Designing an Integrated AHP based Fuzzy Expert System and SWOT Analysis to Prioritize Development Strategies of Iran Agriculture

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Abstract

In spite of successful research on new agricultural practices concerning crop cultivation, the majority of farmers is not getting upper-bound yield due to several reasons. One of the reasons is that expert/scientific advice regarding crop cultivation is not reaching farming community in a timely manner. It is true that we possess a valuable agricultural knowledge and expertise. However, a wide information gap exists between the research level and practice. Farmers need timely expert advice to make them more productive and competitive. In this paper, we made an effort to present a solution to bridge the information gap by exploiting advances in Information Technology (IT). It is interesting to notice a major difference between developed countries and developing countries, serves as a distinguished representative, in their roadmaps to agriculture modernization to developing counties. IT assists to achieve agricultural mechanization efficiently and intelligently. We proposed a framework of strategic plan based on SWOT analysis using IT in Agriculture.

Keywords: *Information Technology; Agriculture; Strategic implementation; SWOT analysis.*

JEL classification: M10, Q18, Q58, M21.

Introduction

During last decade one can observe that progress in IT is affecting all spheres of our life.

Due to progress in hardware technologies, we are able to procure high-speed reliable computers with huge storage capacities. Recent advances in information technology (IT) have increased the opportunities for effective decision support. Nowadays, several applications are available that can support important farm processes. Such IT based developments provide new opportunities to improve the utilization and performance of livelihood technologies such as agriculture, education, library, health and medical services, and artesian technologies. In order to set priorities amongst the currently available IT applications, the identification of

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information needs is essential. Investments should be aligned with these information needs; applications that support the needs with the greatest economic benefit and use the least resources should get the highest priority.

Related to agriculture, it can be noted that food production has improved significantly during last three decades due to all-round efforts such as modernizing agriculture, providing it with modern inputs like improved seeds, fertilizers and pesticides, better cultivation methods, application of modern tools and farm equipment etc. The agricultural sector has today achieved total food self-sufficiency and also made the country a net exporter of agricultural produce (Subba Rao, 2002). However, agriculture is still facing a multitude of problems to maximize productivity. Due to several reasons, the majority of the farming community is not getting upper bound yield despite successful research on new agricultural practices by inventing new crop varieties, crop cultivation and pest control techniques. One of the reasons is that the appropriate and timely scientific advice about farming is not reaching the farmers (Sudarshan Reddy et al., 1998; Chowdary et al, 1998).

It is interesting to notice a major difference between developed countries and developing countries, of which Iran serves as a distinguished representative, in their roadmaps to agriculture modernization. To developing counties, such as Iran, IT is a gift from the modern history of civilization. IT assists Iran to achieve agricultural mechanization efficiently and intelligently. More importantly, IT will probably become one of a very few tools that will guide Iran and the world to a sustainable agriculture.

To highlight the application of IT in agriculture constraints, future potentials and challenges a SWOT (strength, weakness, opportunity and threat) analysis has been taken up in this work. The SWOT suggests that there is a huge possibility to improve the agriculture using IT. Opportunities and threats discussed are relevant in the present context and should be given due consideration.

