ERP Sandtable Simulation Evaluation Based on ANP

Ran Bi, Jinyu Wei, Rui Chen

School of Management, Tianjin University of Technology, Tianjin 300191, China
E-MAIL: holly_ran@163.com, weijinyu@eyou.com, chenrui_ff@163.com

Abstract - **ANP(Analytic Network Process) is a decision-making method based on AHP(Analytic Hierarchy Process) for solving problems with feedback and dependence. In this paper, the theory of ANP will be introduced. An illustration on ERP(Enterprise Resource Planning) sandtable simulation evaluation will be presented to discuss how to make a decision using ANP.**

Keywords - **ANP; feedback; dependence; ERP sandtable**

I. INTRODUCTION

Referring to sandtable, it is easy to make us associate it to sandtable using for directing campaigns during battle times or sandtable using for displaying district layout by real estate developers. There is a common ground that they both simulate a real land form, which makes people they serve control his concerned position without presenting himself but devise strategies within a command tent and make decisions correctly[1].

ERP is short for Enterprise Resource Planning. Enterprise resources include workshops, equipments, materials, finance, suppliers and customers. The essential of ERP is how to organize production rationally to achieve the highest profit and the lowest cost given limited resources[1].

It is UFSoft in China who first associate ERP and sandtable in 2003[2]. UFSoft simulated enterprise operating on sandtable by referring to ERP theory and setting regulations for producing and operating. In addition, other scholar such as Chan-Hsing Lo, Chih-Hung Tsai and Rong-Kwei Li in Taiwan also researched how to convey the ERP sandtable simulated data to a real operating environment[3].

ANP(analytic network process) is a method invented by Thomas L. Saaty in 1996 who is a famous professor in Pittsburgh University. ANP is an extension of AHP(analytic hierarchy process)[4]. The main idea of AHP is dividing a system into certain hierarchy such as goal, criteria, sub-criteria and alternatives. And it only considers the control from upper elements to nether elements and elements in the same hierarchy are supposed to be independent to each other. This hierarchy structure can solve easy problems expediently, but it is restricted in complicated systems. In many actual problems, elements in the same hierarchy are dependent to others and nether elements can also control upper elements. This kind of problems with feedback and dependence should be constructed to be network. ANP is invented under this situation[5]. ANP is a comprehensive decision-making technique that captures the outcome of the dependence and feedback within and between the clusters of elements[6]. Actually, hierarchy structure is just a special case of network structure, so AHP is case included in ANP[7].

In the process of ERP sandtable simulation, we will always be confronted with decisions. It is common that criteria and alternatives are dependent, and the inner of criteria and alternatives may also be dependent. This kind of decision problems cannot be solved using hierarchy structure of AHP, so we will turn to ANP for help.

II. ESSENTIAL THEORY OF ANP

A. Network structure of ANP

A complicated system can always be denoted to be a network structure[8]. A typical network structure is as below:

