APPLICATION OF ANALYTICAL HIERARCHY PROCESS IN DETERMINIG THE BEST LOCATION FOR THE WHEY PROTEIN PRODUCTION FACTORY

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Summary: *The location of the whey protein production factory (WPPF) is of most importance when determining the best choice through evaluation of the available alternatives using multi-criteria selection procedures in consideration of all effective criteria in order to achieve the optimum production efficiency. In this study, the target zone has been chosen in western Iran (Hamedan Province) and the Alternatives are industrial complexes throughout the region. In order to validate research procedure, expert's opinions have been criticized using Delphi method. Considered criteria in this study includes: Land expenses, industrial complex's facilities, convenience of accessing feed source, lack of serious competent factories ; which has been analyzed by utilization of AHP method. Expert Choice software has been utilized to facilitate calculation.*

1. Introduction

The increasing usages of whey proteins in pharmaceutical and hygienic industries, alongside many other applications in other industries which are being expanded every day, have made this substance an important component of many commonly used products. Unfortunately due to lack of operational manufacturing facilities, the remarkable demand for this product is being more concern able every year; also misuse of whey as a byproduct of cheese manufacturing factories is being concerned as an environmental crisis.

Hopefully there's been more attention being attracted to this subject and there is an adequate potential for this field of production in western Iran, in which Hamedan province stands out due to its industrial capacities (Hamedan Province Industries Organization report., 2005-2006).It should be considered that selecting an inadequate location for the WPPF not only would make the project face financial difficulties, but also would decrease interests for exploitation of this valuable byproduct of the numerous cheese production factories throughout the region.

There's a remarkable demand for an appropriate management in determining the best location and also resolving the priority of other alternatives in comparison to the selected location considering various criteria, concerning the importance of the subject. Due to complexity of the problem, AHP method has been utilized for solution. Flexibility of the results achieved in this study, particularly in the sensitivity analyze stage, in which changes in priority of the alternatives considering the changes in criteria in future, also taking into account latest statistical information and methods, has made this study a distinctively extended research, which has never been done before.

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2. AHP Application

AHP is a decision-aiding tool for dealing with complex, unstructured, and multiple-criteria discrete decisions. Since its initial development, AHP has been applied to a wide variety of decision areas in manufacturing (Partovi,F., 2006). Saaty developed the following steps for applying the AHP:

1. Define the problem and determine its goal.

2. Structure the hierarchy from the top (the objectives from a decision-maker's viewpoint) through the intermediate levels (criteria on which subsequent levels depend) to the lowest level which usually contains the list of alternatives.

3. Construct a set of pair-wise comparison matrices (size n×n) for each of the lower levels with one matrix for each element in the level immediately above by using the relative scale measurement shown in table 1.The pair-wise comparisons are done in terms of which element dominates the other.

4. There are n (n-1)/2 judgments required to develop the set of matrices in step 3 . Reciprocals are automatically assigned in each pair-wise comparison.

5. Hierarchy synthesis is now used to weight the eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.

6. Having made all the pair-wise comparisons, the consistency is determined by using the eigenvalue, λ, to calculate the consistency index, CI as follows:

$$CI = (\lambda - n)/(n-1) \quad (1)$$

where n is the matrix size, judgment consistency can be checked by taking the consistency ratio (CR) of CI with the appropriate value in table 2.The CR is acceptable, if it does not exceed 0.10. If it is more, the judgment matrix is inconsistent. To obtain a consistent matrix, judgments should be reviewed and improved.

7. Steps 3-6 are performed for all levels in the hierarchy.

Table 1: pair-wise comparison scale for AHP preference.

Numerical rating	Verbal judgments of preferences
9	Extremely preferred
8	Very strongly to extremely
7	Very strongly preferred
6	Strongly to Very strongly
5	Strongly preferred
4	Moderately to strongly
3	Moderately preferred
2	Equally to moderately
1	Equally preferred

Table 2: Average random consistency (RI)

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Fortunately, there is no need to implement the steps manually. Professional commercial software, Expert Choice, developed by Expert Choice, Inc, is available on the market which simplifies the implementation of the AHP's steps and automates many of its computations (Al-Harbi.K.M.AL-S., 2001).

3. AHP for Selection WPPF

Project managers are faced with decision environments and problems in projects that are complex. The elements of the problems are numerous, and the interrelationships among the elements are extremely complicated. Relationships between elements of a problem may be highly nonlinear; changes in the elements may not be related by simple proportionality. Furthermore, human value and judgment systems are integral elements of project problems. Therefore, the ability to make sound decisions is very important to the success of a project. In fact, Schuyler makes it is a skill that is certainly near the top of the list of the project management skills, and notices that few of us have had formal training in decision making (Al-Harbi.K.M.AL-S., 2001).

