0.09	0.082	0.265	0.192
		Improved Productivity of Production Resources (0.257)	0.048	0.03	0.301	0.168	0.137	0.121	0.123	0.15
		Improved Trade Balance (0.089)	0.017	0.02	0.287	0.141	0.119	0.15	0.163	0.14
		Maintained Employing Development (0.111)	0.021	0.03	0.262	0.145	0.108	0.096	0.123	0.266
		Creating Value Added (0.093)	0.017	0.01	0.213	0.134	0.109	0.105	0.167	0.272
	Scientific Development (0.263)	Knowledge and Technology Achievement (0.527)	0.139	0.02	0.183	0.127	0.121	0.117	0.163	0.289
		New Resources, Services and Products Achievement (0.301)	0.079	0.01	0.167	0.129	0.135	0.129	0.13	0.31
		Number of Research Beneficiaries (0.172)	0.045	0.01	0.148	0.137	0.123	0.118	0.107	0.367
	Environmental Sustainable Development (0.173)	Declined Pollution (0.504)	0.087	0.02	0.405	0.108	0.096	0.1	0.072	0.219
		Base Resource Conservation (0.248)	0.043	0.04	0.214	0.144	0.117	0.112	0.2	0.213
		Genetic Resource Conservation (0.116)	36.557	0	0.212	0.138	0.135	0.15	0.154	0.211
		Declined Natural Disasters (0.132)	0.023	0.01	0.185	0.117	0.109	0.113	0.173	0.303
	Feasibility of Study (0.377)	Less Cost of Research (0.205)	0.077	0. 02	0.357	0.153	0.136	0.121	0.107	0.126
		Less Duration of Research (0.159)	0.061	0. 02	0.324	0.144	0.138	0.147	0.116	0.131
		Required Area, Laboratory, and Equipments (0.143)	0.054	0.02	0.255	0.228	0.173	0.105	0.123	0.116
		Expertise Human Force (0.155)	0.058	0.01	0.258	0.189	0.158	0.146	0.119	0.13
		Conformity with Research Orientations and Policies (0.202)	0.076	0.01	0.234	0.145	0.136	0.104	0.142	0.239
		Participation of Beneficiaries in Study (0.136)	0.051	0.01	0.221	0.122	0.115	0.1	0.14	0.302
	Weighted Mean Scores				0.251	0.144	0.125	0.116	0.142	0.222
	Final Priority				1	3	5	6	4	2

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For the purpose of the present study, weighted sum vector is firstly estimated by

WSV=A.W;

then, consistency vector estimated by

CV= $\frac{WSV}{W}$;

and finally, consistency index estimated by

$$CI = \frac{\lambda - n}{n-1};$$

n represents matrix dimensions and λ is the mean consistency vector.

The consistency rate is:

$$CR = \frac{CI}{RI};$$

in which RI is the random index, suggested by Saaty, in proportion of the matrix dimensions(Table 5).

To apply a group AHP to a combination of individual matrixes, the geometric mean is used and as a result, the consistency rate of comparisons will be greatly reduced.

To select the best options or prioritize them, all the w_is of rival options are multiplied by the w_is of the coresponding decision indexes, resulting in the weighted mean of each option. Finally an option with the highest weighted mean is set as the best option and other options are placed at next priorities. Obviously, as the study programs and projects were assessed by eighteen indexes, the same number of categories W_i were produced, as shown by Table 6; accordingly, the achieved priority of each program is also presented at the bottom of the table.

According to the table, the feasibility of study, scientific development, economic development, and environmental sustainable development indexes form the priorities of the Fisheries Research Institute with 0.377, 0.263, 0.187, and 0.173 scores, respectively. In addition, achievement of new knowledge and technology (0.139), declined pollution (0.087), increased food security (0.084), and access to new resources, services and products (0.079) receive the highest priorities. Accordingly, the priorities of research programs on South Basin of Caspian Sea in the Fisheries Research Institute are respectively introduced as follows: Study of Physical and Chemical Properties of Water (0.251), Study of Environmental Pollutions (0.222), Study of Frequency and Biomass of Phytoplankton (0.144), Study of Frequency and Biomass of Mnemiopsis Leidyi (0.142), Study of Frequency and Biomass of Zeo Plankton (0.125) and finally, Study of Frequency and Biomass of Macrobenthos (0.116) (Table 6).

Discussion

Given the situation of decreasing research budgets, the demands for more accountability, and the high expectations of emerging technologies such as biotechnology, priority setting has become an important task in fisheries research planning. . Hence, in a first place, research plans need to be compared and prioritized in terms of a research strategic plan; then, priority-based research programs are to be determined under each plan; and finally, priorities should also be set for the concerned projects with respect to each selected program. The particular characteristics of fisheries research require special attention in setting priorities. Little experience has been acquired in this field, and information about it is limited. Performance assessments of fisheries

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research projects are therefore often quite subjective. It is crucial to apply a priority setting method that reduces individual biases as well as the risks of arriving at the wrong choices. However, in effect, the priority-setting and approval of research programs and projects within fisheries research system are far from efficiency and impact by many reasons including vague research policies and priorities, numerous involved authorities and institutions, unrealistic fund allocations of programs and projects, and governing bureaucratic procedures in the priority-setting process. Each one of these institutions and authorities tends to study the need for research in its own viewpoint which is not only inconsistent but also varied and, in some cases, conflicting with another, resulting in certain negative consequences.

