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The analytic network processes method & fuzzy cognitive map method in decision making: a comparative study

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Abstracts: Decision making problems always puzzled managers and decision makers in enterprises or organizations. There are many useful soft operation research methods could solve the complicated problem. The paper raises two classic approaches ANP (Analytical network process) and FCM (Fuzzy cognitive map). Those two methods have some similarities and differences. In thus, according to different decision problems, people could compare the two approaches' characteristics and choose the best tool to deal with the problems. At the end of the paper, a case study has been given for us.

Keywords: ANP, FCM, Decision making

1. INTRODUCTION

Nowadays many managers or decision maker always face the challenging situation of selecting the right solution for a given decision making problem. In order to handle multiple, convicting values, a class of methodologies has developed over the last 60 years called problem structuring methods (PSM), or soft operational research (OR) methods. These methods are characterized as a family of approaches for supporting decisions by groups of a diverse composition within a complex environment to agree a problem focus and make commitments to a series of actions. They are usually applied to unstructured problems or ill-structured problems characterized by multiple actors, multiple perspectives, conflicting interests, and high levels of uncertainty and can often involve models as transitional objects to aid the decision-making process [1].

A scientific decision making process can be recognized by Figure 1[2] .

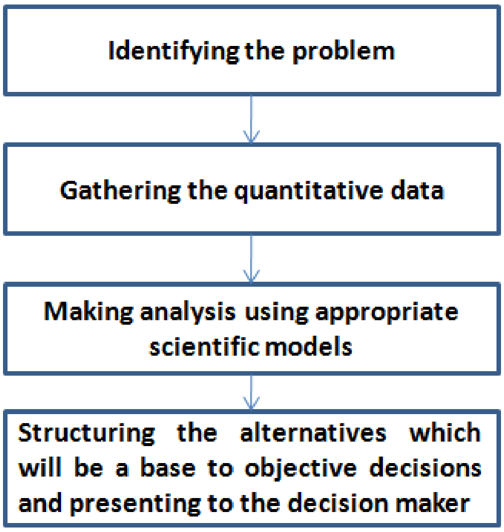

Figure 1. Decision making process

Almost all the decision making methods accept the process above. For example, ANP and FCM are helping tools to make future plans or solve the complicated problems by using qualitative or quantitative data. They all belongs to soft operation research methods and have some similarities and differences. Past studies on the soft operation research methods have concentrated upon particular implementations of these methods; few investigations compare the two soft operation research methods for people to know them well. In hence, in this research, comparison between the two decision making models, Analytical Network Process (ANP) and cognitive map, are introduced.

This paper can be used by academics as a foundation for further research and development in the area of decision making models. Managers can use this paper for choosing the right decision making method in business decision situations. This paper is structured in five sections. Section2 presents briefly the ANP method; section 3 introduces the FCM theory; section4 describes the similarities and differences of ANP and FCM; then, in section5, the paper use a case study to analyze the final results from these two decision making methodologies, Finally, the main conclusions are exposed.

2 ANP

2.1 Foundations

ANP is one of the most important methods of multicriteria decision aid; (also named MCDA) the multicriteria decision aid method could scientifically select the best decision or optimization under situations characterized for having more than one criterion.

ANP is firstly introduced by Saaty, In 1980, he create the AHP (Analytic Hierarchy Process) method in his book named ‘‘The Analytic Hierarchy Process’’, After that, Thomas L. Saaty developed this issue in his published book named ‘‘The Analytic Network Process’’.

AHP and ANP are both the appropriate methods for solving the decision and evaluation problems, but there are something different. Saaty suggested the usage of AHP to solve the problem of independence on alternatives or criteria and the usage of ANP to solve the problem of dependence among alternatives or criteria[3].

ANP provides a general framework to deal with decisions without making assumptions about the independence of higher-level elements from lower level elements and about the independence of the elements within a level. In fact ANP uses a network without the need to specify levels as in a hierarchy [4], which could deal with more complicated problems than AHP.

2.2 ANP

The ANP is composed of four major steps [5]:

Step 1: Model construction and problem structuring: The problem should be stated clearly and be decomposed into a rational system, like a network. This network structure can be obtained by decision-makers through brainstorming or other appropriate methods.

