Application of Three Parameter Interval Grey Numbers in Enterprise Resource Planning Selection

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ABSTRACT

This paper applies a new multi attribute decision-making (MADM) model to help companies for enterprise resource planning (ERP) selection problem, based on Balanced Score Card (BSC) method. This paper uses three-parameter interval grey numbers which is derived from Grey theory (proposed by J. Deng). The numbers are used instead of linguistic variables. Besides, We have used a new weighting method that is resulted from combination of SMARTER and Shannon Entropy methods and also a new ranking method namely Grey ELECTRE (that is a generalization of ELECTRE I) for three parameter interval grey numbers in this paper. Finally, we discussed an industrial case study for ERP selection.

Keywords

Enterprise Resource Planning (ERP), Balanced Score Card (BSC), Three parameter interval grey numbers, Shannon Entropy, Grey ELECTRE

1. INTRODUCTION

In the dynamic and unpredictable business environment of nowadays, companies face the challenge of expanding markets and rising customer expectations. This compels them to lower costs of supply chain, shorten throughput times, reduce inventories, expand product choice, provide more reliable delivery date, enhance customer service, improve quality, and coordinate global demand, supply and production [1,2,3].

An enterprise resource planning (ERP) system is an information system to plan and integrate all of an enterprise›s subsystems including purchase, production, sales and finances [4]. An ERP system typically implements a common enterprise-wide database with a range of application modules [5]. ERP software automates and integrates business processes and allows information sharing in different business functions. In addition, ERP software supports finances, operations, human resources, logistics, sale, and market by more effective and productive business processes. At the same time it improves the performance of organization's functions by controlling the aforementioned parameters [6]. Selecting the most suitable ERP system yields positive results like increasing productivity, delivering on time, reducing setup time, and decreasing purchase cost. Failure to select a suitable ERP system usually weakens the company performance or crashes the whole project [7,8]. Decision makers use Multi Attribute Decision-Making

(MADM) to help them make preference decisions selection regarding a finite set of available alternative courses of action characterized by multiple potentially conflicting attributes [9].

ERP selection problem was considered in many articles. Wei and his colleagues presented an ERP selection model based on AHP [10]. They proposed two main attributes: suitable system and suitable salesman. Cebeci introduced a model to select an ERP system for textile industries with BSC approach [11]. Another model that used integrating of QFD, fuzzy linear regression and 0–1 goal programming was presented by Bernroider & Stix [12] to solve ERP selection problem. Ravi and his coworkers developed ANP model for ERP software selection problem with BSC approach [13].

We present an integrated model based on AHP-Entropy-Grey incidence method on three parameter interval grey numbers with BSC approach in this paper. We used a combination of AHP-Entropy method to weight the attributes in uncertain conditions. Besides, three parameter interval grey numbers derived from Grey system theory is implemented to change linguistic variables to quantitative. Finally, a case study is presented to show how this model works.

2. PRELIMINARIES

2.1 Balanced Score Card (BSC)

Performance measurement systems at different levels of decision making, either in the industry or service contexts, are essential [14]. BSC have been proposed by Kaplan and Norton [15,16]. This tool evaluates performance by four different perspectives: financial, internal business process, customer, and learning and growth [17] (Figure 1).

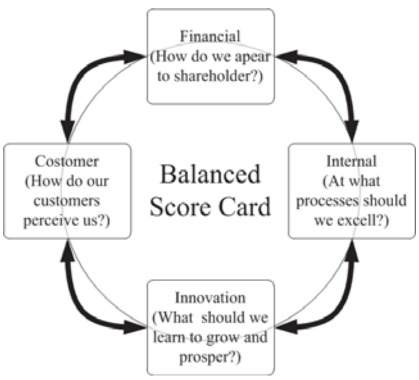

Figure 1. Four perspectives of BSC

Now, the BSC seems to serve as a control panel, pedals and steering wheel [18]. Many companies are adopting BSC as the foundation for their strategic management system. Some managers have used it as they align their businesses to new strategies, moving away from cost reduction towards growth opportunities based on more customized and value-adding products and services [19].