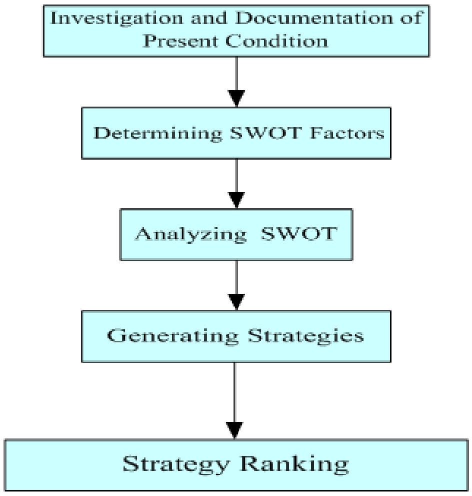

Figure 1. A framework for this research

1. SWOT Analysis

Strategic management can be understood as the collection of decisions and actions taken by business management, in consultation with all levels within the organization, to determine the long-term activities of the organization (Houben et al., 1999). Many approaches and techniques can be used to analyze strategic cases in the strategic management process (Dincer, 2004). Among them, Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis, which evaluates the opportunities, threat s, strengths and weaknesses of an organization, is the most common (Hill and Westbrook, 1997). SWOT analysis is an important support tool for decision-making, and is commonly used as a means to systematically analyze an organization's internal and external environments (Kurttila et al., 2000; Stewart et al., 2002). By identifying its strengths, weaknesses, opportunities, and threats, the organization can build strategies upon its strengths, eliminate its weaknesses, and exploit its opportunities or use them to counter the threats. The strengths and weaknesses are identified by an internal environment appraisal while the opportunities and threats are identified by an external environment appraisal (Dyson, 2004). The internal appraisal examines all aspects of the organization covering, for example, personnel, facilities, location, products and services, in order to identify the organizations strengths and weaknesses. The external appraisal scans the political, economic, social, technological and competitive environment with a view to identifying opportunities and threats. The environmental SWOT analysis is indicated in Figure 2.

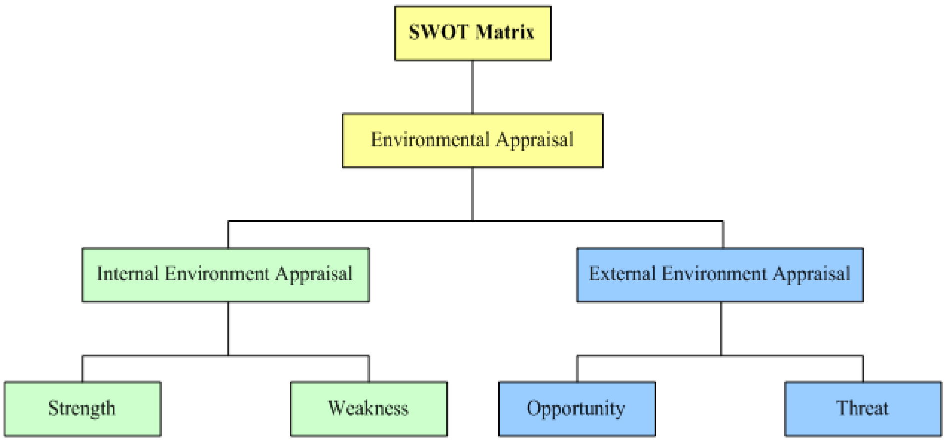

Figure 2. Environmental SWOT Analysis

SWOT analysis summarizes the most important internal and external factors that may affect the organization's future, which are referred to as strategic factors (Kangas et al., 2003). The external and internal environments consist of variables which are outside and inside the organization, respectively. The organization's management has no short-term effect on either type of variable.

Comprehensive environmental analysis is important in recognition of the variety of internal and external forces with which an organization is confronted. On the one hand these forces may comprise potential stimulants, and on the other hand, they may consist of potential limitations regarding the performance of the organization or the objectives that the organization wishes to achieve (Houben et al, 1999). The obtained information can be systematically represented in a matrix (Ulgen and Mirze, 2004); different combinations of the four factors from the matrix can aid in determination of strategies for long-term progress. When used properly, SWOT can provide a good basis for strategy formulation (Kajanus et al., 2004). However, SWOT analysis is not without weaknesses in the measurement and evaluation steps (McDonald, 1993). In conventional SWOT analysis, the magnitude of the factors is not quantified to determine the effect of each fact or on the proposed plan or strategy (Masozera et al., 2006).

In other words, SWOT analysis does not provide an analytical means to determine the relative importance of the factors, or the ability to assess the appropriateness of decision alternatives based on these factors. While it does pinpoint the factors in the analysis, individual factors are usually described briefly and very generally. More specifically, SWOT allows analysts to categorize factors as being internal (Strengths, Weaknesses) or external (Opportunities, Threats) in relation to a given decision, and thus enables them to compare opportunities and threats with strengths and weaknesses (Shrestha et al., 2004). Based on the aforementioned description the following SWOT matrix (Table 1) is configured.

