Make-or-buy Decision Model Using Fuzzy-AHP Method for School Foodservice System

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Abstract

Recently a multi-attribute structure analysis method is one of the evident areas of important points in the decision support system analysis. This research developed an internet/intranet-based solution builder for a three-step decision support system using fuzzy-AHP in the view of 1) brainstorming for the idea generation, 2) fuzzy-AHP (fuzzy analytic hierarchy process) as a multi-attribute structured analysis method and 3) aggregation logic model to integrate the results of individual analysis. We applied this decision support system to the make-or-buy decision problem for school foodservice system considering the multi-attributes in the decision making. A computer program is developed and demonstrated in internet/intranet-based decision problem. It was known that this solution builder provides decision makers a good tool for make-or-buy group decision making.

Keywords : AHP, Decision Support System

1. Introduction

The purpose of this study is to develop an internet/intranet-based solution builder (Solution Builder 2004) for a three-step multi-attribute decision support system. A great deal of researches have been under taken on decision support systems to determine the proper alternatives for example, operations research, mathematical models and decision theory, while there are few researches to develop the solution builders for these decision support systems based on internet/intranet to include a group decisions. Recently, information network and decision technology are integrated in an effective decision support system to increase the decision efficiency. Most of the conventional concepts used in decision support systems do not seem to appropriate for modeling the kind of the internet/intranet based characteristics. This paper is concerned with development of a solution builder for decision support system and its software for the multi-attribute structured decision problems. In this research, we developed an integrated decision support system based on tools; decision analysis methods, internet/intranet and computer system as shown in Figure 1.

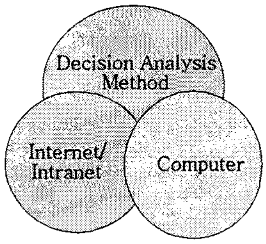
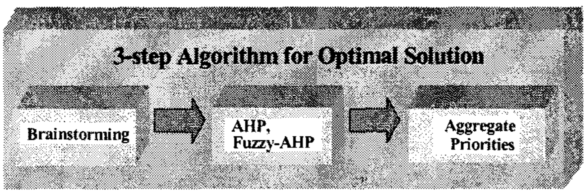


Figure 1. Decision Support Tools

We used a two-step approach : 1) in step 1, we construct decision alternatives and implemented the individual analysis using AHP(analytic hierarchy process) and fuzzy set ranking methodologies to overcome the special decision problems; those of multi-objective, multi-criterion, and multi-attribute, and 2) in step 2, we integrated the evaluation results of individual evaluations by reviewers. In this research, we developed and demonstrated a methodology for the decision makers to guide an internet/intranet based decision support system using its computer programs.

These programs transform several individual multi-criteria rank-ordered lists of decision alternatives into one aggregated and prioritized rank-ordered list. Also a literature survey about the majority-rule method (MRM), a fuzzy set priority method was performed and these methods were known to be applicable to the aggregation of multiple



criteria rank-ordered

Figure 2. Three-step Approach of Decision Problem

ordinal priority. Figure 2 shows this three-step approach of decision support system. We compared the results with other developed software which is Criteria DecisionPlus v2.0 using the same example and show the sample output.

2. Properties of Make-or-Buy Decision Problem

The make-or-buy decision problem also is known as "sourcing", "outsourcing", or "subcontracting" decisions and it will affect all the decision problems in many areas. In any business organization, every time a purchase order is made out something is being purchased. Behind each purchase order, there is a decision to buy and not to make, and behind each production order is a decision to make and not to buy. It is important to note that the make-or-buy decision problem in this study has several properties which are implemented using several analytical tools. Special attention will be directed towards reviewing those analytical tools and quantitative methods designed to assist practicing managers confronted with a make-or-buy decision problems. Furthermore, a number of questions will be addressed so as to understand some of the properties and issues responsible for differentiating one type of make-or-buy decision problem from another. These questions may be :

- What backgrounds trigger a make-or-buy decision problem?
- What factors could be considered in make-or-buy decision problem ?
- Along which dimensions should make-or-buy decision problem be categorized ?

The factors that can be influence any make-or-buy decision problem can be classified in five broad areas as Table 1.