Step 2: Pairwise comparison matrices and priority vectors. In this step alternatives are determined. Selecting the alternatives from the successful ones in their field of activity by using the preliminary elimination will increase the quality of the decision. And the elements are determined.Decision-makers are asked to respond to a series of pairwise comparisons of two elements or two clusters interactions between and within clusters and to be evaluated in terms of their contribution to their particular upper level criteria[6].

In addition, interdependencies among elements of a cluster must also be examined pairwise; the influence of each element on other elements can be represented by an eigenvector. The relative importance values are determined with Saaty’s 1–9 scale, where a score of 1 represents equal importance between the two elements and a score of 9 indicates the extreme importance of one element (row cluster in the matrix) compared to the other one (column cluster in the matrix) [7].

A reciprocal value is assigned to the inverse comparison Like with AHP, pairwise comparison in ANP is performed in the framework of a matrix, and a local priority vector can be derived as an estimate of the relative importance associated with the elements (or clusters) being compared by solving the following equation:

Step 3: Supermatrix formation:

To obtain global priorities in a system with interdependent influences, the local priority vectors are entered in the appropriate columns of a matrix. As a result, a supermatrix is actually a partitioned matrix, where each matrix segment represents a relationship between clusters in a system.

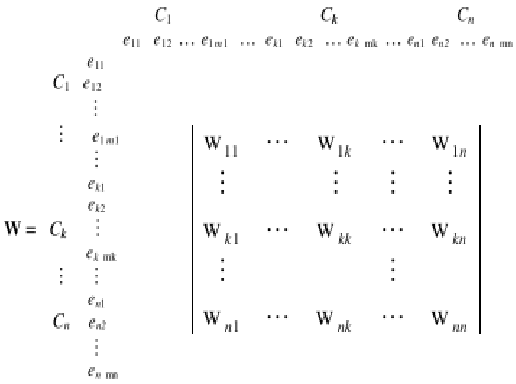

Figure 2. A standard form for a supermatrix

Generally in this step the supermatrix will be an unweighted one. Because in each column it consists of several eigenvectors which of them sums to one (in a column of a stochastic) and hence the entire column of the matrix may sum to an integer greater than one. The supermatrix needs to be stochastic to derive meaningful limiting priorities. So for this reason to get the weighted supermatrix.

firstly the influence of the clusters on each cluster with respect to the control criterion is determined. This yields an eigenvector of influence of the clusters on each cluster. Then the unweighted supermatrix is multiplied by the priority weights from the clusters, which yields the weighted supermatrix.

The limit supermatrix has the same form as the weighted supermatrix, but all the columns of the limit supermatrix are the same.

The final priorities of all elements in the matrix can be obtained by normalizing each cluster of this supermatrix. Additionally, the final priorities can be calculated using matrix operations, especially where the number of elements in the model is relatively few. Matrix operations are used in order to easily convey the steps of the methodology and how the dependencies are worked out.

Step 4: Selection of the best alternatives: If the supermatrix formed in Step 3 covers the whole network, the priority weights of the alternatives can be found in the column of alternatives in the normalized supermatrix. On the other hand, if a supermatrix only comprises clusters that are interrelated, additional calculations must be made to obtain the overall priorities of the alternatives. The alternative with the largest overall priority should be selected, as it is the best alternative as determined by the calculations made using matrix operations.

3. FCM

FCM is short from fuzzy cognitive map, is a strategic options development and analysis (SODA) methodology which is a framework for designing problem solving interventions. SODA is one of a number of approaches developed in the soft operational research community over past 30 years to assist strategic decision-making. The origins of SODA lie within cognitive psychology. [8][9]

The fuzzy cognitive map which was stated by Kosko[10] in1986 is an intelligent modeling methodology for complex decision systems, which originated from the combination of Fuzzy logic[11]. And Neural Networks [12]. Compared with other soft operational research techniques, the fuzzy cognitive map is perceived primarily as a facilitative device. FCMs is the signed directed graphs for representing causal reasoning and computational inference processing. FCMs exploit a symbolic representation for the description and modeling of a system [13].

Concepts are utilized to represent different aspects of the system, as well as, their behavior. The dynamics of the system are simulated by the interaction of concepts. FCMs are used to represent both qualitative and quantitative data. The construction of an FCM requires the input of human experience and knowledge on the system under consideration. Thus, FCMs integrate the accumulated experience and knowledge concerning the underlying causal relationships amongst factors, characteristics, and components that constitute the system.