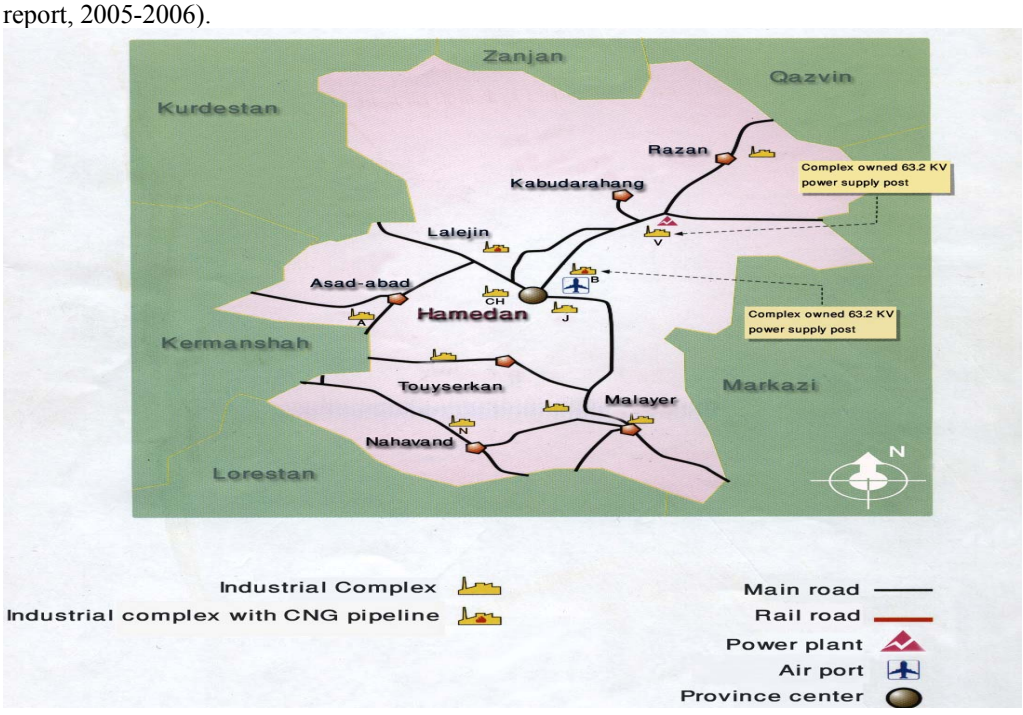
AHP is a popular method used in finding a solution to the problem of MCDM.

One of the reasons for the popularity of AHP as an applicable method in the fact that is takes into consideration not just tangible but also intangible criteria (Aras,H et al., 2004).

For instance, determining the best location for a WPPF is a problem that involves both many numerical and non-numerical criteria. Therefore, AHP method seems to be an easily applicable method in finding a solution to the problem of where exactly to build a WPPF.

AHP approach categorizes a decision problem into several levels and thus uses a hierarchy structure in order to define this problem. In this approach, each element existing in the hierarchy is assumed to be independent of one another (Aras,H et al., 2004).
The layout of these locations is shown in Fig.1.

Figure 1: layout of the six alternatives locations (Hamedan Province Industries Organization report, 2005-2006).



Ranking information representing the various degrees of importance/performance (Table 1) was used to pair-wise compare the different criteria and alternatives.

Rating ranged from equal importance to extreme importance with successively stronger preference of one criterion over the other. All comparisons were conducted in a pair-wise manner relative to their parent element in the hierarchy structure. Due to lack of sufficient quantitative information and the complex multi-objective nature of the problem, it was decided to use AHP, and for easy to work used Expert Choice software. As mentioned before, AHP model involves three levels and the goal in this study, is selection of the best possible location for WPPF plus ranking of the locations considered for it, in order manage and lower the risks of choice made in addition to expansion of the choice management in region.

Five criteria must be considered in selecting a location; they include:

1. Land expenses: Low land expenses are a positive factor as it would facilitate the establishment and development of the factory.

2. Industrial complex's facilities: Some of the inspected complexes offer facilities like private-owned 63.2 KV power supply post, waste water treatment facility and etc. Offering more facilities has been defined as an effective factor.

3. Convenience of accessing feed source: A stable feed source plays a vital role in production efficiency, thus convenience of access to various feed sources, which have an industrial scale production, would secure the project's production; hence convenience of accessing feed source has been identified as the most effective factor.

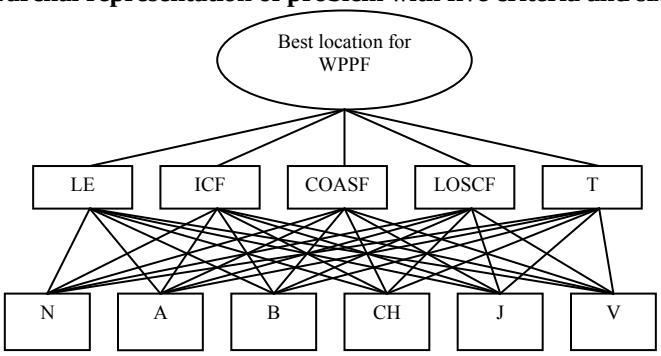
4. Lack of serious competent factories: Considering the importance of the convenience of accessing feed source factor, establishment of competent facilities would have a negative effect on the convenience of accessing feed source factor.

5. Transportation: It's obvious that further development of transportation capacity would increase the continuation of the product.

Other factors such as Security of the complex, social and cultural circumstances, climate conditions and etc have been neglected due to integrity of the target zone (Hamedan Province).

Six suitably available industrial complexes for WPPF were assessed in this study; a general description of the different location types is presented Fig. 2.

Figure 2: A hierarchal representation of problem with five criteria and six alternatives.



A schematic representation of the problem under study is shown in Fig.2.

Where, according to AHP design, the process is presented in three levels. Level one represents the goal which is to determining the best location for WPPF in Hamedan region. The second level represents the different selection criteria, followed by the alternatives in the lower level. From the second and third levels, the best location for WPPF in Hamedan is selected.

The main objective of this study is to determining the most suitable location for adoption in the Hamedan region. The determining process is based on different criteria with the five most important listed above.

The selection criteria are therefore as follows:

LE= Land Expenses

ICF= Industrial Complex's Facilities

COASF= Convenience of Accessing Feed Source

LOSCF= Lack of Serious Competent Factories

T= Transportation

The different industrial complexes representing the alternatives are designated as follows:

N= Nahavand

A= Asad abad

B= Booali

CH= Chaharrah Ghasaban

J= Jadeh malayer

V= Vian

In figure 1, the codes for each industrial complex have been shown below the sign of the complex.