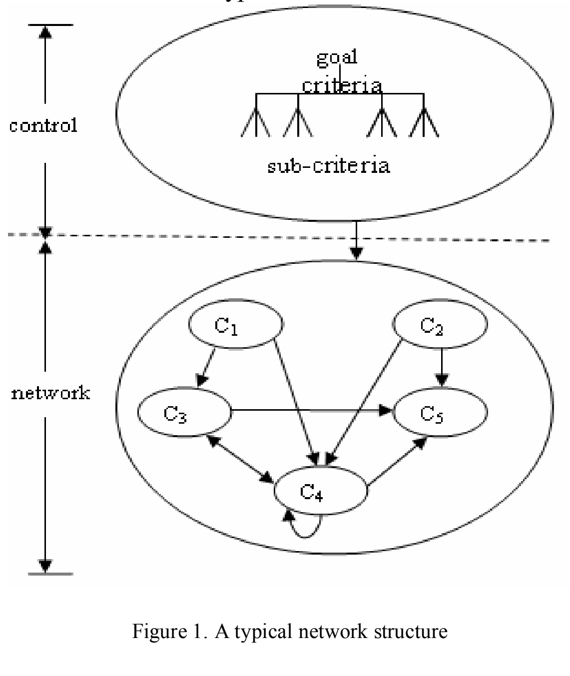

Figure 1. A typical network structure

B. Correlative definition of ANP

Supermatrix[9]*:*

Assume a network structure is composed of hierarchy $C_h(h=1,2,\ldots\ldots,m)$. For each hierarchy C_h, assume there exist elements $e_{h1,} e_{h2,} \cdots\cdots, e_{hm_k}$, so the influence of C_h(h=1,2,……,m) can be denoted as below:

$$W = \begin{matrix} & C_1 & C_2 & \cdots & C_m \\ C_1 & W_{11} & W_{12} & \cdots & W_{1m} \\ C_2 & W_{21} & W_{22} & \cdots & W_{2m} \\ \vdots & \vdots & \vdots & ::: & \vdots \\ C_m & W_{m1} & W_{m2} & \cdots & W_{mm} \end{matrix}$$

Figure 2. A supermatrix of ANP

W_{ij} shows the influence of each element of the *i*th hierarchy on the *j*th hierarchy, which is called a block of a supermatrix, whose form is as follows:

$$W_{ij} = \begin{bmatrix} W_{i_1 j_1} & W_{i_1 j_2} & \cdots & W_{i_1 j_{n_j}} \\ W_{i_2 j_1} & W_{i_2 j_2} & \cdots & W_{i_2 j_{n_j}} \\ \vdots & \vdots & ::: & \vdots \\ W_{i_{n_i} j_1} & W_{i_{n_2} j_2} & \cdots & W_{i_{n_i} j_{n_j}} \end{bmatrix}$$

Figure 3. A block of a supermatrix

Weighted Supermatrix:

The priorities of elements in one hierarchy according to a certain criterion can be denoted with a supermatrix, which means each column of each hierarchy in the supermatrix is column stochastic. But the influence that other hierarchy according to this criterion is not concerned. As a result, each column of the supermatrix is not column stochastic.

It is essential to consider the influence between each two hierarchy. The particular method is: regarding each hierarchy as an element, and pairwise comparing according a certain hierarchy, then computing corresponding priorities. Suppose a_{ij} is the influence weight of the *i*th hierarchy on the *j*th hierarchy, let

$$\overline{W_{ij}} = a_{ij} W_{ij}$$

$\overline{W}$ is a weighted supermatrix. In a weighted supermatrix, addition of elements in each column is 1. Matrix has this trait is called column stochastic[10].

Limited Supermatrix:

What we wish to obtain is the priorities along each possible path in a supermatrix, namely the final influence an element on the highest goal. This kind of result can be acquired by solving $\overline{W}^{\infty}$.

III. ANP APPLICATION——ERP SANDTABLE SIMULATION

This decision refers to research of three types of products: P_2, P_3 and P4;

Decision criteria are: technology, market and organization;

Decision sub-criteria are: cost, time, quality, operation, environment and resource;

Decision goal is: obtain the most profit.

The weight of each factor is received by using Delphi method. To make sure the result is more exact and reasonable, more experts are expected to participate in decisions.