An FCM consists of nodes-concepts, Ci , i = 1, ..., N, Where N is the total number of concepts. Each node–concept represents one of the key factors of the system and it is characterized by a value Ai, i = 1, ..., N.

The concepts are interconnected through weighted arcs, which imply the relations among them. Each interconnection between two concepts, C_i and C_j, has a weight, W_{ij}, which is analogous to the strength of the causal link between C_i and C_j. The sign of W_{ij} indicates whether the relation between the two concepts is direct or inverse. The direction of causality indicates whether the concept C_i causes the concept C_j or vice versa. Thus, there are three types of weights,

$W_{ij} > 0$, expresses positive causality,

$W_{ij} < 0$, expresses negative causality,

$W_{ij} = 0$, expresses no relation.

Human knowledge and experience on the system determines the type and number of nodes, as well as the initial weights of the FCM. The value, A_i, of a concept, C_i, expresses the quantity of its corresponding physical value and it is derived by the transformation of the fuzzy values assigned by the experts to numerical values. Having assigned values to the concepts and weights, the FCM converges to a steady state through the interaction process subsequently described.

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$$A_i(k+1) = f\left(A_i(k) + \sum_{\substack{j=1 \\ j\neq i}}^{n} W_{ji} A_j(k)\right) \tag{1}$$

where k stands for the iteration counter;

and W_{ij} is the weight of the arc connecting concept C_j to concept C_i . The function f is the sigmoid function,

$$f(x) = \frac{1}{1+e^{1\lambda x}} \tag{2}$$

where λ > 0 is a parameter that determines its steepness in the area around zero. This concepts would be represented the network graph by FCM and ANP. Some people said “the area around zero. This function is chosen since the values Ai of the concepts, by definition, must lie within [0, 1]. The interaction of the FCM results in a steady state after a few iterations, i.e., the values of the concepts are not modified further. Desired values of the output concepts of the FCM guarantee the proper operation of the simulated system.

4 COMPARISONS OF THE ANP AND FCM

ANP and FCM are both software operational research methods which could solve the complicated problems; they have some similarities and differences. The comparison of these two approaches would be analyzed as following.

4.1 The similarities between ANP and FCM

(1) Both two methods are used for decision makers to have a future plan or solve problems. These approaches can solve the problems about optimization, and goal programming.

(2) They are all software operational research methods and could mix quantitative and qualitative factors into a decision. They all could get the results from analyzing people's dialog data or unstructured data. People often collect data by brainstorming method, questionnaire and sample- learning.

(3) ANP and FCM are both helping improve management understanding and transparency of the modeling technique. People's thinking process of choosing concepts and the relationship between concepts would be represented the network graph by FCM and ANP. Some people said "the ANP modeling process replaces the many criteria of the hierarchy by proper network relationship 'connectivity' between elements and clusters, so the problem is represented in a closer way to what occurs in real life" [14]. Meanwhile, Eden believe that a fuzzy cognitive map is a "network of ideas linked by arrows" [15].

(4) ANP and FCM both could use a hierarchical structuring of the factors involved. The hierarchical structuring is universal to the composition of all complex systems, and is a natural problem-solving paradigm in the face of complexity. The researches have been shown that the ANP goes beyond linear relationships among elements and allows interrelationships among elements. Meanwhile, in order to structure a problem, the FCM also have hierarchical structures: goals, CFS (critical success factors), actions [16].

(5) ANP is a technique that can prove valuable in helping multiple parties arrive at an agreeable solution due to its structure, and if implemented appropriately can be used as a consensus-building tool. FCM also could collect many people's idea to construct the map. For example, Annibal gave us a new methodology could construct a collective causal map by gathering different people's ideas[17]