Table 1 Major factors Influencing make-or-buy decision problem(by literatures)

Performance Measure Criteria	Examples of measurement Parameters
• Cost	- Total unit cost
• Quality	- Internal failure cost-scrap, rework, rejected - Delivery lead time
• Delivery speed	- delivery lead time
• Delivery reliability	- Percentage of on-time delivery
• Volume flexibility	- Average volume fluctuation
• Product flexibility	- Number of component substitutions made over a given time period.

Drtina (1994) has illustrated how the sourcing problem can be extended to the primary activities of the value chain.

Table 2. Example of performance Evaluation of Make-or-buy decision problem

Item	Major Factors
Manufacturin g Technology	- Importance of technology for competitive advantage - Maturity of technology - Technology uncertainty - Probability of future improvements
Out Source Risk	- Appropriation risk - Technology diffusion - End-product degradation - Benchmarking
Managerial Issues	- Workforce stability - Complexity level in planning, control, or supervision - Assurance and reliability of supply - Benchmarking
Financial Issues	- Cost - Investment - Return on investment
Operational Issues	- Manufacturing capability - Quality - Lead time - Volume uncertainty

We believe that Drtina's general approach correctly defines the scope of the problem and represents a useful guide for most sourcing analyses of value chain activities. The range of sourcing structure found in the industry can be considered by the methodology are shown in Figure 3 (Ellrang (1991), Quinn(1994)). For the performance assessment of make-or-buy decision problem, we recommended the use of the parameters by Leong, Snyder, & Ward (1990) as shown in Table 2.

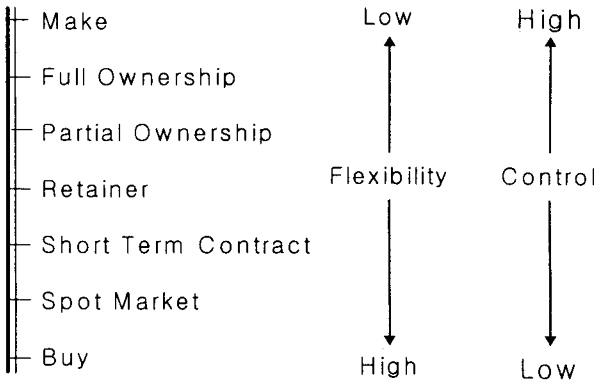
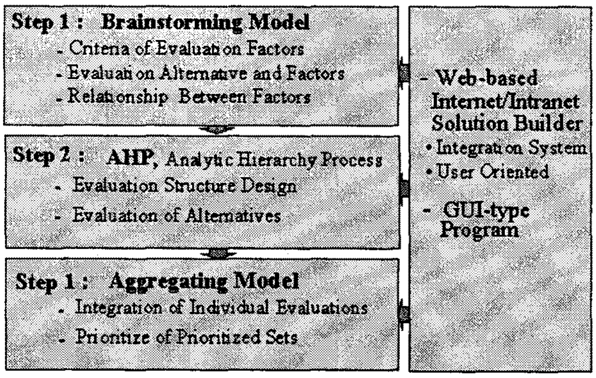


Figure 3>Range of Source Structure of Make-or-buy Decision Problem

3. Three-step Approach of Decision Alternative Analysis

In this study, we developed a solution builder using GUI-type simulation software, Solution Builder-2001 as shown in Figure 4. In the first step, to create the ideas to drive out alternatives from a group reviewers, we used brainstorming method based on internet/intranet, and in the second step, we used Fuzzy-AHP method to evaluate the decision alternatives and determined the preferred alternative. In the last step, we integrated the results of individual evaluations into one ranked order. We developed two heuristic methods based on majority

Figure 4. 3-step approach of Decision Support System of Solution Builder-2001



rule methods. Figure 4 shows a schematic structure of three-step approach of decision support system. It was known that the proposed solution builder can be used as a decision support tool for project evaluation, personal or public project evaluation based on internet/intranet network.

3.1 Brainstorming

The alternative evaluation and its method can be determined based on the system attributes and experiences of evaluators. The GUI-type program of Solution Builder-2004 consisted of main-program and brainstorming subroutine. Computational experiments are performed to a set of sample systems and show the performance and effectiveness of the proposed model. For the model structure and alternatives include the group decision ideas, and to create the ideas of alternatives for decision support system analysis of various groups, we used a brainstorming method. We developed a GUI-type program for users to use this method in network-based environment without any problems. Figure 5 shows a sample output of alternative generation and construct the decision structure of an example of school food selection with 3-echelon structure and 3 alternatives.