4. Utilized methods and techniques:

4.1 Utilizing Delphi Process

The Delphi method has proven a popular tool in information systems (IS) research. Citing a lake of a definitive method for conducting the research and a lake of statistical support for the conclusion drown," Schmidt presented a step-wise methodology for conducting such study. Building on the framework that Schmidt developed, we offer two contributions towards increasing the value of Delphi studies in investigating research questions. First, we fill in many details in the context of Schmidt's framework by proving guidelines on how to conduct a rigorous Delphi study that identifies the most important issues of interest by soliciting qualified experts. Second, we demonstrate hoe to use a Delphi survey as a research tool to serve a variety of different purposes in the theorizing process.
Increasing the rigor will increase the confidence with which researchers can use the results in subsequent studies and a managers can make decisions based on information gathered using this method. Delphi

researchers employ this method primarily in cases where judgmental information in indispensable, and typically use a series of questionnaires interspersed with controlled opinion feedback. A key advantage of the approach is that it avoids direct confrontation of the experts (Okoli,Ch,et al., 2004).

In order to determine and identify parameters and criteria effective on selection of the best location for the WPPF, in addition to appliance of the final result of the researches completed in this field, experts opinions have been taken into account in this study by means of utilizing Delphi method**.**

In addition to the statistical information obtained from the Hamedan's Industries Organization (HIO), the experts whose comments were taken into account in this research include: University Professors, Diary producers, Diary Production Instruments inhibitors, Transportation companies, real state advisors of the concerned Industrial Complexes.

Practical application of Delphi technique in this study comprises the use of this method in determination, recognition and ranking of criteria and alternatives, with the mentioned procedure.

4.2 Application of Expert Choice Software to Facilitate the Calculations

Expert choice represented a significant contribution to the decision making process. It is useful for a decision maker in solving complex problems involving many criteria and several courses of action. An expert choice solution to problem reflects the expertise of the decision maker, not the computer. The software is easy to use and understand, as well as providing visual representations of overall ranking on a computer screen.

Expert choice does not make a choice for you in some mysterious way, or assume that the answer is hidden in the elegance of the underlying mathematics, but helps you to make an informed choice based on your knowledge, experience, and preference.

Expert choice enables decision makers to:

-Support executive decision

-Establish a forum for group decisions

-Manage/organize complexity

-Derive priorities and rank alternatives

-Measure consistency of judgments

-Incorporate quantitative information as well as knowledge, intuition and experience

-Justify the rationale for a decision

-Consider trade-offs among competing criteria

-Synthesize from the goal to determine the best alternatives

-Communicate the rationale for a decision to others

-Incorporate group judgments (http://www.Expertchoice.com).

5. Results

In this part, overall result of the experts answers has been analyzed and evaluated precisely so that the inconsistency ratio has a top of 0.04 (<0.1) which exhibits the precision of the gathered data, then it would be utilized as the primary input data for the Expert Choice software, in section one after defining the goal, the data has been input to software and the results have been shown in figures 3 to 11.

Figure 3-a: Compare the relative preference with respect to :GOAL

		1=EQUAL		3=MODERATE		5=STRONG		7=VERY STRONG		9=EXTREME									
1	LE	9	8	7	6	5	4	3	2	**1**	2	(3)	4	5	6	7	8	9	ICF
2	LE	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	(8)	9	COASF
3	LE	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	(7)	8	9	LOSCF
4	LE	9	8	7	6	5	4	3	2	**1**	2	3	4	5	(6)	7	8	9	T
5	ICF	9	8	7	6	5	4	3	2	**1**	2	3	4	5	(6)	7	8	9	COASF
6	ICF	9	8	7	6	5	4	3	2	**1**	2	3	4	(5)	6	7	8	9	LOSCF
7	ICF	9	8	7	6	5	4	3	2	**1**	2	3	(4)	5	6	7	8	9	T
8	COASF	9	8	7	6	5	4	3	(2)	**1**	2	3	4	5	6	7	8	9	LOSCF
9	COASF	9	8	7	6	5	4	(3)	2	**1**	2	3	4	5	6	7	8	9	T
10	LOSCF	9	8	7	6	5	4	3	(2)	**1**	2	3	4	5	6	7	8	9	T