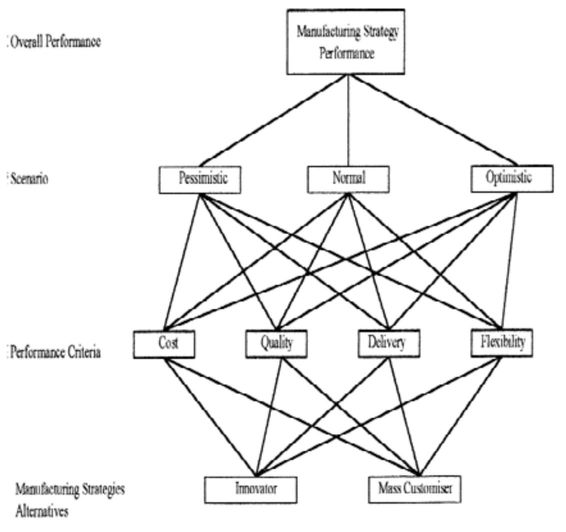

Figure 3. (1) Hierarchical structure of ANP

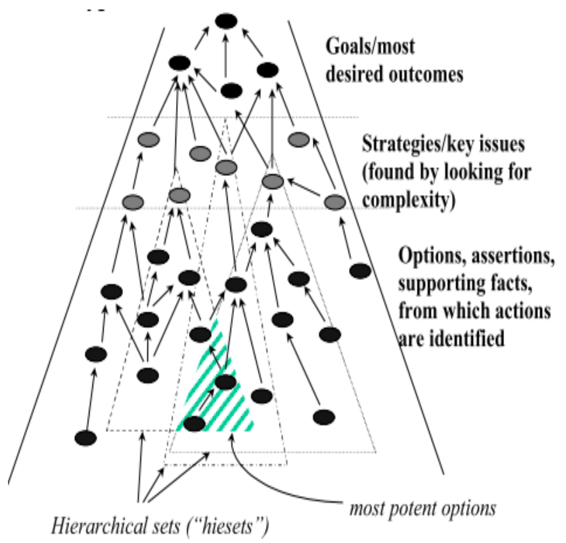

Figure 3. (2) The hierarchy of FCM

4.2 The differences between ANP and FCM

- In the process of ANP algorithm, judgment elicitations are completed using a decomposition approach, which could reduce decision making errors. But in FCM, many people complaint there is no scientific method/process to choose the concepts in FCM. It is obvious that the concepts construction in FCM is one of the most serious problems for people.
- ANP and FCM have different algorithm. The significant character of ANP from other decision

making methods is the super-matrix. However, the FCM approach needs the initial weight matrix, and using the several neural network algorithms.

- In the ANP rank reversal problem is appeased, thereby it is more accurate and useful than other soft operation research as a decision support instrument for intricate situations. People could selection of the best alternatives or criterias, from the results. Whereas, in most of time, the concepts in FCM are all belong to one goal.
- The number of adding all the column vectors in ANP's matrix is 1. In addition, all the vectors in ANP are positive number. Otherwise, the vectors in FCM's adjacent matrix could be any number (positive, negative, and zero).
- Relationships in a network are represented by arcs, where the directions of arcs signify directional dependence [18]. In ANP, inner dependencies among the elements of a cluster are represented by looped arcs. Nevertheless, the FCM has no looped arcs, hence the value of the diagonal line of the FCM's matrix is not zero.
- The main drawback of FCM approach is the dependence of the final weights on the initial weight matrix. Wrong initial estimation of the weights or large deviation among the experts' suggestions may lead in reduced efficiency of the algorithms and/or in undesired states of the system.

5 THE CASE STUDY

This paper revisits the works of Suwignjo, Bititci and Carrie and Joseph's paper in 2003. At first, Suwignjo, Bititci and Carrie give a FCM to describe the problems as Fig.4.