2.2 SMARTER

Edwards & Barron first introduced this method [20]. SMARTER uses attribute ranking to derive the weights. After ranking the attributes, the weight of an attribute ranked i is

$$w_i = \frac{1}{n}\sum_{k=i}^{n} 1/k \qquad (1)$$

2.3 Entropy Method

This measure of uncertainty is given by Shannon [21] as

$$E \approx S\{P_1, P_2, ..., P_n\} = -k\sum_{i=1}^{m}[P_i Ln P_i] \qquad (2)$$

where K is a positive constant.

When decision matrix is clearly explained, entropy can be used as a tool in criteria evaluation.

Here we present this method in a step-by-step approach [22]:

Let the decision matrix D of m alternatives and n attributes (criteria) be as follows:

$$D = \begin{pmatrix} x_{11} & x_{12}\cdots & x_{1n} \\ x_{21} & \ddots & \vdots \\ \vdots & & \\ x_{m1} & \cdots & x_{mn} \end{pmatrix} \qquad (3)$$

The project outcomes of attribute j can be defined as:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \qquad (4)$$

The entropy of the set of project outcomes of attribute *j* is:

$$E_j = -k\sum_{i=1}^{m}[p_{ij} Ln p_{ij}] \qquad (5)$$

where k is a constant such as:

$$k = \frac{1}{Ln(m)} \qquad (6)$$

which guarantees that $0 \le E_j \le 1$

The degree of diversification of information provided by the outcomes of attribute *j* can be defined as:

$$d_j = 1 - E_j \qquad (7)$$

Then the weights of attributes can be obtained by the following formulae:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \qquad (8)$$

If the DM has a prior, subjective weight l_j, then this can be adapted in a new form mentioned below:

$$w'_j = \frac{l_j w_j}{\sum_{j=1}^{n} l_j w_j} \tag{9}$$

In this survey, we obtain weights of attributes from lower band, gravity and upper band matrix separately. Then the mean of weights that outcomes from each matrix is considered as weights of every attributes.

2.4 Three Parameter Interval Grey Numbers

Deng was the first to propose grey system theory [23,24] and then others extended it [25]. If black represents completely unknown information and white represents completely clear data, gray is other information that are somewhat clear and somewhat unclear. A system containing gray information is called a Gray system. Figure 2 shows the concept of Gray system.

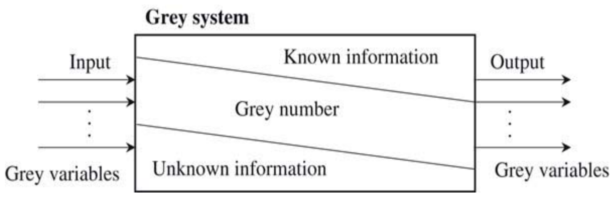

Figure 2. Concept of Gray system

A three parameter interval gray number like $a(\otimes)$ can be shown within $a(\otimes) \in [\underline{a}, \tilde{a}, \overline{a}]$. where $\underline{a}$ is the lower bound, $\tilde{a}$ center of gravity (the number that has the highest possibility), and $\overline{a}$ is the upper bound. When center of gravity is not determined, we are faced with typical gray-numbers.

2.4.1 Operators of Three Parameter Interval Grey Numbers

Let $a(\otimes) \in [\underline{a}, \tilde{a}, \overline{a}]$ & $b(\otimes) \in [\underline{b}, \tilde{b}, \overline{b}]$ be two three parameter interval grey numbers, then

$$a(\otimes) + b(\otimes) \in [\underline{a} + \underline{b}, \tilde{a} + \tilde{b}, \overline{a} + \overline{b}] \tag{10}$$

$$\begin{aligned} a(\otimes) / b(\otimes) \in [&\min\{\underline{a} / \underline{b}, \underline{a} / \overline{b}, \overline{a} / \underline{b}, \overline{a} / \overline{b}\}, \\ &\tilde{a} / \tilde{b}, \max\{\underline{a} / \underline{b}, \underline{a} / \overline{b}, \overline{a} / \underline{b}, \overline{a} / \overline{b}\}] \end{aligned} \tag{11}$$