Figure 3-b: Compare the relative preference with respect to :GOAL

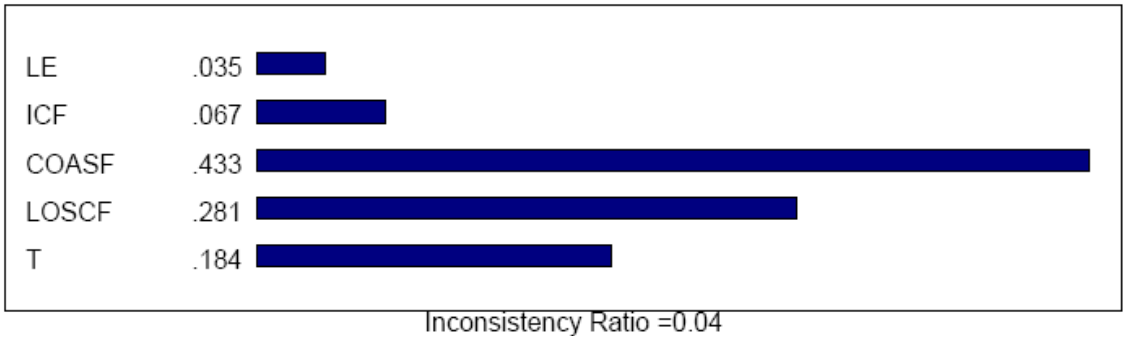


Figure4-a: Compare the relative preference with respect to :LE<GOAL

		1=EQUAL		3=MODERATE		5=STRONG		7=VERY STRONG		9=EXTREME									
1	N	9	8	7	6	5	4	(3)	2	**1**	2	3	4	5	6	7	8	9	CH
2	N	(9)	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	B
3	N	9	(8)	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	J
4	N	9	8	7	6	5	4	3	2	(1)	2	3	4	5	6	7	8	9	A
5	N	9	8	7	6	5	4	3	2	(1)	2	3	4	5	6	7	8	9	V
6	CH	9	8	(7)	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	B
7	CH	9	8	7	6	5	4	(3)	2	**1**	2	3	4	5	6	7	8	9	J
8	CH	9	8	7	6	5	4	3	2	**1**	2	(3)	4	5	6	7	8	9	A
9	CH	9	8	7	6	5	4	3	2	**1**	2	(3)	4	5	6	7	8	9	V
10	B	9	8	7	6	5	4	3	2	**1**	2	(3)	4	5	6	7	8	9	J
11	B	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	(8)	9	A
12	B	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	(9)	V
13	J	9	8	7	6	5	4	3	2	**1**	2	3	4	5	(6)	7	8	9	A
14	J	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	(7)	8	9	V
15	A	9	8	7	6	5	4	3	2	(1)	2	3	4	5	6	7	8	9	V

Figure 4-b: Compare the relative preference with respect to :LE<GOAL

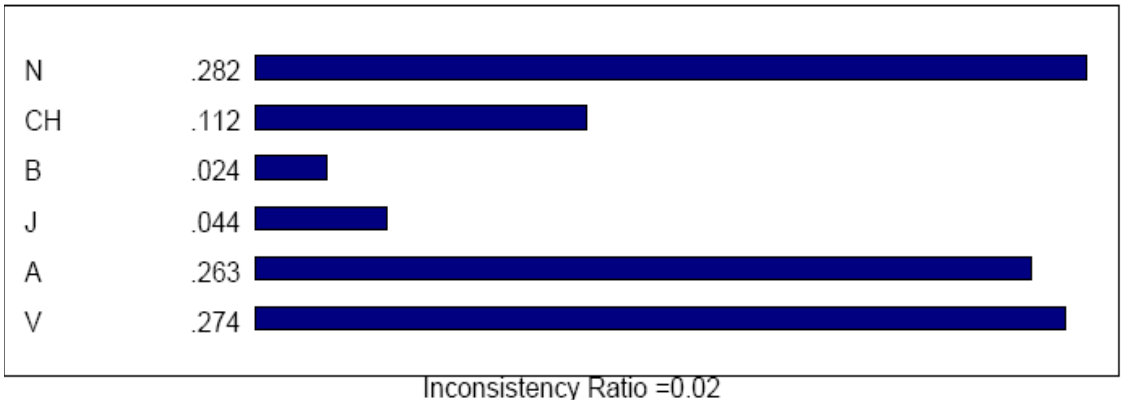


Figure 5-a: Compare the relative preference with respect to: ICF < GOAL

1=EQUAL 3=MODERATE 5=STRONG 7=VERY STRONG 9=EXTREME

1	N	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	CH
2	N	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	B
3	N	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	J
4	N	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	A
5	N	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	V
6	CH	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	B
7	CH	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	J
8	CH	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	A
9	CH	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	V
10	B	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	J
11	B	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	A
12	B	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	V
13	J	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	A
14	J	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	V
15	A	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	V

Figure 5-b: Compare the relative preference with respect to: ICF < GOAL

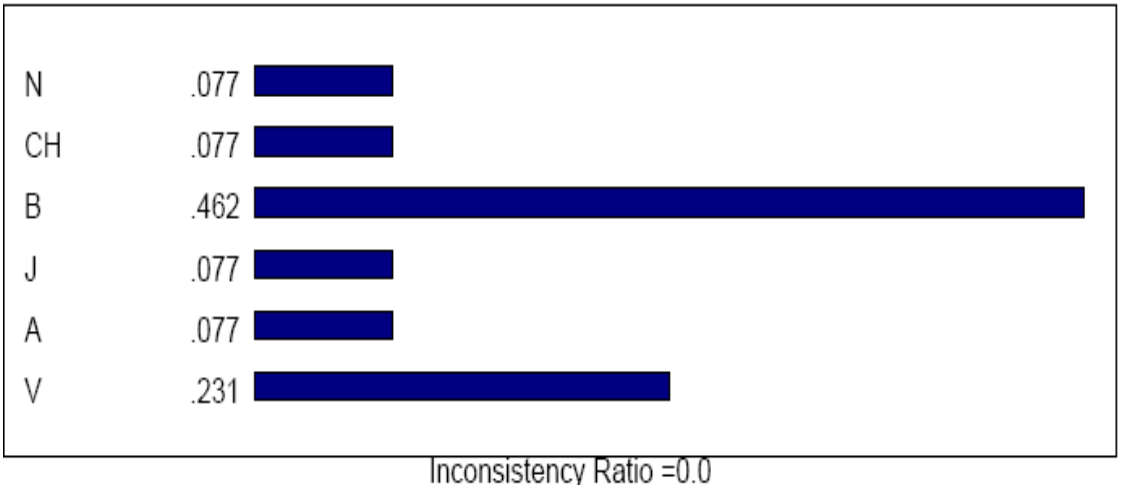


Figure 6-a: Compare the relative preference with respect to: COASF < COAL

C

		1=EQUAL		3=MODERATE		5=STRONG		7=VERY STRONG		9=EXTREME									
1	N	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	CH
2	N	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	B
3	N	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	J
4	N	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	A
5	N	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	V
6	CH	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	B
7	CH	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	J
8	CH	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	A
9	CH	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	V
10	B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	J
11	B	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	A
12	B	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	V
13	J	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	A
14	J	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	V
15	A	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	V