Table 1. SWOT matrix

S	**O**
W	**T**

Here, we propose a strategic framework to develop the IT/ICT programs in agriculture of Iran based on SWOT analysis in order to assist the formulation of the strategy as shown in Figure 3.

2. Determining SWOT factors

The SWOT analysis is the process of analyzing organizations and their environments based on their strengths, weaknesses, opportunities and threats. This includes the environmental analysis—the process of scanning the business environment for threats and opportunities (external factors), and the organizational analysis—the process of analyzing a firm’s strengths and weaknesses (internal factors). The analysis of SWOT is the matching of the specific internal and external factors, which creates a strategic plan. It is essential to note that the internal factors such as operations, finance, marketing, and many more are within the control of the organization. On the contrary, the external factors such as political and economic factors, technology, competition, and many more are out of organization's control. Here, we apply the SWOT analysis to develop the IT/ICT programs in agriculture of Iran. At the first step, the environment of our work is identified. The agriculture of Iran and research centers corresponding to IT/ICT technology have been considered as the internal environment while the enterprises of the country have been considered as the external environment. After defining the SWOT factors by the expert committee, Analytic Hierarchy Process (AHP) is applied to weigh the SWOT factors. Internal and external factor evaluation (IFE and EFE) matrices consisting of two items have been formed: the first item is the weight of each factor that would be obtained by the AHP algorithm and the second item is the score of each factor that could be identified by an IT/ICT expert. To create the development strategies, all aspects of environment should be considered; i.e., the current situation of the system, interaction of the SWOT factors, interconnections between internal and external factors, priority of development, the point of view of the experts in agriculture and other relevant parameters. To prioritize the proposed strategies, a fuzzy expert system approach is applied.

2.1. Determining SWOT weights by AHP

To weigh the parameters, we take a multi criteria decision making approach. Multi-criteria decision making (MCDM), dealing primarily with problems of evaluation or selection, is a rapidly developing area in operations research and management science. The analytical hierarchy process (AHP), is a technique of considering data or information for a decision in a systematic manner. AHP is mainly concerned with the way to solve decision problems with uncertainties in multiple criteria characterization. It is based on three principles: (1) constructing the hierarchy, (2) priority setting, and (3) logical consistency. We apply AHP to weigh the parameters.

Construction of the hierarchy

A complicated decision problem, composed of various attributes of an objective, is structured and decomposed into sub-problems (sub-objectives, criteria, alternatives, etc.), within a hierarchy.

Priority setting

The relative "priority" given to each element in the hierarchy is determined by pair-wise comparisons of the contributions of elements at a lower level in terms of the criteria (or elements) with a causal relationship. In AHP, multiple paired comparisons are based on a standardized comparison scale of nine levels (see Table 2).

Table 2. Scale of relative importance

Intensity of importance	Definition of importance
1	Equal
2	Weak
3	Moderate
4	Moderate plus
5	Strong
6	Strong plus

7	Very strong or demonstrated
8	Very, very strong
9	Extreme

Let $C = \{c_1, ..., c_n\}$ be the set of criteria. The result of the pair-wise comparisons on *n* criteria can be summarized in an $n \times n$ evaluation matrix *A* in which every element a_{ij} is the quotient of weights of the criteria, as shown below:

$A = (a_{ij}), \quad i, j = 1, . . . , n.$

The relative priorities are given by the eigenvector (*w*) corresponding to the largest eigenvalue

($\lambda_{\max}$) as:

$$Aw = \lambda_{\max} w.$$

When pair-wise comparisons are completely consistent, the matrix *A* has rank 1 and $\lambda_{\max} = n$. In that case, weights can be obtained by normalizing any of the rows or columns of *A*.

The procedure described above is repeated for all subsystems in the hierarchy. In order to synthesize the various priority vectors, these vectors are weighed with the global priority of the parent criteria and synthesized. This process starts at the top of the hierarchy. As a result, the overall relative priorities to be given to the lowest level elements are obtained. These overall, relative priorities indicate the degree to which the alternatives contribute to the objective. These priorities represent a synthesis of the local priorities, and reflect an evaluation process that permits integration of the perspectives of the various stakeholders involved.