2.4.2 Decision Making Matrix Normalization

Assume our decision making matrix as below:

$$\begin{aligned} S = \{u_{ij}(\otimes) \mid u_{ij}(\otimes) \in (\underline{u}_{ij}, \tilde{u}_{ij}, \overline{u}_{ij}), 0 \le \underline{u}_{ij} \le \tilde{u}_{ij} \le \overline{u}_{ij} \\ , i = 1,2,\ldots,n,\ j = 1,2,\ldots,m\} \end{aligned} \tag{12}$$

We use the poor transform method to normalize the matrix. Desired value for efficiency is defined as follows:

$$\overline{x}_{ij} = \frac{\overline{u}_{ij} - \underline{u}_j^{\nabla}}{\overline{u}_j^{*} - \underline{u}_j^{\nabla}} \quad \tilde{x}_{ij} = \frac{\tilde{u}_{ij} - \underline{u}_j^{\nabla}}{\overline{u}_j^{*} - \underline{u}_j^{\nabla}} \quad \underline{x}_{ij} = \frac{\underline{u}_{ij} - \underline{u}_j^{\nabla}}{\overline{u}_j^{*} - \underline{u}_j^{\nabla}} \tag{13}$$

Desired value for costing is as below:

$$\overline{x}_{ij} = \frac{\overline{u}_j^{*} - \underline{u}_{ij}}{\overline{u}_j^{*} - \underline{u}_j^{\nabla}} \quad \tilde{x}_{ij} = \frac{\overline{u}_j^{*} - \tilde{u}_{ij}}{\overline{u}_j^{*} - \underline{u}_j^{\nabla}} \quad \underline{x}_{ij} = \frac{\overline{u}_j^{*} - \overline{u}_{ij}}{\overline{u}_j^{*} - \underline{u}_j^{\nabla}} \tag{14}$$

In the above equations, $\overline{u}_j^{*} = \max_{1 \le i \le n}\{\overline{u}_{ij}\}$ and $\underline{u}_j^{\nabla} = \min_{1 \le i \le n}\{\underline{u}_{ij}\}$. When $\overline{u}_j^{*} - \underline{u}_j^{\nabla} = 0$, we can eliminate thia atribute from decision making matrix,because it is uselss.

$x_{ij} \in (\underline{x}_{ij}, \tilde{x}_{ij}, \overline{x}_{ij})$ is a three-parameter interval grey number in $[0,1]$. At this stage, we have a standardized decision making matrix like below:

$$R = \begin{pmatrix} x_{11} & x_{12} \cdots & x_{1n} \\ x_{21} & \ddots & \vdots \\ \vdots & & \\ x_{m1} & \cdots & x_{mn} \end{pmatrix} \tag{15}$$

2.5 Grey- ELECTRE Method

The ELECTRE[1] method was introduced by Benayoun and his colleagues for the first time [26]. Others developed this method [27,28,29]. In this paper we use this method on three parameter interval grey numbers (Grey-ELECTRE).

Grey-ELECTRE has the following steps:

Step 1- Calculate the normalized decision matrix

Step 2- Calculate the weighted normalized decision matrix

$$\begin{aligned} V &= [v_{ij}] \\ v_{ij} &= x_{ij} * w_j \end{aligned} \tag{16}$$

Step 3- Determine the concordance and discordance set

The concordance set C_{kl} of A_k and A_l is composed of all the criteria for which A_k is preferred to A_l. In other words,

$$C_{kl} = \{ j \mid x_{kj} \ge x_{lj} \} \tag{17}$$

The complementary subset is called the discordance set, which is

$$D_{kl} = \{ j \mid x_{kj} < x_{lj} \} \tag{18}$$

Step 4- Calculate the concordance matrix

Member of this matrix is obtained by formulae 19.

$$I_{kl} = \sum w_j ;\ j \in A_{k,l} \tag{19}$$

Then, this matrix is similar to formulae 20

$$I = \begin{bmatrix} - & I_{12} & I_{13} \cdots & I_{1m} \\ I_{21} & - & I_{23} \ \cdots & I_{2m} \\ . & & & \\ . & & & \\ . & & & \\ I_{m1} & I_{m2} & \ldots I_{m(m-1)} & - \end{bmatrix} \tag{20}$$