Figure 6-b: Compare the relative preference with respect to: COASF < COAL

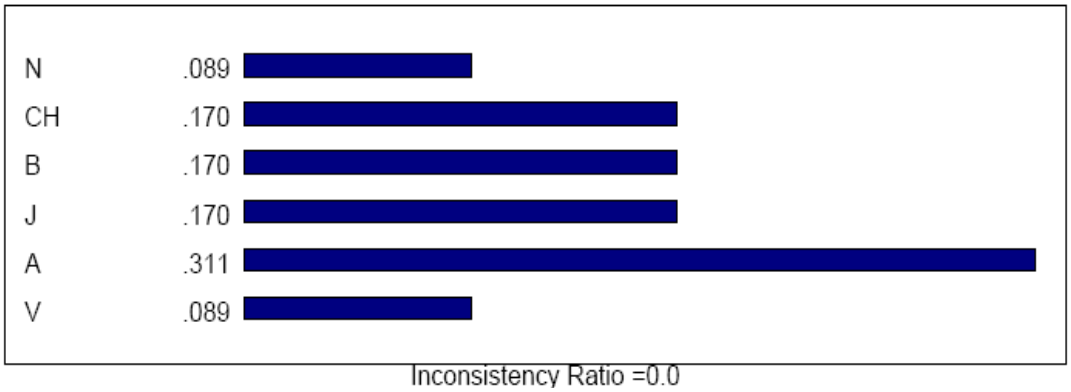


Figure 7-a: Compare the relative preference with respect to: LOSCF < GOAL

		1=EQUAL		3=MODERATE		5=STRONG		7=VERY STRONG		9=EXTREME									
1	N	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	CH
2	N	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	B
3	N	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	J
4	N	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	A
5	N	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	V
6	CH	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	B
7	CH	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	J
8	CH	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	A
9	CH	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	V
10	B	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	J
11	B	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	A
12	B	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	V
13	J	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	A
14	J	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	V
15	A	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	V

Figure 7-b: Compare the relative preference with respect to: LOSCF < GOAL

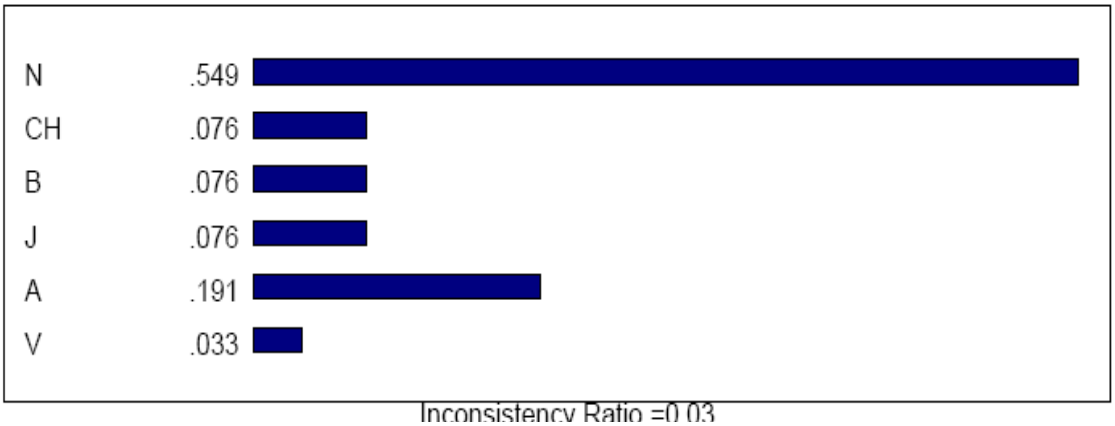


Figure 8-a: Compare the relative preference with respect to: T < GOAL

	1=EQUAL 3=MODERATE 5=STRONG 7=VERY STRONG 9=EXTREME																	
1	N	9	8	7	6	5	4	3	(2)	**1**	2	3	4	5	6	7	8	9	CH
2	N	9	8	7	6	5	4	3	(2)	**1**	2	3	4	5	6	7	8	9	B
3	N	9	8	7	6	5	4	3	(2)	**1**	2	3	4	5	6	7	8	9	J
4	N	9	8	7	6	(5)	4	3	2	**1**	2	3	4	5	6	7	8	9	A
5	N	9	8	7	6	5	4	3	(2)	**1**	2	3	4	5	6	7	8	9	V
6	CH	9	8	7	6	5	4	3	2	(1)	2	3	4	5	6	7	8	9	B
7	CH	9	8	7	6	5	4	3	2	(1)	2	3	4	5	6	7	8	9	J
8	CH	9	8	7	6	5	4	3	(2)	**1**	2	3	4	5	6	7	8	9	A
9	CH	9	8	7	6	5	4	3	2	(1)	2	3	4	5	6	7	8	9	V
10	B	9	8	7	6	5	4	3	2	(1)	2	3	4	5	6	7	8	9	J
11	B	9	8	7	6	5	4	3	(2)	**1**	2	3	4	5	6	7	8	9	A
12	B	9	8	7	6	5	4	3	2	(1)	2	3	4	5	6	7	8	9	V
13	J	9	8	7	6	5	4	3	(2)	**1**	2	3	4	5	6	7	8	9	A
14	J	9	8	7	6	5	4	3	2	(1)	2	3	4	5	6	7	8	9	V
15	A	9	8	7	6	5	4	3	2	**1**	2	(3)	4	5	6	7	8	9	V

