Application of ANP in Production Line Selection

A Case Study for ERP Sand Table Simulation Evaluation

Jinyu Wei
Department of Management
Tianjin University of Technology
Tianjin300191, China
weijinyu@tjut.edu.cn

Ran Bi
Department of Management
Tianjin University of Technology
Tianjin300191, China
holly_ran@163.com

***Abstract*—Production line selection is evaluated as a critical factor in Enterprise Resource Planning (ERP). With the scope of this paper, production line selection was considered as a multi-criteria decision problem and a model aiming the usage of Analytic Network Process (ANP) was developed to evaluate the criteria and alternatives in a feedback system. The criteria were included into the model to rate benefits, opportunities, costs and risks (BOCR). Final synthesis of alternatives was obtained by using rated BOCR. The proposed approach can be adopted as an evaluation tool by decision-makers in systems which include feedback and dependence.**

***Keywords*—production line selection, Enterprise Resource Planning, Analytic Network Process, BOCR**

I. INTRODUCTION

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].

ERP has a well-developed theoretical background and a number of research studies have been carried out to examine the kernel of ERP [2-9]. F. Robert Jacobs and F. C. 'Ted' Weston Jr [2] showed a history of ERP; Sanna Laukkanen, Sami Sarpola and Petri Hallikainen [3] introduced the objectives and constraints of ERP adoption and Hong Seng Woo [4] presented critical success factors for implementing ERP.

It is UFSoft in China who first associate ERP and sand table in 2003 [10]. UFSoft simulated enterprise operating on sand table 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 sand table simulated data to a real operating environment [11].

ERP play a key role in enterprise business and selection of production line is critical to an enterprise’s eventual success. A suitable production line can provide favourable contributions to an enterprise’s market competitiveness. In such circumstances the problem of production line selection is chosen to study the process of ERP sand table simulation evaluation in this research.

A wide variety of mathematical approaches have been proposed for decision making problems, such as linear weighting methods [12], data envelopment analysis, analytic hierarchy process (AHP) [13], total cost approaches [14], and mathematical programming techniques [15]. AHP is a relatively popular tool for modelling strategic decisions and Saaty suggested the usage of AHP to solve the problems of independence on alternatives or criteria. AHP is conceptually easy to use, however, in many actual decision problems, strict hierarchical structure cannot be built because of dependencies (inner/outer), influences between and within clusters (criteria, alternatives). This kind of problems with feedback and dependence should be constructed to be network and ANP is very useful to solve them. The Analytic Network Process (ANP), developed by Thomas L. Saaty, is the most comprehensive framework for the analysis of societal, governmental and corporate decisions that is available today to the decision-makers. It is a process that allows one to include all the factors and criteria, tangible and intangible which have bearing on making a best decision. The Analytic Network Process allows both interaction and feedback within clusters of elements (inner dependence) and between clusters (outer dependence). Such feedback best captures the complex effects of interplay in human society, especially when risk and uncertainty are involved.

The ANP has been applied to a large variety of decisions: marketing, medical, political, social, forecasting and prediction and many others. ANP model is used by Laura. M. and Joseph. S [16], for logistics and supply chain management; V. Ravi, Ravi Shankar and M. K. Tiwari [17], for end-of-life computers in reverse logistics; Eddie W. L. Cheng and Heng Li [18], for strategic partnering; Weiwen Wu and Yuting Lee [19], for knowledge management strategies selection; Ozden Bayazit and Birsen Karpak [20], for successful total quality management.

In production line selection problem, decision-makers might intuitively feel that some factors are more important that others in affecting their final preference among alternatives. If there is some feedback and interdependency among the factors, an unimportant factor may turn out to be far more important than even the most intuitively important one. Therefore, ANP is preferred over other approaches to handle the production line selection problem.

II. ESSENTIAL THEORY OF ANP

A. Network structure of ANP

A complicated system can always be denoted to be a network structure [21]. A typical network structure is as below.

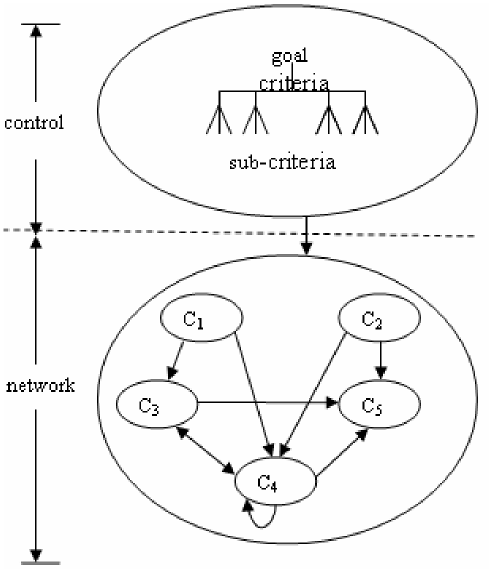

Figure 1. A typical network structure

B. Supermatrix [22]

The first phase of ANP is to compare the criteria in whole system to form the supermatrix. This is done through pairwise comparisons by asking "How much importance does a criterion have compared to another criterion with respect to our interests or preferences?" The relative importance value can be determined using a scale of 1-9 to represent equal importance to extreme importance.