Step 5- Calculate the discordance matrix

The member of this matrix is obtained by

1. ELimination and Choice Expressing REality

$$NI_{kl} = \frac{Max\left\{\sqrt{(\underline{v}_{kj}-\underline{v}_{lj})^2+(\tilde{v}_{kj}-\tilde{v}_{lj})^2+(\overline{v}_{kj}-\overline{v}_{lj})^2}\right\},\ j\in D_{k,l}}{Max\left\{\sqrt{(\underline{v}_{kj}-\underline{v}_{lj})^2+(\tilde{v}_{kj}-\tilde{v}_{lj})^2+(\overline{v}_{kj}-\overline{v}_{lj})^2}\right\},\ j\in\left(all\cdot of\cdot criterias\right)} \quad (21)$$

Then this matrix is like

$$NI = \begin{bmatrix} - & NI_{12} & NI_{13}\ldots & NI_{1m} \\ NI_{21} & - & NI_{23} & \ldots NI_{2m} \\ . & & & \\ . & & & \\ . & & & \\ NI_{m1} & NI_{m2} & \ldots\ NI_{m(m-1)} & - \end{bmatrix} \quad (22)$$

Step 6- Determine the concordance dominance matrix

The threshold value is obtained by

$$\overline{I} = \sum_{l=1}^{m}\sum_{k=1}^{m} I_{kl} \,/\, m(m-1) \quad (23)$$

Then the concordance dominance matrix H is structured by the two following formulae.

$$\begin{aligned} I_{kl} \geq \overline{I} &\rightarrow H_{kl} = 1 \\ I_{kl} < \overline{I} &\rightarrow H_{kl} = 0 \end{aligned} \quad (24)$$

Step 7- Determine the discordance dominance matrix

The threshold value can be obtained by

$$\overline{NI} = \sum_{l=1}^{m}\sum_{k=1}^{m} NI_{kl} \,/\, m(m-1) \quad (25)$$

Then, the discordance dominance matrix G is structured by

$$\begin{aligned} NI_{kl} \geq \overline{NI} &\rightarrow G_{kl} = 0 \\ NI_{kl} < \overline{NI} &\rightarrow G_{kl} = 1 \end{aligned} \quad (26$$

Step 8- Determine the aggregate dominance matrix

In this step, member of the aggregate dominance matrix F is obtained by

$$F_{kl} = H_{kl}.G_{kl} \quad (27)$$

Step 9- Eliminate the less favorable alternatives

If $F_{lk} = 1$, then A_k is preferred to A_l for both the concordance and discordance criteria.

3. RESEARCH METHODOLOGY

At first, we gathered the goals under four perspectives of BSC and then changed the linguistic variables to three parameter interval grey numbers. After calculating weights of each perspective using SMARTER method, we used them as subjective weights in Entropy method. It is then possible to extract final weights of every perspective from Entropy method. Finally, we utilized Grey-ELECTRE method for ranking and selection of the best ERP system. This methodology is depicted at Figure 3.

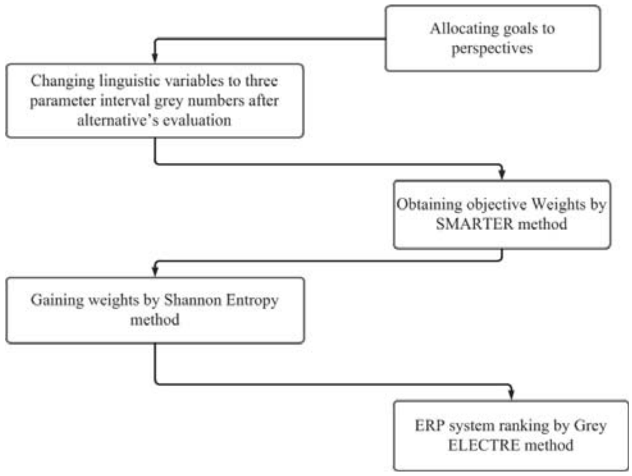

Figure 3. Research methodology

4. CASE STUDY

An Iranian manufacturer would like to prepare an ERP system. They made this decision to reach some goals that is shown in Table 1. They arranged these goals by consulting experts.