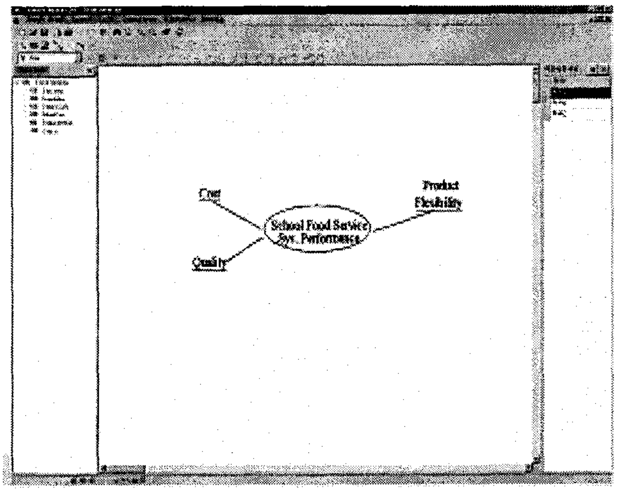


Figure 5. Sample out put of brain storming

The decision structure and its method may be determined based on the system attributes and experiences of evaluators. To construct the decision structure and alternatives and to include the group decision ideas, we used a brainstorming.

3.2 Fuzzy-AHP Method

The theory of fuzzy sets has extended traditional mathematical decision theories so that they can cope well with any vagueness problem which cannot adequately be treated by probability distributions. The impacts and the relationships among the characteristics in any decision problems can sometimes be described only by vague verbal descriptions. The concepts and rules of fuzzy decision making provide us with the necessary tools for structuring a decision from a kind of information. The model used in this study had a limited capability in studying the fuzzy set priority that could be obtained from the summed frequency matrix of Shannon(1986) method. The fuzzy priority is computed and compared with the rank order of Shannon method. The fundamental concept of fuzzy set priority relation R was derived from the result obtained by Shannon method.

From the Shannon's summed frequency matrix for complementary cells, A_{ij} and A_{ji}, an additional fuzzy set matrix was made by considering

A_{ij} = 1 - A_{ji} for all cells. The fuzzy matrix complement cell values sum to 1 and fuzzy set difference matrix is defined as follows :

$R - R^T =$ U(A,B)-U(B, A), if U(A, B)>U(B, A),
= 0 otherwise

where, for U(A, B) quantifies, A is preferable to B.

To obtain fuzzy preferences, the following five steps were considered:

Step 1: Find the summed frequency matrix (using Shannon method)

Step 2: Find the fuzzy set matrix R which is the summed frequency matrix divided by the total number of evaluators

Step 3: Find the difference matrix

$R - R^T$ = U(A, B)-U(B, A), if U(A, B) > U(B, A),
= 0 otherwise

where, for U(A,B) quantifies, A is preferable to B.

Step 4: Determine the portion of each project that is not dominated as follows:

$$A_{ColA}^{ND} = 1 - \max(X_{1.ColA}, X_{2.ColA}, \cdots, X_{n.ColA})$$

Step 5: The priority of the fuzzy set is then the rank order of XND values with a decreasing order.

An example is shown as follows :

$$R = \begin{bmatrix} 0.0 & 0.8 & 0.6 & 0.0 \\ 0.2 & 0.0 & 0.0 & 0.4 \\ 0.4 & 0.1 & 0.0 & 0.4 \\ 0.4 & 0.6 & 0.6 & 0.0 \end{bmatrix}$$

$$R^T = \begin{bmatrix} 0.0 & 0.2 & 0.4 & 0.4 \\ 0.8 & 0.0 & 0.1 & 0.6 \\ 0.6 & 0.0 & 0.0 & 0.6 \\ 0.6 & 0.4 & 0.4 & 0.0 \end{bmatrix}$$

$$R - R^T = \begin{bmatrix} 0.0 & 0.6 & 0.2 & 0.2 \\ 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.1 & 0.0 & 0.0 \\ 0.0 & 0.2 & 0.2 & 0.0 \end{bmatrix}$$

X_A^{ND} = 1 - Max(0.0) = 1 - 0.0 = 1.0

X_B^{ND} = 1 - Max(1.0) = 1 - 1.0 = 0.0

X_C^{ND} = 1 - Max(0.2) = 1 - 0.2 = 0.8

X_D^{ND} = 1 - Max(0.2) = 1 - 0.2 = 0.8

Thus, the fuzzy set priority score is given by 1.0 > 0.0 > 0.8 > 0.8 and the alternative priority is given by A > C > D > B.