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

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

which is the general form of the supermatrix. 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.

$$W_{ij} = \begin{bmatrix} W_{i_1 j_1} & W_{i_1 j_2} & \cdots & W_{i_1 j_{n_j}} \\ W_{i_2 j_1} & W_{i_2 j_2} & \cdots & W_{i_2 j_{n_j}} \\ \vdots & \vdots & \cdots & \vdots \\ W_{i_{n_1} j_1} & W_{i_{n_2} j_2} & \cdots & W_{i_{n_i} j_{n_j}} \end{bmatrix}$$

C. 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

$$\overline{W_{ij}} = a_{ij} W_{ij} . \quad (1)$$

$\overline{W}$ is a weighted supermatrix. In a weighted supermatrix, addition of elements in each column is 1. Matrix has this trait is called column stochastic [23]. This step is much similar to the concept of Markov chain for ensuring the sum of these probabilities of all states equals to 1.

D. 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 $\overline{W}^{\infty}$,

$$\overline{W}^{\infty} = \lim_{k \to \infty} \overline{W}^{k} . \quad (2)$$

The weighted supermatrix is raised to limiting powers such as in (2) to get the global priority vector or called weights, so the most important criterion and the best alternative are acquirable [24].

III. A CASE STUDY

Although advanced production lines can provide new opportunities and benefits, some additional costs and risks are inevitable. Therefore, before adopting new production lines, the benefits, opportunities, costs and risks (BOCR) of these alternatives, must be evaluated [25]. In this paper, Saaty's BOCR approach, an advanced network in ANP, is utilized to solve production line selection problem.

A. Modeling [27-34]

To build the production line selection model and to calculate the weights, a software called Super Decisions is used. The Super Decisions software is a simple easy-to-use package for constructing decision models with dependence and feedback and computing results using the supermatrices of the ANP.

This problem refers to selection of four types of production line: current production line, semi-automatic production line, full-automatic production line and flexible production line. Benefits, opportunities, costs and risks are criteria, each of which has its own sub-criteria. The top level network is shown in Fig. 2 and the subnets under the BOCR merits and the relationship between clusters are illustrated in Fig. 3.

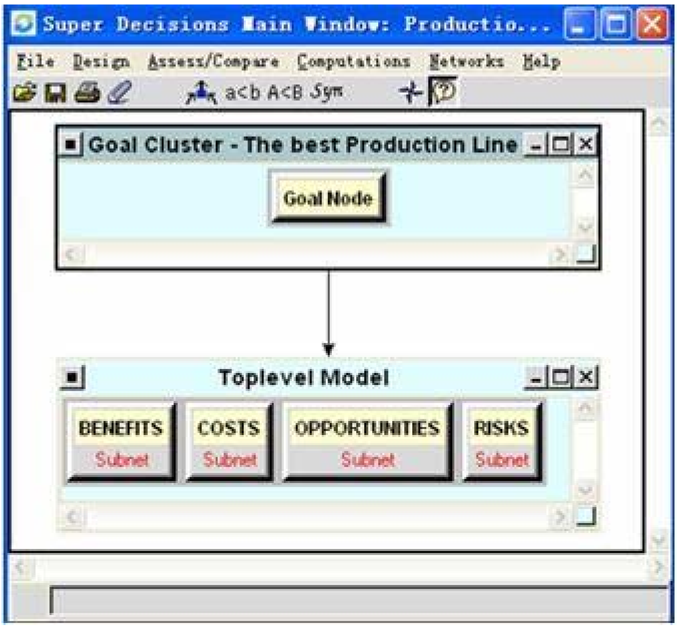

Figure 2. The top level network for production line selection model

Figure 3. The subnets under BOCR merits

B. Obtaining pairwise comparison matrices

After modelling, paired comparisons under each control criterion are performed. This phase is done by using Delphi method. To make sure the result is more exact and reasonable, more experts are expected to participate in pairwise comparison. The elements in a cluster are compared by applying Saaty's 1-9 scales according to their influence on an element in another cluster which they are connected to (or on elements in their own cluster). The Super Decisions software reports an inconsistency ratio for each pairwise comparison matrix [26]. A comparison matrix is considered to be consistent when its inconsistency ratio is less than 0.1

C. Calculate the priorities of the criteria

The Super Decisions software can provide the priority vector for the alternatives in the subnets when pairwise comparisons are done and give the synthesized priority vector for the alternatives over all the subnets when the calculations are done in the control network.