Table 1. Goals and their own perspectives

Aspects	Goals
Financial	Efficiency increasing
	Costs optimizing
	Achive to competetive price
Customer	Costomer satisfaction
	Customer Holding
	New Market Recognition
Internal business process	Adoptability
	Flexibility
	Standard of Production
	Quality
Learning and growth	Supporting
	Traning

Using experts' ideas, the gathered alternatives and their values are shown in Table 2. According to experts, some alternatives that were ranked higher are shown in Table 2 among ERP software.

Table 2. Alternatives and their values

	Financial	Customer	Internal business process	Learning and growth
Oracle	Medium	Weak	Very strong	Weak
Sage	Strong	Medium	Strong	Medium
MFG	Medium	Strong	Weak	Medium

Linguistic variable are changed to three parameter interval grey number by Table 3.

Table 3. Linguistic variables and their equivalent in three parameter interval grey number

Very weak	(0.0,0.1,0.2)
Weak	(0.2,0.3,0.4)
Medium	(0.4,0.5,0.6)
Strong	(0.6,0.7,0.8)
Very strong	(0.8,0.9,1.0)

We obtained the weights of every perspective by SMARTER method and then calculated the final weights using Entropy method. These weights are shown in Table 4.

Table 4. SMARTER Weights and Entropy Weights

	Financial	Customer	Internal business process	Learning and growth
SMARTER Weights	0.27	0.52	0.07	0.14
Entropy Weights	0.0861	0.6856	0.1424	0.0860

Finally, we gain aggregate dominance matrix by Grey-ELECTRE method shown in Table 5.

Table 5. Aggregate dominance matrix

	Oracle	Sage	MFG
Oracle	0	0	0
Sage	1	0	0
MFG	1	1	0

Therefor MFG is the best alternative, Sage is the second and Oracle is the third.

5. CONCLUSION

In this paper, we discussed the application of a new multi criteria decision-making (MCDM) model for enterprise resource planning (ERP) selection based on Balanced Score Card (BSC). Also, we explained the concept of three-parameter interval grey numbers which is derived from Grey theory. Grey theory plays an important role in uncertain conditions. These numbers are used instead of linguistic variables in order to reduce uncertainty. Besides, we introduced a new weighting method which results from combination of SMARTER and Entropy method. The new method can reduce and control risk conditions. A new ranking method namely Grey ELECTRE method that is a generalization of ELECTRE I for three parameter interval grey numbers are used in this paper. Finally, the authors discussed an industrial case study for ERP selection to show how this model works.

REFERENCES

[1] Yuan, L., Xiu Wu, L., & Hong Zhen, L. (2006). A Knowledge Management System for ERP Implementation,. *Systems Research and Behavioral Science*, Vol. 23, pp. 157.

[2] Umble, E., Haft, R., & Umble, M. (2003). Enterprise Resource Planning: Implementation Procedures and Critical Success Factors. *European Journal of Operational Research,* Vol. 146, pp. 241–257.

[3] Chang, T.-H., Hsu, S.-C., Wang, T.-C., & Wu, C.-Y. (2012). Measuring the Success Possibility of Implementing ERP by Utilizing the Incomplete Linguistic Preference Relations. *Applied Soft Computing,* Vol. 12, pp. 1582–1591.

[4] Gürbüz, T., Alptekin, S. E., & Alptekin, G. I. (2012). A Hybrid MCDM Methodology for ERP Selection Problem with Interacting Criteria. *Decision Support Systems*.

[5] Davenport, T. (1998). Putting the Enterprise into the Enterprise System. *Harvard Business ness Review,* Vol. 76, No. 4, pp. 121-131.

[6] Hallikainen, P., Kimpimaki, H., & Kivijarvi, H. (2006). Supporting the Module Sequencing Decision in the ERP Implementation Irocess. *39th Hawaii international conference on system sciences.* Hawaii .

[7] Liao, X., Li, Y., & Lu, B. (2007). A Model for Selecting an ERP System Based on Linguistic Information Processing. *Information Systems,* Vol. 32, pp. 1005–1017.

[8] Yazgan, H. R., Boran, S., & Goztepe, K. (2009). An ERP Software Selection Process with Using Artificial Neural Network Based on Analytic Network Process Approach. Expert Systems with Applications, Vol. 36, No.5, pp. 9214–9222.