3.3 Integration of Individual Evaluation

For the integration of the results of individual evaluations, and prioritized sets, we used two heuristic models which are a kind of majority-rule methods. These methods were compared to determine the most preferred one for the decision support system purpose.

1) *Heuristic 1*

In this method the preference score is given by the sum of the marks received from the evaluators, where for m alternatives, the marks are given, in decreasing order preference, (m-1), (m-2), ..., 0. The ranking was based on the scores of each alternatives. In this case, the highest score will be the first priority.

Table 3. Example Result of Heuristic Method 1

Alt.	Preference Matrix	Raw Sum	Weighed Value
School A	0.0 1.0 1.0	2.0	0.133
School B	4.0 0.0 2.0	6.0	0.400
School C	4.0 3.0 0.0	7.0	0.467
Heuristic Method 1 Rank Order	C > B > A		

For example of the Heuristic Method 1, a sample result with N = 5 evaluators and M = 3 alternatives are given as:

Evaluator 1: B > A > C,

Evaluator 2: B > C > A

Evaluator 3: C > A > B,

Evaluator 4: C > B > A

Evaluator 5: C > B > A

The value of each cell of basic evaluation score matrix is given by one if the raw alternative wins against the column alternative, otherwise given by 0. In the summed frequency matrix, the weighted value of the raw sum is the basis of rank order, thus the Heuristic Method 1 rank order is given by , C(0.467) > B(0.400) > A(0.133).

2) *Heuristic 2*

In this method, the evaluator frequency matrices were added to form a summed frequency matrix where a count was made for each alternative of the number of times it was preferred to each of the other alternatives. Then, the preference matrix was developed by a comparison of the scores in the component cells (A, B versus B, A). If the A, B value equals B, A, then each component cell in the matrix is given by "1/2". On the other hand if the A, B value is greater than the B, A, then A, B is given by "1" and B, A cell of the preference matrix is given by 0. The alternatives were ranked by the order of their preference matrix row sums and also we used fuzzy set priority method which is a kind of majority-rule methods. By applying the Heuristic Model 2 to the same example of Heuristic Method 1, the result is given by C(0.450) > A(0.392) > B(0.158).

3) Fuzzy Set Priority Method

The theory of fuzzy sets has extended traditional mathematical decision theories so that they can cope with the kind of vagueness which cannot adequately be represented by probability distributions. The model for this study had a limited capability to study the fuzzy set priority that could be obtained from the summed frequency matrix of Heuristic Model 2. The fundamental concept of fuzzy set priority relation R was derived from result by heuristic model 2. From the summed frequency matrix for complementary cells, A_{ij} and A_{ji} an additional fuzzy set matrix was made by considering

$A_{ij} = 1 - A_{ji}$ for all cells. The fuzzy matrix complement cell values sum to 1.

By applying the Fuzzy Set Priority Model to the same example of Heuristic Method, the result is given by A(0.38) > C(0.31) > B(0.01).

4) Computer Program Development

We developed the computer program using C-language through the use of the module based tool and applied to a set of example problems of multi-structured decision support system. The computer model for this research emphasized the flexibility of programming options as well as future operational flexibilities for the improvement. The schematic flow diagram of the model is shown in Figure 6. The flexibility of the model encompasses the wide variety of areas to provide the methodology and tools to permit exploration research in such areas as fuzzy set priority, preference scoring constants, and comparative aggregation methodologies. Table 3 presents the comparison of sample runs between two heuristic and fuzzy set priority methods. We applied this model to a set of examples of multi-structured decision support system as shown in Figure 6.

First, we determined the weighted values by eigenvectors of AHP and also by fuzzy set priority method.