Consistency check

A measure of consistency of the given pair-wise comparison is needed. The consistency is defined by the relation between the entries of *A*; that is, we say *A* is consistent if $a_{ik} = a_{ij} \cdot a_{jk}$, for all *i,j,k*. The consistency index (*CI*) is:

$$CI = \frac{(\lambda_{\max} - n)}{(n-1)}.$$

The final consistency ratio (*CR*), on the basis of which one can conclude whether the evaluations are sufficiently consistent, is calculated to be the ratio of the *CI* and the random consistency index (*RI*):

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

The value *0.1* is the accepted upper limit for *CR*. If the final consistency ratio exceeds this value, the evaluation procedure needs to be repeated to improve consistency. The measurement of consistency can be used to evaluate the consistency of decision makers as well as the consistency of all the hierarchies.

We are now ready to give an algorithm for computing parameter weights using the AHP. The following notations are used.

Notations and definitions:

n: Number of criteria.

i: Number of parameters.

p: Index for parameters, p=1or 2.

d: Index for criteria, $1 \leq d \leq D$.

R_{pd}: The weight of *pth* item with respect to *dth* criterion.

w_d: The weight of *dth* criterion.

Algorithm: PWAHP (compute weights using the AHP).

Step 1: Define the decision problem and the goal.

Step 2: Structure the hierarchy from the top through the intermediate to the lowest level.

Step 3: Construct the parameter-criteria matrix using steps 4 to 8 using the AHP.

{Steps 4 to 6 are performed for all levels in the hierarchy.}

Step 4: Construct pair-wise comparison matrices for each of the lower levels for each element in the level immediately above by using a relative scale measurement. The decision maker has the option of expressing his or her intensity of preference on a nine-point scale. If two criteria are of equal importance, a value of 1 is set for the corresponding component in the comparison matrix, while a 9 indicates an absolute importance of one criterion over the other (Table 1 shows the measurement scale).

Step 5: Compute the largest eigenvalue by the relative weights of the criteria and the sum taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.

Analyze pair-wise comparison data using the eigenvalue technique. Using these pair-wise comparisons, estimate the parameters. The eigenvector of the largest eigenvalue of matrix A constitutes the estimation of relative importance of the attributes.

Step 6: Construct the consistency check and perform consequence weights analysis as follows:

$$A = \left(a_{ij}\right) = \begin{bmatrix} 1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & 1 & \cdots & w_2/w_n \\ \vdots & \vdots & \ddots & \\ w_n/w_1 & w_n/w_2 & & 1 \end{bmatrix}.$$

Note that if the matrix A is consistent (that is, $a_{ik}= a_{ij} \cdot a_{jk}$, for all $i, j, k = 1, 2, ..., n$), then we have (the weights are already known),

$$a_{ij} = \frac{w_i}{w_j}, \qquad i, j = 1,2,..., n.$$

If the pair-wise comparisons do not include any inconsistencies, then $\lambda_{\max} = n$. The more consistent the comparisons are, the closer the value of computed $\lambda_{\max}$ is to n. Set the consistency index (CI), which measures the inconsistencies of pair-wise comparisons, to be:

$$CI = \frac{(\lambda_{\max} - n)}{(n-1)},$$

and let the consistency ratio (CR) be:

$$CR = 100\left(\frac{CI}{RI}\right),$$

where n is the number of columns in A and RI is the random index, being the average of the CI obtained from a large number of randomly generated matrices.

Note that RI depends on the order of the matrix, and a CR value of 10% or less is considered acceptable (Saaty, 1980).

Step 7: Form the parameter-criteria matrix as specified in Table 3:

Table 3. The parameter-criteria matrix

	C_1	C_2	...	C_d
parameter 1	R_{11}	R_{12}	...	R_{1d}
parameter 2	R_{21}	R_{22}	...	R_{2d}

Step 8: As a result, configure the pair-wise comparison for criteria-criteria matrix as in Table 4.

Table 4 The criteria-criteria pair-wise comparison matrix

	C_1	C_2	...	C_d	w_d
Criteria 1	1	a_{12}	...	a_{1d}	w_1
Criteria 2	$1/a_{12}$	1	...	a_{2d}	w_2
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
Criteria d	$1/a_{1d}$	$1/a_{2d}$	...	1	w_d

The w_d are gained by a normalization process. The w_d are the weights for criteria.