A. Modeling:

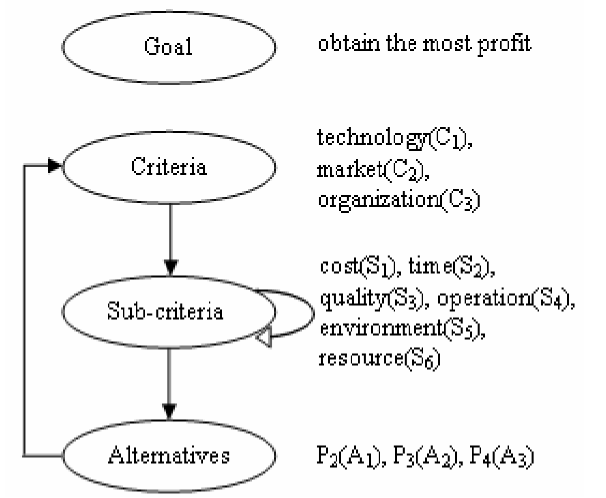

Figure 4. The decision network structure

B. The unweighted supermatrix

According to the model above, a supermatrix is shaped as follows[11]:

$$W = \begin{bmatrix} 0 & 0 & W_{13} \\ W_{21} & W_{22} & 0 \\ 0 & W_{32} & 0 \end{bmatrix}$$

Figure 5. The unweighted supermatrix without computing

Where

W_{13} represents the weights of criteria with respect to the alternatives,

W_{21} represents the weights of sub-criteria with respect to the criteria,

W_{32} represents the weights of alternatives with respect to the sub-criteria,

W_{22} represents the inner dependence matrix of sub-criteria.

Next, it is time to construct the four matrixes above.

Take the structure of W_{13} for example:

For A_1, make pairwise comparisons for C_1,C_2,C_3, and the result is:

Table 1. An example of how to form a supermatrix

A_1	C_1	C_2	C_3	eigenvector
C_1	1	3	5	0.637
C_2	1/3	1	3	0.258
C_3	1/5	1/3	1	0.105

So the first column of W_{13} is $[0.637, 0.258, 0.105]^T$.

With the method above, a supermatrix can be obtained as below:

$$W=\begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.637 & 0.192 & 0.250 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.258 & 0.634 & 0.250 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.105 & 0.174 & 0.500 \\
0.310 & 0.221 & 0.132 & 0.127 & 0.125 & 0.200 & 0.135 & 0.105 & 0.245 & 0 & 0 & 0 \\
0.140 & 0.221 & 0.165 & 0.222 & 0.200 & 0.140 & 0.220 & 0.077 & 0.335 & 0 & 0 & 0 \\
0.216 & 0.158 & 0.175 & 0.125 & 0.198 & 0.265 & 0.045 & 0.230 & 0.300 & 0 & 0 & 0 \\
0.155 & 0.062 & 0.156 & 0.095 & 0.253 & 0.185 & 0.210 & 0.126 & 0.055 & 0 & 0 & 0 \\
0.095 & 0.246 & 0.200 & 0.285 & 0.112 & 0.110 & 0.135 & 0.230 & 0.045 & 0 & 0 & 0 \\
0.084 & 0.092 & 0.172 & 0.146 & 0.112 & 0.100 & 0.255 & 0.232 & 0.020 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.634 & 0.136 & 0.354 & 0.246 & 0.778 & 0.500 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.192 & 0.654 & 0.325 & 0.321 & 0.111 & 0.250 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.174 & 0.210 & 0.321 & 0.433 & 0.111 & 0.250 & 0 & 0 & 0
\end{bmatrix}$$

Figure 6. The unweighted supermatrix after computing

C. *The weighted supermatrix*

The matrix in Figure 6 is not column stochastic. With the method mentioned in 2.2, the corresponding weighted supermatrix is as below:

$$\overline{W}=\begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.637 & 0.192 & 0.250 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.258 & 0.634 & 0.250 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.105 & 0.174 & 0.500 \\
0.310 & 0.221 & 0.132 & 0.064 & 0.063 & 0.100 & 0.068 & 0.053 & 0.123 & 0 & 0 & 0 \\
0.140 & 0.221 & 0.165 & 0.111 & 0.100 & 0.070 & 0.110 & 0.038 & 0.167 & 0 & 0 & 0 \\
0.216 & 0.158 & 0.175 & 0.062 & 0.099 & 0.133 & 0.022 & 0.115 & 0.150 & 0 & 0 & 0 \\
0.155 & 0.062 & 0.156 & 0.048 & 0.126 & 0.092 & 0.105 & 0.063 & 0.028 & 0 & 0 & 0 \\
0.095 & 0.246 & 0.200 & 0.142 & 0.056 & 0.055 & 0.068 & 0.115 & 0.022 & 0 & 0 & 0 \\
0.084 & 0.092 & 0.172 & 0.073 & 0.056 & 0.050 & 0.127 & 0.116 & 0.010 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.317 & 0.068 & 0.177 & 0.123 & 0.389 & 0.250 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.096 & 0.327 & 0.163 & 0.161 & 0.055 & 0.125 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.087 & 0.105 & 0.160 & 0.216 & 0.056 & 0.125 & 0 & 0 & 0
\end{bmatrix}$$

Figure 7. The weighted supermatrix

D. *The limited supermatrix*

$$\overline{W}^{\infty}=\begin{bmatrix}
0.101 & 0.101 & 0.101 & 0.101 & 0.101 & 0.101 & 0.101 & 0.101 & 0.101 & 0.101 & 0.101 & 0.101 \\
0.093 & 0.093 & 0.093 & 0.093 & 0.093 & 0.093 & 0.093 & 0.093 & 0.093 & 0.093 & 0.093 & 0.093 \\
0.056 & 0.056 & 0.056 & 0.056 & 0.056 & 0.056 & 0.056 & 0.056 & 0.056 & 0.056 & 0.056 & 0.056 \\
0.098 & 0.098 & 0.098 & 0.098 & 0.098 & 0.098 & 0.098 & 0.098 & 0.098 & 0.098 & 0.098 & 0.098 \\
0.092 & 0.092 & 0.092 & 0.092 & 0.092 & 0.092 & 0.092 & 0.092 & 0.092 & 0.092 & 0.092 & 0.092 \\
0.094 & 0.094 & 0.094 & 0.094 & 0.094 & 0.094 & 0.094 & 0.094 & 0.094 & 0.094 & 0.094 & 0.094 \\
0.069 & 0.069 & 0.069 & 0.069 & 0.069 & 0.069 & 0.069 & 0.069 & 0.069 & 0.069 & 0.069 & 0.069 \\
0.084 & 0.084 & 0.084 & 0.084 & 0.084 & 0.084 & 0.084 & 0.084 & 0.084 & 0.084 & 0.084 & 0.084 \\
0.063 & 0.063 & 0.063 & 0.063 & 0.063 & 0.063 & 0.063 & 0.063 & 0.063 & 0.063 & 0.063 & 0.063 \\
0.111 & 0.111 & 0.111 & 0.111 & 0.111 & 0.111 & 0.111 & 0.111 & 0.111 & 0.111 & 0.111 & 0.111 \\
0.078 & 0.078 & 0.078 & 0.078 & 0.078 & 0.078 & 0.078 & 0.078 & 0.078 & 0.078 & 0.078 & 0.078 \\
0.061 & 0.061 & 0.061 & 0.061 & 0.061 & 0.061 & 0.061 & 0.061 & 0.061 & 0.061 & 0.061 & 0.061
\end{bmatrix}$$

Figure 8. The limited supermatrix

From the matrix above, it is clear that the priorities of three criteria are 0.101, 0.093, 0.056; the priorities of six sub-criteria are 0.098, 0.092, 0.094, 0.069, 0.084, 0.063; the priorities of three alternatives are 0.111, 0.078, 0.061. Therefore, the most considered criterion is technology due to the highest priority of 0.101; the most important factor is cost due to the highest priority of 0.098; and the best alternative is to produce P_2 due to the highest priority of 0.111.