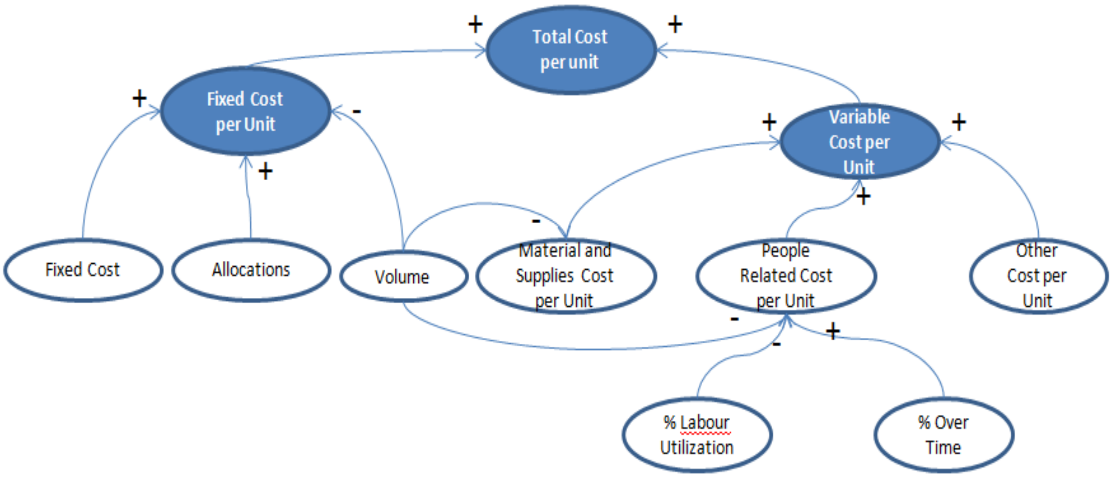

Figure 4. Factors affecting 'total production cost per unit' and their relationships[19]

Table 1. The final supermatrix and results for the combined effects of the SBC model of factors affecting "total production cost per unit" and their relationships[20]

	TCU	FCU	VCU	FC	ALL	VOL	MAT	PEO	OTH	LU	OT
TCU	1	0	0	0	0	0	0	0	0	0	0
FCU	0.500	1	0	0	0	0	0	0	0	0	0
VCU	0.500	0	1	0	0	0	0	0	0	0	0
FC	0.137	0.274	0	1	0	0	0	0	0	0	0
ALL	0.158	0.316	0	0	1	0	0	0	0	0	0
VOL	0.314	0.410	0.217	0	0	1	0	0.1	0	0	0
MAT	0.144	0	0.288	0	0	0	1	0	0	0	0
PEO	0.365	0	0.730	0	0	0	2	1	0	0	0
OTH	0.063	0	0.126	0	0	0	0	0	1	0	0
LU	0.005	0	0.011	0	0	0	0	0.014	0	1	0
OT	0.323	0	0.646	0	0	0	0	0.886	0	0	1

Joseph Sarkis applied the ANP method to solve the problem, the results as Tab.1.

In this paper, the author uses the FCM approach for solving the same problem. The initial weighted matrix is {0.5,0.5,0.2,0.3,0.3,0.2,0.3,0.3,0.4,0.5,0.2}. The algorithm as right:

$$A_i(k+1) = f(\sum_{\substack{j=1 \\ j \neq i}}^{n} W_{ji} A_j(k)) \tag{3}$$

$$f(x) = \frac{1}{1+e^{1\lambda x}} \tag{4}$$

The results are shown in tab.2,

Table 2. The iterative result

Initial weight matrix	0.5	0.5	0.2	0.3	0.3	0.2	0.3	0.3	0.4	0.5	0.2
The first iterative results	0.58662	0.56439	0.57752	0.5	0.5	0.5	0.52498	0.55087	0.5	0.5	0.5
The second iterative results	0.63898	0.62246	0.63198	0.5	0.5	0.5	0.56218	0.62246	0.5	0.5	0.5
The third iterative results	0.65186	0.62246	0.64528	0.5	0.5	0.5	0.56218	0.62246	0.5	0.5	0.5
The fourth iterative results	0.65337	0.62246	0.64528	0.5	0.5	0.5	0.56218	0.62246	0.5	0.5	0.5
The fifth iterative results	0.65337	0.62246	0.64528	0.5	0.5	0.5	0.56218	0.62246	0.5	0.5	0.5

The results describes that Fixed cost per unit(FCU), variable cost per unit(VCU), people related cost per unit (PEO) are important to the goal total cost per unit (TCU), these are similar with the Joseph Sarkis's results. The difference is the rate of importance of percents of people related cost per unit (PEO) and overtime (OT) are little less than Joseph Sarkis's results.

6. CONCLUSIONS

In this article, the author describes the two soft operation research approaches ANP and FCM. Those are decision making methods which could solve the unstructured or ill-structured problems. The papers points out the similarities and differences of the two methods and analyze the same case by different algorithm. The author believes that different problems or situations could take advantage of different methods. People could compare the advantages of ANP and FCM, and then choose the best method.

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