The weights of the alternatives in point of BOCR are summarized in Fig. 4 and the total weights of the alternatives are showed in Fig. 5. The rates of computed BOCR are given in Fig. 6.

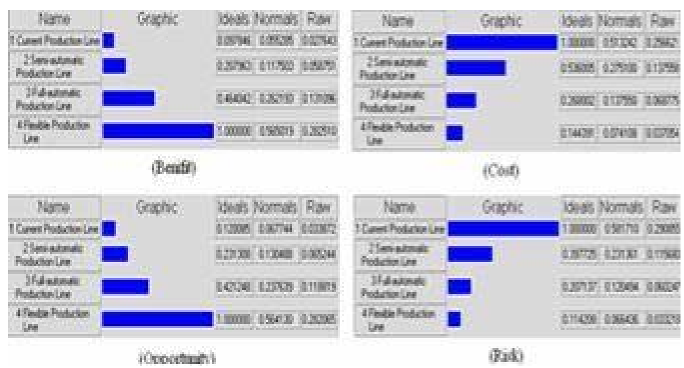

Figure 4. The weights of the alternatives in point of BOCR subnets

Name	Graphic	Ideals	Normals	Raw
1 Current Production Line		0.110372	0.059817	0.083883
2 Semi-automatic Production Line		0.246407	0.133541	0.187269
3 Full-automatic Production Line		0.488398	0.264689	0.371182
4 Flexible Production Line		1.000000	0.541953	0.760000

Figure 5. The total weights of the alternatives

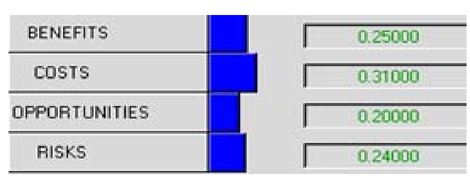

Figure 6. The rates of BOCR

From Fig. 4, Fig. 5 and Fig. 6, it is intuitive for the decision-makes to learn which criterion needs more attention and which alternative is better than others under a certain criterion.

IV. CONCLUSIONS

Production line selection, which is one of most important processes in ERP, must be systematically considered from the decision-makers. Enterprises can make decisions more exactly and more rationally with ANP. This study has extended the limited applications of ANP, especially with BOCR. In this study, production line selection was considered as a multi-criteria decision problem and a model was proposed by using ANP. In addition, usage of Super Decision, a user-friendly software, makes the decision making process by using ANP more easy.

The model developed in this paper has a limitation as well: the results reported in this research are based on the opinion of the decision-makes, whose preference to some criterion might have influenced the results. Although Delphi method is used in pairwise comparison phase, some subjective factors are still inevitable.

ACKNOWLEDGMENT

This paper was supported by Education Committee Science and Technology Development Foundation of Tianjin (No. 20042126) and Philosophy Social Science Research Key Program of Tianjin (No. TJGL06-041). The authors of this paper would like to sincerely acknowledge the valuable suggestions of the referees, which have immensely helped to enhance the quality of the paper.

REFERENCES

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

[2] F. Robert Jacobs and F. C. 'Ted' Weston Jr, “Enterprise resource planning (ERP)-A brief history,” Journal of Operations Management, vol. 25, no. 2, pp. 357-363, 2007.

[3] Sanna Laukkanen, Sami Sarpola, and Petri Hallikainen, “Enterprise size matters: objectives and constraints of ERP adoption,” Journal of Enterprise Information Management, vol. 20, no. 3, pp. 319-334, 2007.

[4] Hong Seng Woo, “Critical success factors for implementing ERP: the case of a Chinese electronics manufacturer,” Journal of Manufacturing Technology Management, vol. 18, no. 4, pp. 431-442, 2007.

[5] Galen Gruman, “Is Open Source The Answer to ERP?” CIO, vol. 10, no. 9, pp. 23-28, 2007.

[6] Chrwan-jyh HO, “Measuring system performance of an ERP-based supply chain,” International Journal of Production Research, vol. 45, no. 6, pp. 1255-1277, 2007.

[7] Ramaraj Palanisamy, “Capturing Users' Tacit Knowledge in ERP Implementation: An Exploratory Multi-Site Case Study,” Journal of information & knowledge management, vol. 6, no. 1, pp. 9-23, 2007.