IV. CONCLUSIONS

ANP is a decision method which is more systemic, general and scientific than AHP. The key of ANP is the calculation about supermatrix. The calculation about supermatrix is complicated, but we can turn to correlative software for help. Using ANP to simulate ERP sandtable can make us consider factors influence operation of enterprise adequately, including feedback and dependence among the factors. With this method, enterprises can make decisions more exactly and more rationally. China is still in an elementary phase about the application of ANP. The aspects of how to construct models neatly and scientifically, how to calculate the matrix quickly and correctly and developing ANP analytic software are still expected to be researched and studied.

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REFERENCES

[1] Xinling Wang, Ming Ke, Xirun Geng, ERP sandtable simulation instructor, Electronic Industry Publish, Beijing, Jan. 2005.

[2] Yubo Liu, Jinyu Wei, Zhi Liu, ERP sandtable scene-design research, Tianjin University of Technology Transaction, Tianjin, Jul. 2006.

[3] Chan-Hsing Lo, Chih-Hung Tsai, Rong-Kwei Li, "A Case Study of ERP Implementation for Opto-Electronics Industry", *International Journal of The Computer, the Internet and Management*, Jun. 2005.

[4] Lianfen Wang, "Theory and arithmetic of Analytic Network Process(ANP)", *Systems Engineering Theory and Practice*, Vol 3, Mar. 2001.

[5] Laura. M., Joseph. S., "Stragegic Analysis of Logistice and Supply Chain Management Systems Using Analytic Network Process", *Transpn Res.-E*, Vol 34, No. 3, pp. 201-215, Apr. 1998.

[6] V. Ravi, Ravi Shankar, M. K. Tiwari, "Analyzing alternatives in reverse logistics for end-of-life computers: ANP and balanced scorecard approach", *Computer & Industrial Engineering*, Vol 48, pp. 327-356, Jan. 2005.

[7] Eddie W. L. Cheng, Heng Li, "Application of ANP in process models: An example of strategic partnering", *Building and Environment*, Vol 42, pp. 278-287, Jul. 2005.

[8] Shubai Xu, Practical Decision-making Method——Theory of Analytic Hierarchy Process, Tianjin University Publisher, Tian jin, 1998.

[9] Saaty T.L, Decision Making With Dependence Feedback: The Analytic Network Process, RWS Publications, Pittsburgh, 2001.

[10] Xiaoli Tang, Junwen Feng, ANP Theory and Application expectation, Statistics and Decision-making, Jun. 2006.

[11] Weiwen Wu, Yuting Lee, "Selecting knowledge management strategies by using the analytic network process", *Expert Systems with Applications*, Voi 32, pp. 841-847, Jan. 2006.

[12] Sanjay Jharkharia, Ravi Shankar, "Selection of logistics service provider: An analytic network process(ANP) approach", *Omega*, Vol 35, pp. 274-289, Jan. 2005.

[13] Rachung Yu, Gwo-Hshiung Tzeng, "A soft computing method for multi-criteria decision making with dependence and feedback", *Applied Mathematics and Computation*, Vol 180, pp. 63-75, Nov. 2005.

[14] Ozden Bayazit, Birsen Karpak, "An analytic network process-based framework for successful total quality management(TQM): An assessment of Turkish manufacturing industry readiness", *Int. J. Production Economics*, Vol 105, pp.27-96, Dec. 2005.

[15] Jih-Jeng Huang, Gwo-Hshiung Tzeng, Chorng-Shyong Ong, "Multidimensional data in multidimensional scaling using the analytic network process", *Pattern Recognition Letters*, Vol26, pp. 755-767, Sep. 2004.

[16] Jin Woo Lee, Soung Hie Kim, "Using analytic network process and goal programming for interdependent information system project selection", *Computers & Operations Research*, Vol27, pp. 367-382, Dec. 1998.

[17] R. J. Kuo, S. C. Chi, S. S. Kao, "A decision support system for selecting convenience store location through integration of fuzzy AHP and artificial neural network", *Computers in Industry,* Vol 47, pp. 199-214, Jun. 2001.