Step 9: Compute the overall weights for the SWOT factors.

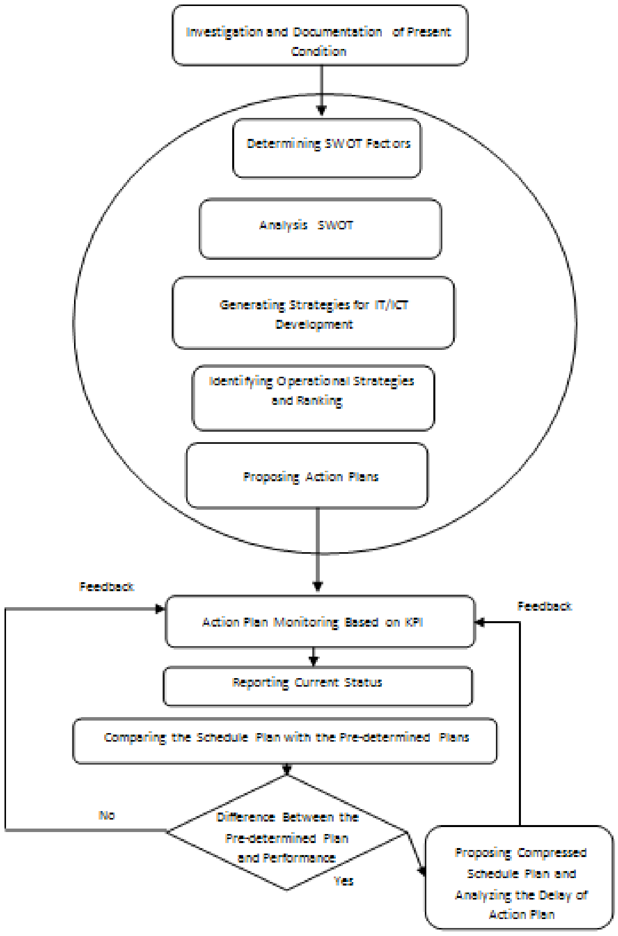

Figure 3. Strategic planning flowchart

3. Prioritizing the strategies

Knowledge-based systems are systems based on the methods and techniques of Artificial Intelligence. Their core components are the knowledge base and the inference mechanisms. Some particular types of knowledge-based systems are expert systems, case-based reasoning systems and neural networks.
Expert Systems (ES) are computer programs that are derived from a branch of computer science research called Artificial Intelligence (AI). AI's scientific goal is to understand intelligence by building computer programs that exhibit intelligent behavior. It is concerned with the concepts and methods of symbolic inference, or reasoning, by a computer, and how the knowledge used to make those inferences will be represented inside the machine.

Building expert systems by using shells offers significant advantages. A system can be built to perform a unique task by entering into a shell all the necessary knowledge about a task domain. The inference engine that applies the knowledge to the task at hand is built into the shell. If the program is not very complicated and if an expert has had some training in the use of a shell, the expert can enter the knowledge himself.

An expert system tool, or shell, is a software development environment containing the basic components of expert systems. Associated with a shell is a prescribed method for building applications by configuring and instantiating these components. Some of the generic components of a shell are shown in Figure 4 and described below. The core components of expert systems are the knowledge base and the reasoning engine.

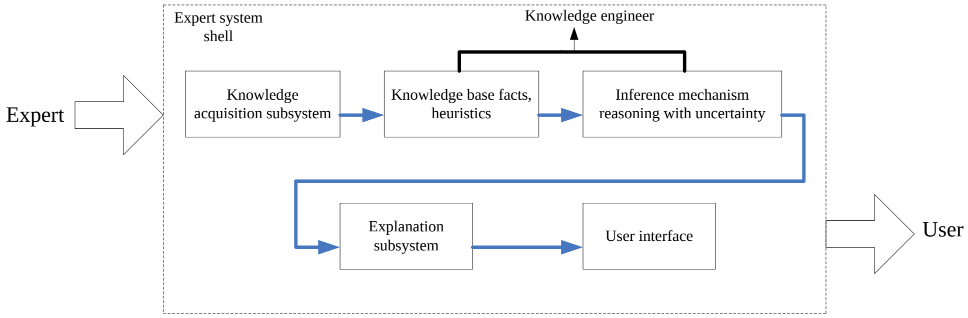

Figure 4. Basic Components of Expert System Tools

Knowledge base: A store of factual and heuristic knowledge. An ES tool provides one or more knowledge representation schemes for expressing knowledge about the application domain. Some tools use both frames (objects) and IF-THEN rules. In PROLOG the knowledge is represented as logical statements.