Indeed, applying appropriate methods of priority-setting seems to be a prerequisite to make efficient the priority-setting process of research programs and projects. For this purpose, there might be used different methods; and among others, multiple index decision-making methods are now widely used in various contexts, resting on their high capabilities in modeling real issues, simplicity and understandability for users. Mathematical techniques and methods of planning and decision-making, though providing an optimum result, simply show such ability under particular conditions and assumptions. They need precise and definite primary information which might not be readily provided in real issues and otherwise cost too much. In addition, in these methods, it is not feasible to consider all aspects of a given issue while certain aspects in modeling with a quantitative feature and economical assessments are taken into consideration. Thus, generally speaking, many effective variables and conditions could never be applied by reason of their qualitative mode. Therefore, as the multiple index decision-making methods can take account of both quantitative and qualitative conditions and variables of an issue at same time, they have been widely applied and expanded.

Decision making in developing-country national agricultural research systems (NARS) is becoming increasingly complex. The research systems acknowledged that more formal (or more rigorous) priority setting is necessary for better decision making. The most useful priority setting methods for agricultural and fisheries Research are the analytic hierarchy process (AHP). So, this article presents an introduction application manner of the Analytical Hierarchy Process (AHP) as a mostly common method of setting research program priorities in research programs of the Fisheries Research Institute. Produced results are of great importance in illustrating group decisions more explicitly and make contingency in the views of decision-making group; thus, conflicts and controversies in dominant views are avoided and the adopted decisions are more likely to be enforced. In spite of these advantages, it should be noticed that obtaining required data is practically time-intensive and convincing the decision-makers of effective participation with analyzing group is not an easy task. However, the above method might be obviously used in setting priorities of the research plans and projects as well,

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varying in that determining and defining assessment indexes and criteria should be revised. For this purpose, primary indexes can be identified through a comparative study and then finalized by contribution and participation of the concerned elites and experts.

Finally, it should be noticed that like any other methods in decision-making, these techniques tend to simply turn data into information and provide decision-maker with them; and so, it is up to the decision-maker to make optimum decision under organizational situations and circumstances according to the produced results, and avoid to absolutely adopting the results. Therefore, it is frequently suggested that training workshops involving decision-makers are set up in order to analyze the produced results and make a final decision. Moreover, since the conditions and factors effective on research priority-setting are growing and complicating under the influence of increasing developments and changes, and as little simplifications in modeling decisions should be made to allow their improvement, application of a phased AHP is recommended. On the other hand, by using other multiple index decision-making methods including 'TOPSIS' and 'ELECTRE', we can provide different scenarios of priorities and achieve considerable results for decision-makers by comparing them. In this context, analyzing result signification can help explaining strengths and weaknesses of each method and presenting a practice to adopt the most appropriate method in terms of the existing conditions. This is suggested as one of the research grounds.

References

Azar, A. and Zare'ei, A., 2002. Explanation of the factors effective on productivity of organization by using multi-index decision-making models. *Daneshvar*. 42(**2**), 1-16.

Azar, A., 1995. Design of Mathematical Cost Planning Model in Public Organizations. A Ph.D. thesis. Management College. Tehran University.

Alphonce, C. B., 1997. Application of the Analytic Hierarchy Process in Agriculture of Developing Countries. Agricultural System 53(**1**), 97-112.

Anders, M. M. and Mueller R. A. E., 1995. Managing Communication and Research Task Perceptions in Interdisciplinary Crops Research. Quarterly *Journal of International agriculture*, 34, 53- 69.

Asgharpour, M. J., 1999. Multi-Criteria Decision-Making. Tehran: Tehran University Publications, pp. 400

Bose, R. K. and Anandalingam G., 1996. Sustainable urban energy-environment management with multiple objectives. *Energy*, 21 (**4**), 305–318.

Braunschweig, T., 2000. Priority Setting in Agricultural Biotechnology Research. ISNAR.

Chedid, R.., Akiki, H. and Rahman, S., 1998. Decision support technique for the design of hybrid solar-wind power systems. *IEEE Transactions on Energy Conversion*, 13 (**1**), 76–83.

Contant, R. B. and Bottomley A., 1988. Priority Setting In Agricultural Research, The Hague: International Service for National Agricultural Research Working Paper No. 10.

Falconi, C., 1993. Economic Evaluation. *In* Monitoring and Evaluating Agricultural Research: A Sourcebook, edited by D.

[DOR: 20.1001.1.15622916.2011.10.1.5.4]

Horton, P. Ballantyne, W. Peterson, B. Uribe, D. Gapasin and K. Sheridan. Oxon: CAB International.