Figure 8-b: Compare the relative preference with respect to: T < GOAL

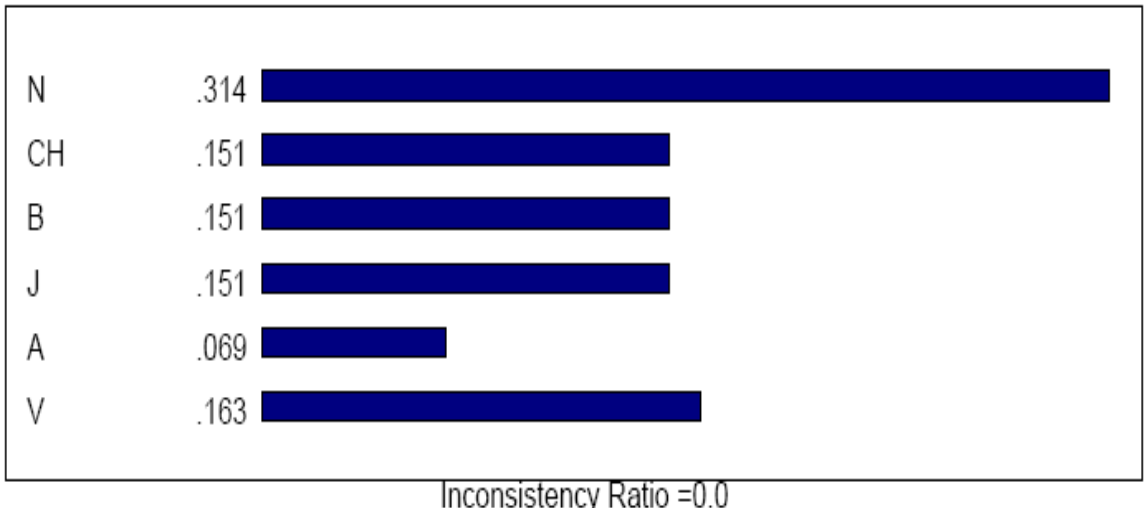


Figure 8-c: Synthesis of leaf nodes with respect to GOAL

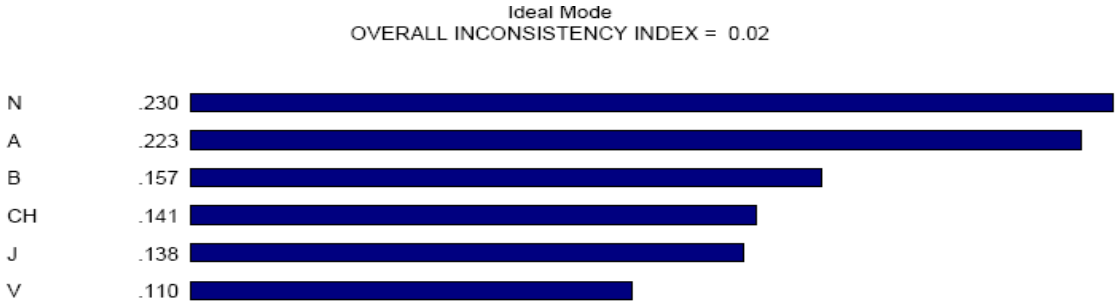


Figure 8-d: Dynamic sensitivity w.r.t GOAL for nodes below GOAL

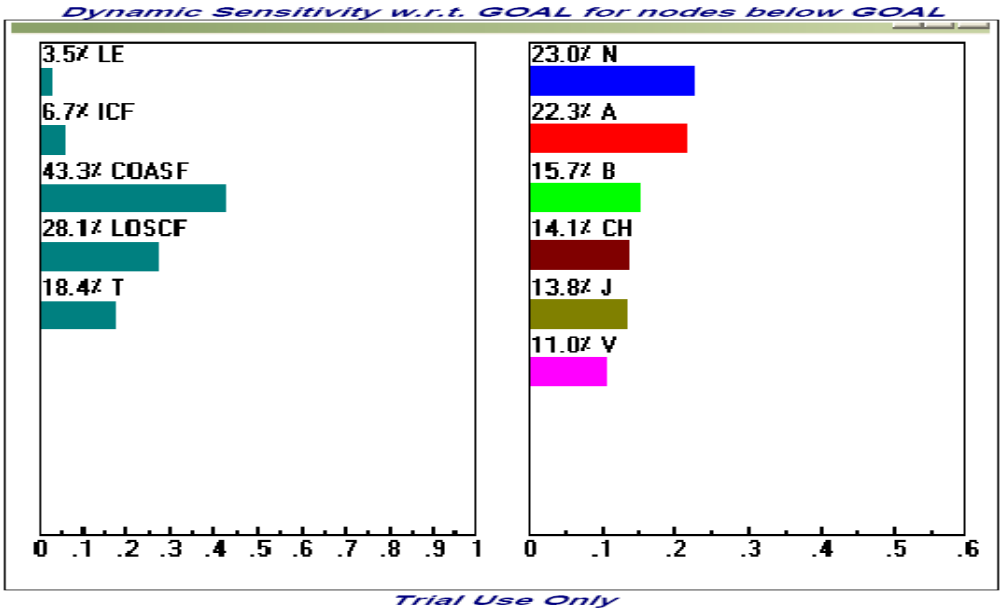
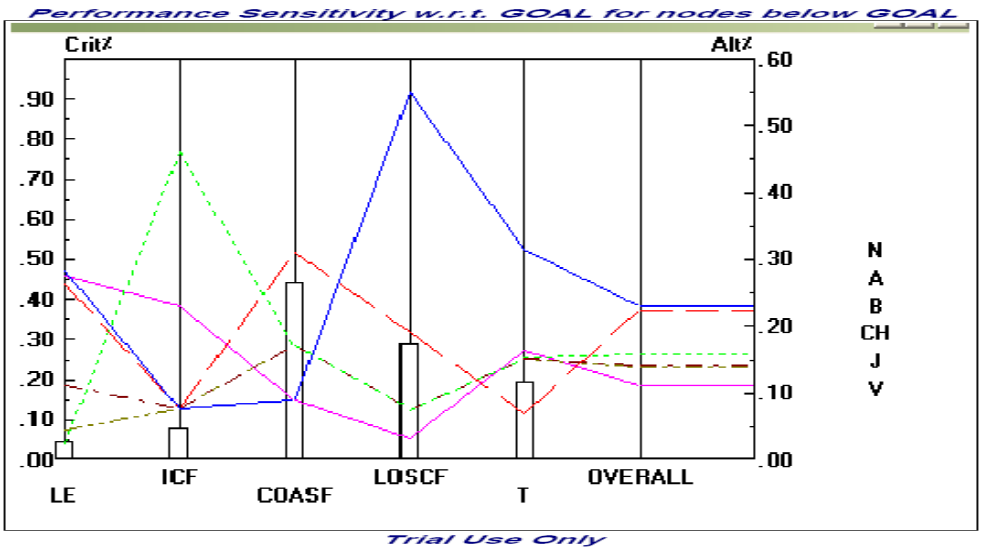


Figure 8-e: Performance sensitivity w.r.t GOAL for nodes below GOAL



By the end of the process, COASF has been identified as the best criteria, where LOCSF, ICF, T and LE have been introduced as the following ranks.

N has been identified as the most adequate location, where next priorities are A, B, CH, J and V.

6. Discussion

Sensitivity analysis is used to investigate the sensitivity of the alternatives to changes in the priorities of the criteria. As the land expenses is not exactly predictable and the facilities offered by various industrial complexes would be improved in future, it would be desirable to monitor the effects made by changes in the mentioned criteria's properties in order to identify the most suitable alternative in the certain future concerning the developments in progress in the region. In figures 12 and 13, the effects of certain changes in two of the criteria have been shown.