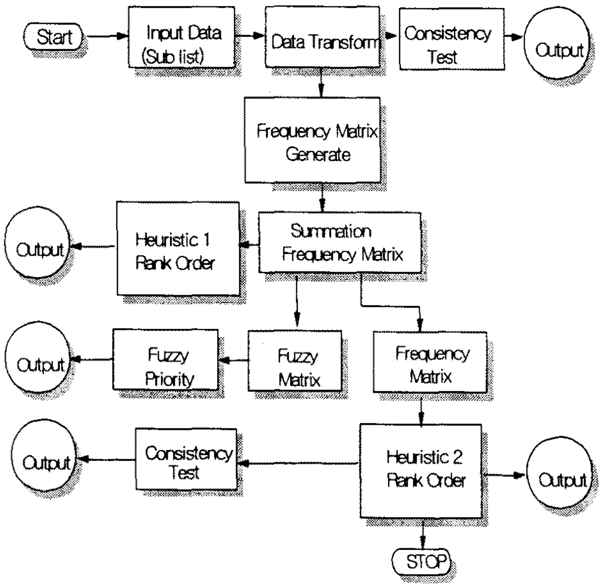


Figure 6. Schematic Flow Diagram of the Proposed Model

4. Model Application to School Food Service System

An example problem presented in this study is a new school food service problem for the purpose of illustration of this model. We applied this model to a sample problem of school food service system where we have to decide whether we have the system outsourcing or by making. To decide the evaluation actors and service alternatives, In step 1, we used the brainstorming process and we converted this into AHP-evaluation structure. In step 2, using the heuristics and fuzzy-AHP method, we find the eigen value by pair-wise comparison matrix. This evaluation was done by 4 evaluation members and in step 3 the results were integrated by two heuristic and fuzzy set priority methods. Following tables and figures are the sample outputs of this problem.

1) Brainstorming Module : Step 1

Figure 7 shows a sample out of school foodservice system with 3-echelon decision structure.

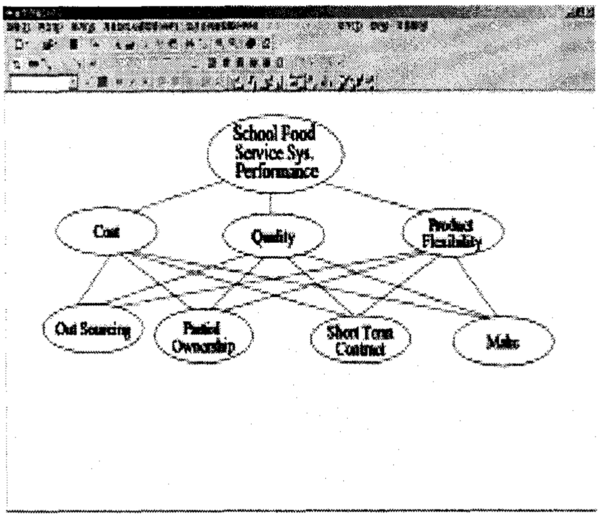


Figure 7. Sample Output of Brainstorming

2) Evaluation of Alternatives : Step 2

Figure 8, 9 and 10 show a sample output of alternative evaluation, construct the decision structure and the sample result of a reviewer. The final result of example is given by :

C1(0.38) > C2(0.27) > C3(0.21)> C3(0.14).