Falconi, C., 1999. Methods for Priority Setting in Agricultural Biotechnology Research, in Cohen, J. I. (ed.) Managing Agricultural Biotechnology- Addressing Research Programme Needs and Policv Implications. CAB International: Wallingford, pp. 40-52.

Forman E. and Peniwati, K., 1998. Aggregating Individual Judgment and Priorities with the Analytic Hierarchy Process. *European Journal of Operation Research*, 108,156 - 169.

Güngör Sen, C. and Çınar, G., 2010. Evaluation and pre-allocation of operators with multiple skills: A combined fuzzy AHP and max–min approach. *Expert Systems with Applications*, 37, 2043–2053.

Herkert, J. R. Farrell, A and Winebrake, J. J., 1996. Technology choice for sustainable development. *IEEE Technology Society Magazine*, 15 (**2**), 12–20.

Hwang. C. L. and Yoon. K. P. 1995. Multiple Attribute Decision Making: An Introduction, London, Sage University, Papers Series, Quantitative Applications in the Social Sciences, No 07-104, London: Sage publications.

Innes, J. P. and Sean Pascoe, S., 2010. A multi-criteria assessment of fishing gear impacts in demersal fisheries. *Journal of Environmental Management*, 91, 932–939.

ISNAR 1998. Agricultural Research Priority Setting: Information Investments for Improved Use of Resources. Edited by Bradford Mills.

Kablan, M., 1997. Prioritization of decentralized electricity options available for rural areas in Jordan. Energy *Conversion and Management*, 3(**14**), 1515–1521.

Kagazyo, T., Kaneko, K., Akai, M. and Hijikata, K., 1997. Methodology and evaluation of priorities for energy and environmental research projects. *Energy* 22 (2/3), 121–129.

Karami, E., 2006. Appropriateness of farmers' adoption of irrigation methods: The application of the AHP model. *Agricultural Systems*, 87, 101–119.

Liberatore, M.J., 1989. A Decision Approach for R&D Project Selection. In The Analytic Hierarchy Process: Applications and Studies, edited by B.L.

Lockett, G., Hetherington, B., Yallup, P., Stratford, M. and Cox, B., 1986. Modeling a Research Portfolio Using AHP: A Group Decision Process. *R&D Management*, 16(**2**), 151-60.

Manahan, M. P., 1989. Technology Acquisition and Research Prioritization. *International Journal of Technology Management*, 4(**1**), 9-19.

Mills, B., 1998. Agricultural Research Priority Setting: Information Investments for Improved Use of Resources. The Hague, The Netherlands: *International Service for National Agricultural Research*, 12, 1-143.

Norton, G., 1989. Methods to Assist with Agricultural Research Priority Setting. Paper presented at the International Agricultural Research Management Workshop, ISNAR, The Hague, November 7, 1989.

Norton, G., 1993. Scoring Methods. *In* Monitoring and Evaluating Agricultural

[DOR: 20.1001.1.15622916.2011.10.1.5.4]

Research: A Sourcebook, edited by D. Horton, P. Ballantyne, W. Peterson, B. Uribe, D. Gapasin and K. Sheridan. Oxon: CAB International.

Pakdin Amiri, M., 2010. Project selection for oil-fields development by using the AHP and fuzzy TOPSIS methods, Expert Systems with Applications, pp.7.

Pardey, P. G., and Roseboom, J., 1998. Development of National Agricultural Research Systems in an International Quantitative Perspective. In Technology Policy for Sustainable Agricultural Growth, IFPRI Policy Briefs No. 7. Washington, D.C.

Poh, K. L. and Ang, B. W., 1999. Transportation fuels and policy for Singapore: An AHP planning approach, *Computers & Industrial Engineering*. 37, 507–525.

Rabelo, L., Eskandari, H., Shaalan, T. and Helal, M., 2007. Value chain analysis using hybrid simulation and AHP. *International Journal of Production Economics*, 105, 536–547.

Ramanathan, R. and Ganesh, L. S., 1995. Energy resource allocation incorporating qualitative and quantitative criteria: An integrated model using goal programming and AHP. Socio Economic Planning Sciences, 29 (**3**), 197–218.

Saaty, T. L., 1995. Transport planning with multiple criteria: The analytic hierarchy process applications and progress review. *Journal of Advanced Transportation*, 29 (**1**), 81–126.

Wong, K. W. J. and Li, H., 2008. Application of the analytic hierarchy process (AHP) in multi-criteria analysis of the selection of intelligent building systems. *Building and Environment*, 43, 108–125.

Zayed, T., Amer, M. and Pan, J., 2008. Assessing risk and uncertainty inherent in Chinese highway projects using AHP. *International Journal of Project Management*, 26, 408–419.

Zhang, X. and Lu, X., 2009. Multiple criteria evaluation of ecosystem services for the Ruoergai Plateau Marshes in southwest China, Ecological Economics, pp. 8.

[DOR: 20.1001.1.15622916.2011.10.1.5.4]