Figure 12-a: Performance sensitivity w.r.t GOAL for nodes below GOAL

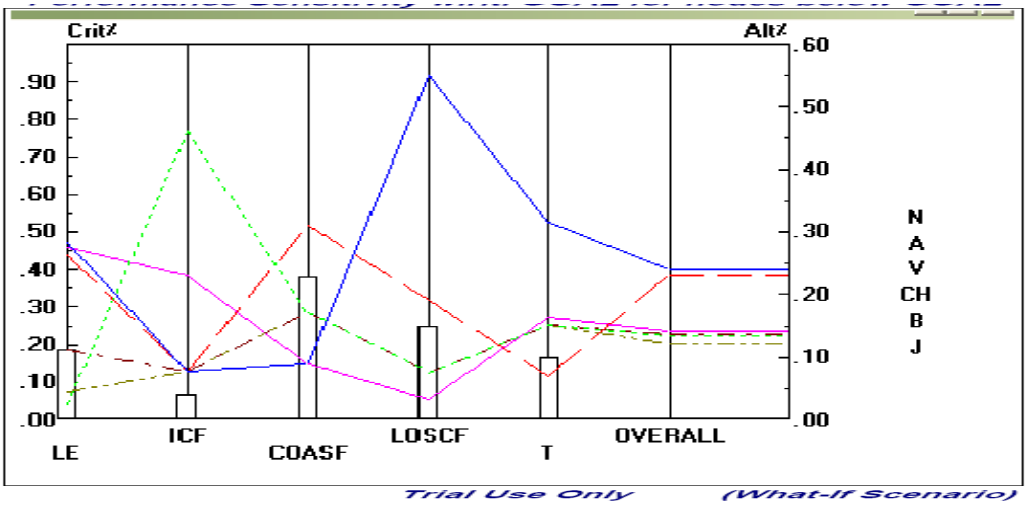


Figure 12-b: Dynamic sensitivity w.r.t GOAL for nodes below GOAL

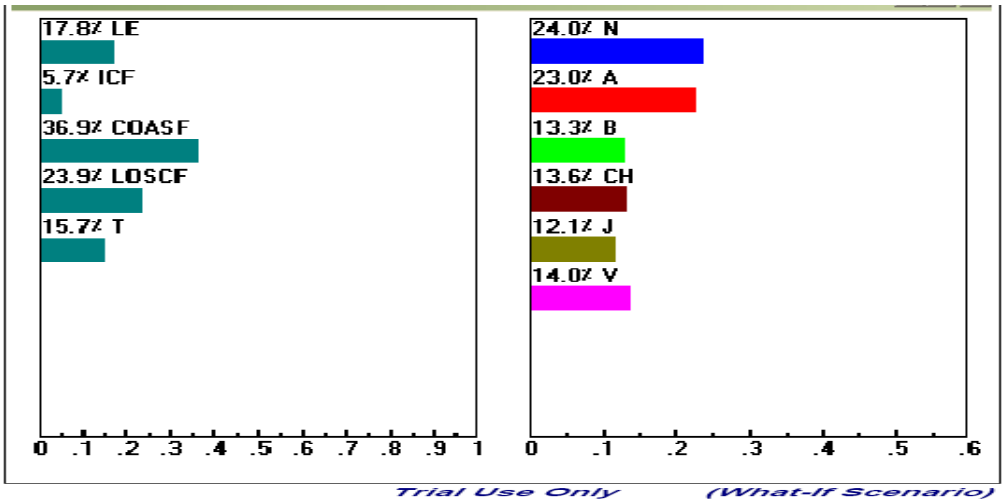


Figure 13-a: Performance sensitivity w.r.t GOAL for nodes below GOAL

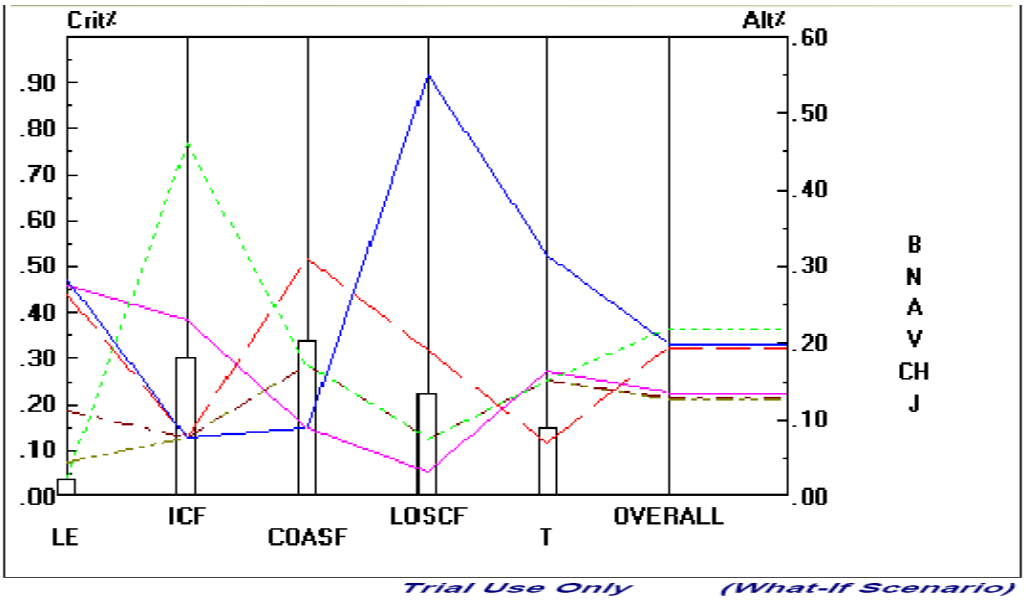
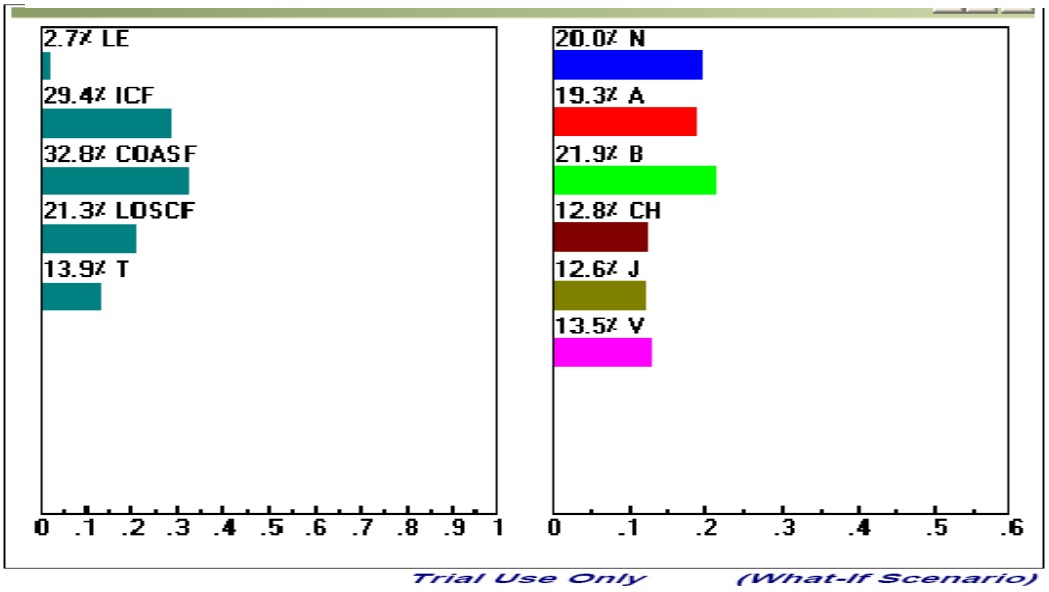


Figure 13-b: Dynamic sensitivity w.r.t GOAL for nodes below GOAL



7. Conclusion

Considering the significant value of the whey powder, lack of sufficient number of WPPFs in despite of the presence of numerous cheese production factories in western Iran, the increasing interests for

constructing WPPFs; considerable demand for an appropriate management in terms of optimum exploitation of recourses and available facilities is sensible more than ever. Thus determining the most adequate location, along defining the priority of other alternatives is of most importance.

Due to complicated nature of the problem and presence of various criteria, AHP method has been utilized for solving the problem where EC software has been used to facilitate the calculation process. After all, Nahavand industrial complex has been identified as the most adequate location for constructing WPPF.

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