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A Hybrid Grey-Game-MCDM Method for ERP Selecting Based on BSC

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ABSTRACT: An enterprise resource planning (ERP) software is needed for industries and companies that want to develop in future. Many of the manufactures and companies have a problem with ERP software selection. An inappropriate selection process can affect both the implementation and the performance of the company significantly. Although several models are proposed to solve this problem many of them did not consider uncertainty as an effective environmental factor. In the current paper a new model is designed. This model is based on balanced score card (BSC) and in addition, uncertainty is considered. This paper used three-parameter interval grey numbers concept that derived from Grey-theory in order to reduce uncertainty. Beside, hybrid model for weighting based on Shapley and Entropy methods are used. This combination approach is also because of reducing uncertainty. And at the end, a new method named projection attribute function method is used for ranking. There is a case study at the end of this paper that shows how this model works.

Keywords: *Balanced Score card (BSC), Enterprise resource planning (ERP), Projection attribute function method, Shannon entropy, Shapley value*

INTRODUCTION

Nowadays modern organizations operate in an economic environment where customer demands are continuously change and increases as there are unpleasant conditions (Yazgan et al., 2009). These organizations strive to reduce total cost through supply chain, production cycle, and inventory. Additionally, they request increasing diversity of products, more accurate delivery dates and coordinating the supply and production effectively (Xiuwu, et al., 2007).

An enterprise resource planning (ERP) system is an information system that is designed in order to plan and integrate all of an enterprise's subsystems including production, sales, purchase and finance (Gürbüz et al., 2012). An ERP system typically implements a common enterprise-wide database together with a range of application modules (Davenport, 1998). Though an ERP system is costly and complex, but it is vital for companies to face the rapidly changing and competitive business environment (Chang et al., 2012).

The offered ERP software packages cannot provide a once-for-all business model for each process of all companies. In other words, no single ERP packaged software can meet all company functionalities or all special business requirements (Wei et al., 2005). ERP software automates and integrates business processes and allows information sharing in different business functions. In addition ERP software supports the finance, human resource, operations and logistic, sale and market. At the same time it improves the performance of organization's functions by

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controlling them (Hallikainen, et al., 2006).An inappropriate selection process can significantly affect not only the implementation but also the performance of the company (Cebeci, 2009).

ERP selection problem was studied in many papers and several models were introduced. For example, Wei and others presented an ERP selection model based on AHP (Wei051). They proposed two main attributes, suitable system and suitable salesman. Cebeci was presented a model to select an ERP system for textile industries with BSC approach (Cebeci, 2009). Another model that is used to integrate QFD, fuzzy linear regression and 0–1 goal programming was presented by Bernroider and Stix to solve ERP selection problem (Bernroider and Stix, 2006). Also an ANP model for ERP software selection problem with BSC approach was developed by Ravi and his college (Raviet al., 2005).

A hybrid model based on Game-Entropy-projection attribute function method over three parameter interval grey numbers with BSC approach is introduced in the present paper. Combination of Game and Entropy method is used to weight the criteria in uncertain conditions. This combination method can cover weaknesses of each method in compared to a time when they are used separately. Besides, three-parameter interval grey numbers concept that extracted from Grey system theory is used to change linguistic variables into quantitative types. At last, a case study of an Iranian manufacture is brought to show how this model works.

Preliminaries

BSC

The need for performance measurement systems at different levels of decision making, either in the industry or service contexts, is undoubtedly not something new (Bititici, Cavalieri, & Cieminski, 2005)BSC have been proposed by Kaplan and Norton (Kaplan and Norton, 1992) (Kaplan and Norton, Using the balanced scorecard as a strategic management system, 1996) This means evaluates performance by four different perspectives: the financial, the internal business , the customer, and the innovation and learning (Kumar and Bhagwat, 2007). These perspectives are shown in figure 1.

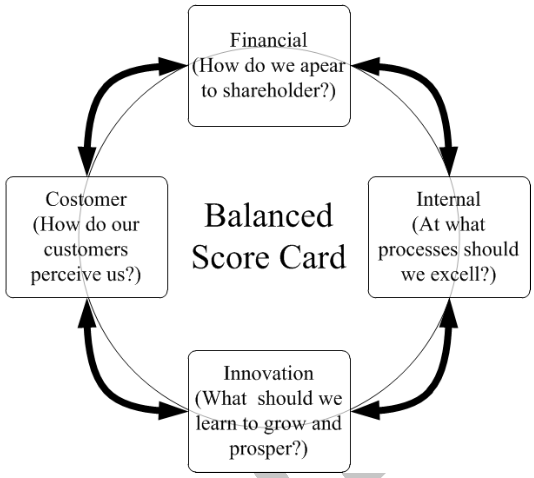

Figure 1: Four perspectives of BSC

The BSC seems to serve as a control panel, pedals and steering wheel (Malmi, 2001). Many companies are adopting the 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 and towards growth opportunities based on more customized, value-adding products and services (Martinsons et al., 1999).