Reasoning engine: Inference mechanisms for manipulating the symbolic information and knowledge in the knowledge base to form a line of reasoning in solving a problem. The inference mechanism can range from simple modus pones backward chaining of IF-THEN rules to case-based reasoning.

Knowledge acquisition subsystem: A subsystem to help experts build knowledge bases. Collecting knowledge needed to solve problems and build the knowledge base continues to be the biggest bottleneck in building expert systems.

Explanation subsystem: A subsystem that explains the system's actions. The explanation can range from how the final or intermediate solutions were arrived at to justifying the need for additional data.

User interface: The means of communication with the user. The user interface is generally not a part of the ES technology, and was not given much attention in the past. However, it is now widely accepted that the user interface can make a critical difference in the perceived utility of a system regardless of the system's performance.

Here, we apply fuzzy expert system according to the following steps.

Algorithm: Fuzzy Expert System

In an expert system a membership function is proposed for criteria regarding to the experts idea. To propose an expert system the following steps should be taken:

1. Determining the objective, alternatives and criteria
2. Identifying the input and output variables
3. Proposing membership functions for input and output variables
4. Proposing rules to determine the relations between inputs and outputs
5. Selecting an appropriate inference mechanism
6. Placement of alternatives corresponding to each criteria
7. Extracting the evaluation result by the proposed expert system
8. Sensitivity analysis of evaluated alternatives

4. Action plans

The implementation strategy is the most detailed component of the proposed IT/ICT program development implementation framework. This step requires the definition of robust actions, the evaluation of budgetary requirements, the study of time and organizational constraints, the elaboration of human resource issues, management and plan coordination, migration and diffusion, etc. In addition, the action plans need to be examined concerning its risks, strategic importance and harmonized integration within the overall evolution of the specific organization. There are two main stages to the development of the implementation strategy: (a) definition of action plan elements which must be clearly defined before elaboration of these plans can take place, and (b) elaboration of action plan; once the definition and role of action plans are established, the action plans can be detailed. Activities that need to be undertaken in stage (a) include: (1) inventory of actions, (2) study of implementation procedures (budgetary constraints, organizational constraints, types of financing, etc.), and (3) action prioritization with reference to strategic importance. Activities that need to be undertaken in stage (b) include: (1) study of each action element (objectives, work breakdown structure, anticipated results, etc.), (2) time dimension (constraints, precedence, control points, etc.), (3) cost dimension (purchase costs, development costs, maintenance costs, etc.), and (4) analysis of human resource issues (training, support, etc.). Elaboration of action plans will ensure that the IT/ICT program development implementation strategies are well documented and can be readily followed.

4.1. Monitoring plans and short and long term goals

Developing a strategic implementation plan for an IT/ICT program does not guarantee its successful implementation. Consideration should be given to the continual performance monitoring of the implemented IT/ICT programs over their lifecycles, while monitoring plans should consider performance measures and data collection strategies required for their implementations by the organization. To assess the IT/ICT program development, one must select an easily definable and a limited number of performance measures with a mixture of short and long term goals. Here, we define some attributes/indices to monitor the implementation of the proposed action plan by considering short-term and long-term objectives.

Conclusions

Strategic planning is a significant element for implementing projects. A benefit method for analyzing different strategies is SWOT. SWOT analysis summarizes the most important internal and external factors that may affect the organization's future, which are referred to as strategic factors. The loss and risk are two parameters that each strategy faces during its implementation. In this paper, integration between SWOT analysis and expert system was applied to evaluate varied strategies for improving agriculture system.

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