[8] Shan L. Pan, Sue Newell, Jimmy Huang, and Robert D. Galliers, “Overcoming Knowledge Management Challenges During ERP Implementation: The Need to Integrate and Share Different Types of Knowledge,” Journal of the American Society for Information Science and Technology, vol. 58, no. 3, pp. 404-419, 2007.

[9] Olsen. KA and Saetre. P, “IT for niche companies: is an ERP system the solution?” Information systems journal, vol. 17, no. 1, pp. 37-58, 2007.

[10] Yubo Liu, Jinyu Wei, and Zhi Liu, “ERP sandtable scene-design research,” Tianjin University of Technology Transaction, vol. 21, no. 1, pp. 12-16, 2006.

[11] Chan-Hsing Lo, Chih-Hung Tsai, and Rong-Kwei Li, “A Case Study of ERP Implementation for Opto-Electronics Industry,” International Journal of The Computer, vol. 32, no. 1, pp. 23-26, 2005.

[12] Grando A and Sianesi A, “Supply management: a vendor rating assessment,” CEMS Business Review, vol. 1, pp. 199-212, 1996.

[13] Wang Ting, Yi Shuping, and Yang Yuanzhao, “Performance evaluation method for business process of machinery manufacturer based on DEA/AHP hybrid model,” Chinese journal of mechanical engineering, vol. 20, no. 3, pp. 91-97, 2007.

[14] Monezka RM and Trecha SJ, “Cost-based supplier performance evaluation,” Journal of Purchasing and Materials Management, vol. 24, no. 2, pp. 2-7, 1998.

[15] Das C and Tyagi R, “Wholesaler: a decision support system for wholesale procurement and distribution,” International Journal of Physical Distribution and Logistics Management, vol. 24, no. 10, pp. 4-12, 1994.

[16] Laura. M. and Joseph. S., “Stragegic Analysis of Logistics and Supply Chain Management Systems Using Analytic Network Process,” Transpn Res.-E, vol. 34, no. 3, pp. 201-215, April 1998.

[17] V. Ravi, Ravi Shankar, and 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, January 2005.

[18] Eddie W. L. Cheng and Heng Li, “Application of ANP in process models: An example of strategic partnering,” Building and Environment, vol. 42, pp. 278-287, July 2005.

[19] Weiwen Wu and Yuting Lee, “Selecting knowledge management strategies by using the analytic network process,” Expert Systems with Applications, vol. 32, pp. 841-847, January 2006.

[20] Ozden Bayazit and 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, December 2005.

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

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

[23] Xiaoli Tang and Junwen Feng, “ANP Theory and Application expectation,” Statistics and Decision-making, vol. 12, pp. 138-140, 2006.

[24] Rachung Yu and 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, 2006.

[25] Senol Erdogmus, Muzaffer Kapanoglu, and Eylem Koc, “Evaluating high-tech alternatives by using analytic network process with BOCR and multiactors,” Evaluation and Program Planning, vol. 28, pp. 391-399, 2005.

[26] Saaty T.L., The Analytic Hierarchy Process, Pittsburgh: RWS Publications, 1980.

[27] Saaty T.L., “Rank from comparisons and from ratings in the analytic hierarchy/network processes,” European Journal of Operational Research, vol. 168, pp. 557-570, 2006.

[28] Jin Woo Lee and Soung Hie Kim, “Using analytic network process and goal programming for interdependent information system project selection,” Computers & Operations Research, vol. 27, pp. 367-382, December 1998.

[29] Jih-Jeng Huang, Gwo-Hshiung Tzeng, and Chorng-Shyong Ong, “Multidimensional data in multidimensional scaling using the analytic network process,” Pattern Recognition Letters, vol. 26, pp. 755-767, September 2004.

[30] Sanjay Jharkharia and Ravi Shankar, “Selection of logistics service provider: An analytic network process(ANP) approach,” Omega, vol. 35, pp. 274-289, January 2005.

[31] Saaty T.L. and Y. Cho, “The decision by the us congress on China’s trade status: a multicriteria analysis,” Socio-Economic Planning Sciences, no. 35, pp 243-252, 2001.

[32] Cengiz Kahraman, Tijen Ertay, and Gulcin Buyukozkan, “A fuzzy optimization model for QFD planning process using analytic network approach,” European Journal of Operational Research, vol. 171, pp. 390-411, 2006.

[33] Saaty T.L., L.G.Vargas, and K.Dellmann, “The allocation of intangible resources: the Analytic Hierarchy Process and Linear Programming,” Socio-Economic Planning Sciences, vol. 37, pp. 169-184, 2003.

[34] Saaty T.L. and M. Ozdemir, “Negative priorities in the Analytic Hierarchy Process,” Mathematical and Computer Modelling, vol. 37, pp. 1063-1075, 2003.