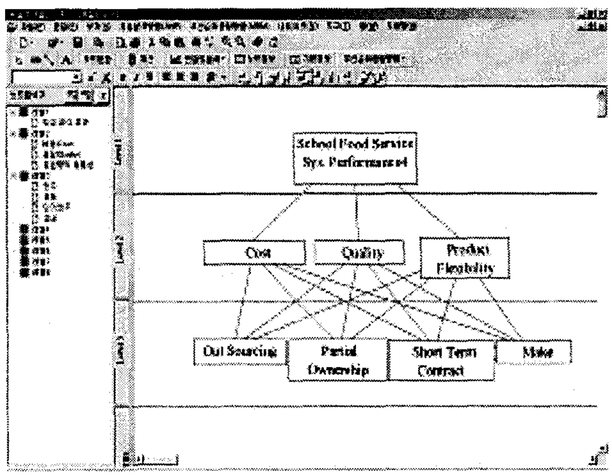


Figure 8. Ample Output of AHP Structure Diagram

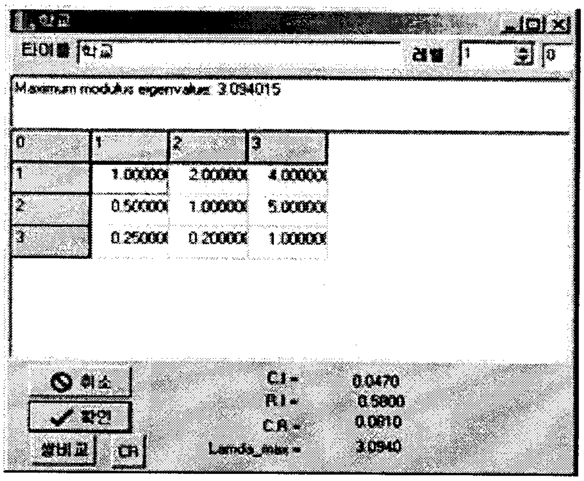


Figure 9. Sample Output of Pair-wise Comparison

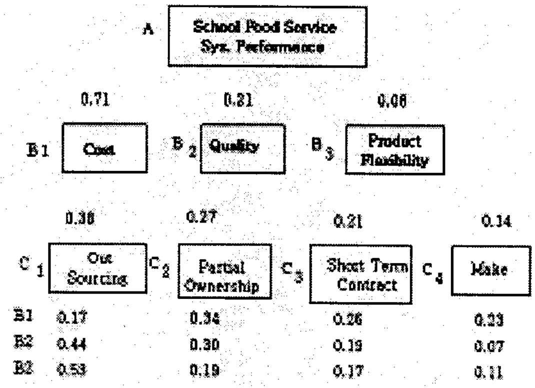


Figure 10. Sample Output of Evaluation by Level

Table 4 shows sample output of pair-wise comparison of matrix of example problem in each node.

3) Integration of Evaluations Results: Step 3

In this step, we integrated the results of the reviewers by the majority rule. The individual results of 4 reviewers are given by:

Reviewer 1: C1 > C3 > C2 > C4

Reviewer 2: C2 > C1 > C3 > C4

Reviewer 3: C2 > C1 > C3 > C4

Reviewer 4: C1 > C2 > C4 > C3

Using the Heuristic 1, Heuristic 2 and Fuzzy Set Ranking methods, we integrated the results of these reviewers as following

Table 4. Sample Output of Pair-wise Matrix

A	B1	B2	B3	Eigen Val.	
B1	1.00	2.00	4.00	0.71	λ_{max}=3.09
B2	0.50	1.00	5.00	0.21	CI=0.0815
B3	0.25	0.20	1.00	0.08	CR=0.14

B1	C1	C2	C3	C4	Eigen Val	
C1	1.00	0.33	0.50	0.50	0.17	
C2	3.00	1.00	1.00	2.00	0.34	λ_{max}=5.760
C3	2.00	1.00	1.00	1.00	0.26	CI=0.190
C4	2.00	0.50	1.00	1.00	0.23	CR=0.170

B2	C1	C2	C3	C4	Eigen Val	
C1	1.00	2.00	4.00	5.00	0.44	
C2	0.50	1.00	3.00	7.00	0.30	λ_{max}=5.107
C3	0.25	0.33	1.00	5.00	0.19	CI=0.0275
C4	0.20	0.14	0.20	1.00	0.07	CR=0.024

B3	C1	C2	C3	C4	Eigen Val	
C1	1.00	3.00	9.00	4.00	0.53	
C2	0.33	1.00	1.00	1.00	0.19	λ_{max}=5.760
C3	0.11	1.00	1.00	3.00	0.17	CI=0.190
C4	0.25	1.00	0.33	1.00	0.11	CR=0.170

Table 5. Results of Integrated Priority

Majority Rule used	Priority by Alternative
1. Heuristic model 1	C2 > C1> C3 > C4
2. Heuristic model 2	C1 > C2> C4 > C3
3. Fuzzy Set Ranking Method	C1 > C2> C3 > C4

In this example, we could conclude the best food supply method is the alternative C!(Outsourcing).

5. Summary and Conclusions

We developed a three-step approach based on web-based make-or-buy decision model for multi-structured decision support systems in the view of multi-attribute evaluation. Those steps are : 1) brainstorming to define the alternatives and performance evaluation factors, 2) individual evaluation the alternatives using fuzzy-AHP, heuristic and fuzzy set reasoning methods, and 3) integration the individual evaluations using majority rule method. Finally, for a simple and efficient computation, we developed a systematic and practical program to calculate all the algorithms. The model was applied to a school food service system problem by comparative computations for various multi-structured decision support examples. By the sample results of both AHP and fuzzy set reasoning method, it is known that the proposed model is a good method for the performance evaluation of multi-attribute and multiple goals.

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