[9] Chang, C.-W., Wu, C.-R., Lin, C.-T., & Lin, H.-L. (2007). Evaluating Digital Video Recorder Using

Analytic Hierarchy and Analytic Network Processes. *Information Sciences,* Vol. 177, No. 16, pp. 3383–3396.

[10] Wei, C., Chien, C., & Wang, M. (2005). An AHP-based Approach to ERP System Selection. *International Journal of Production Economics,* Vol. 96, No.1, pp. 47-62.

[11] Cebeci, F. (2009). Fuzzy AHP-based Decision Support System for Selecting ERP Systems in Textile Industry by Using Balanced Scorecard. *Expert Systems with Applications,* Vol. 36, No. 5, pp. 8900-8909.

[12] Bernroider, W.N., & Stix, V. (2006). Profile Distance Method-A Multi-attribute Decision Making Approach for Information System Investments. *Decision Support Systems,* Vol. 42, No. 2, pp. 988-998.

[13] Ravi, V., Shankar, R., & Tiwari, M. K. (2005). Analyzing Alternatives in Reserve Logistics for End-of-life Computers: ANP and Balanced Scorecard Approach. *Computers and Industrial Engineering,* Vol. 48, No. 2, pp. 327-356.

[14] Bititici, U., Cavalieri, S., & Cieminski, G. (2005). Editorial: Implementation of Performance Measurement Systems: Private and Public Sectors. *Production Planning and Control,* Vol. 16, No. 2, pp. 99-100.

[15] Kaplan, R., & Norton, D. (1992). The Balanced Scorecard: Measures That Drive Performance. *Harvard Business Review,* Vol. 70, No. 1, pp. 71-99.

[16] Kaplan, R., & Norton, D. (1996). Using the Balanced Scorecard as a Strategic Management System. *Harvard Business Review,* Vol. 74, No. 1, pp. 75-85.

[17] Kumar, S., & Bhagwat, R. (2007). An Integrated BSC-AHP Approach for Supply Chain Management Evaluation. *Measuring Business Excellence,* Vol. 11, No. 3, pp. 57 - 68.

[18] Malmi, T. (2001). Balanced Scorecards in Finnish Companies: a Research Note. *Management Accounting Research,* Vol. 12, Vo. 2, pp. 207-20.

[19] Martinsons, M., Davison, R., & Tse, D. (1999). The Balanced Scorecard: a Foundation for the Strategic Management of Information Systems . *Decision Support Systems,* Vol. 25, No. 1, pp. 71-88.

[20] Edwards, W., & Barron, F. (1994). Smarts and Smarter: Improved Simple Methods for Multiattribute Utility Measurement. *Organizational Behavior and Human Decision,* Vol. 60, No. 3, pp. 306-325.

[21] Shannon, C. E., & Weaver, W. (1947). *The Mathematical Theory of Communication,.* Urbana: University of Illinois Press.

[22] Hwang, C., & Yoon, K. (1970). *Multiple Attribute Decision Making,Methods and Applications.* Berlin: Springer-verlag.

[23] Deng, J. (1989). The Introduction of Grey System. *The Journal of Grey System,* Vol. 1, No. 1, pp. 1–24.

[24] Deng, J. (2002). *Grey System Theory.* Wuhan: Huazhong University of Science and Technology Press.

[25] Liu, S. F. (2005). *Grey System Theory and Application.* Beijing: Science Press.

[26] Benayoun, R., Sussman, B., & Roy, B. (1966). *Manual de Reference du Programme ELECTRE.* Paris: Direction Scientifique SEMA.

[27] Nijkamp, P. (1974). A Multicriteria Analysis for Project Evaluation: Economic-Ecological Evaluation of a Land Reclamation Project. *Papers of Regional Associations,* Vol. 35, pp. 87-111.

[28] Roy, B. (1971). Problems and Method with Multiple Objective Functions. *Mathematical Programming,* Vol. 1, No. 2, pp. 239-266.

[29] van Delft, A., & Nijkamp, P. (1976). A Multi-Objective Decision Model for Regional Development, Environmental Quality Control and Industrial Land Use. *Papers of the Regional Science Association,* Vol. 36, No. 1, pp. 35-57.