Three Parameter Interval Gray Numbers

Grey system theory was introduced by J. Deng (Deng, 2002) (Deng, The introduction of grey system, 1989) and was extended by others (Liu et al., 2005). In abbreviation, If black represents the information that is completely unknown and white represents the data that is quite clear, gray is other information that somewhat are clear and somewhat are unclear. A system which contains gray Information is called Gray-system. Figure 2 shows the concept of Gray system.

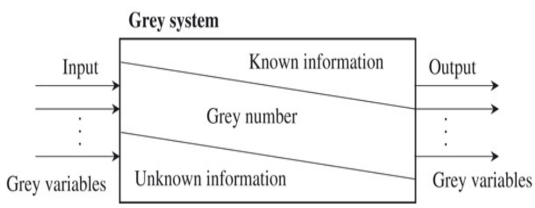

Figure 2: Concept of grey system

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

Operators of Three Parameter Interval Grey Numbers

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

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

$$a(\otimes) / b(\otimes) \in [\min\{\underline{a}/\underline{b}, \underline{a}/\overline{b}, \overline{a}/\underline{b}, \overline{a}/\overline{b}\}, \tilde{a}/\tilde{b}, \max\{\underline{a}/\underline{b}, \underline{a}/\overline{b}, \overline{a}/\underline{b}, \overline{a}/\overline{b}\}$$

Decision Making Matrix Normalization

Assume our decision making matrix is like below:

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

We use the following method for matrix normalization that is named poor transform method.

Desired value for efficiency

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

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

And desired value for costing

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

At the above equations,

$$\overline{u}_j^{*} = \max_{1 \le i \le n}\{\overline{u}_{ij}\}, \underline{u}_j^{\nabla} = \min_{1 \le i \le n}\{\underline{u}_{ij}\}.$$

When $\overline{u}_j^{*} - \underline{u}_j^{\nabla} = 0$, then we can eliminate this atribute from decision making matrix, because it is an effectless parametre.

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

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

Cooperative Game and Shapley Value

Game theory is rapidly becoming established as one of the cornerstones of the social sciences (Shaun and Varoufakis, 1995). This branch is the study of multi person decision problems (Gibbons, 1992) which they can have coalition (cooperative game) or not (non-cooperative game).

Cooperative game in the characteristic function form (also called a TU-game) is a function $v: 2^n \rightarrow \mathbb{R}$ with a finite set N as the grand coalition of the players. For each coalition S (a subset of N), v(S) represents the worth of S (the gain possible to be achieved jointly by all the players from S when they collaborate) (Radzik, 2012).

The Shapley value (Aumann and Shapley, 1974) (Shapley, 1953) is a well-known solution concept in cooperative game theory. Imagine the situation where if some players (for example some economic agents) make up a cooperative relationship, (i.e., a coalition) then they can get more gains than those if they do not do so. In such situations, one of their interests is how much share can be got by each of them when the coalitions are forming. The Shapley value shows a vector whose elements are agents' share derived from several reasonable bases (Tsurumi et al., 2001).

Denoting $\Phi = (\square_1(v), \square_2(v), \ldots, \square_n(v))$ as an allocation scheme, the Shapley value is denoted by the condition:

$$\otimes_i(v) = \sum_{\substack{S \subseteq N \\ i \in S}} \frac{(|s|-1)!(n-|s|)!}{n![v(s) - v(s[i])}$$

where S is any available coalition of N, |S| is the number of the players in the coalition. v (S \ {i}) is the characteristic function of the coalition S except i (Barron, 2008).

Shannon Entropy Method

This measure of uncertainty is given by Shannon (Shannon and Weaver, 1947) as

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

K is a positive constant here.

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 (Hwang and Yoon, 1970):

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

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

The project outcomes of attribute j can be defined as

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}$$

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

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

k is a constant as:

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

this 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

$$d_j = 1 - E_j$$

Then the weights of attributes can be obtained by

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j}$$

If the DM has a prior, subjective weight λ_j, then this can be adapted in a new form

$$w_j' = \frac{\lambda_j w_j}{\sum_{j=1}^{n} \lambda_j w_j}$$

In this paper weights of attributes are gained from lower band, gravity and upper band matrix separately. Then the mean value of weights that outcomes from each matrix is considered as weights of every attributes.

Method of Projection Attribute Function

Denote

$$\underline{x}_j^+ = \max\{\underline{x}_{ij}\}, \overline{x}_j^+ = \max\{\tilde{x}_{ij}\}, \underline{x}_j^- = \min\{\underline{x}_{ij}\}, \tilde{x}_j^- = \min\{\tilde{x}_{ij}\}, \overline{x}_j^- = \min\{\overline{x}_{ij}\}$$

Definition: Suppose evaluation vector of alternatives is denoted by

$$x_i(\otimes) = (x_{i1}(\otimes), x_{i2}(\otimes), ..., x_{im}(\otimes)), i = 1, 2, ..., n \quad (1)$$

Then the m dimension three-parameter nonnegative interval grey number vectors

$$x^+(\otimes) = (x_1^+(\otimes), x_2^+(\otimes), ..., x_m^+(\otimes)), i = 1, 2, ..., n$$
$$x^-(\otimes) = (x_1^-(\otimes), x_2^-(\otimes), ..., x_m^-(\otimes)), i = 1, 2, ..., n$$

are called ideal optimal alternative evaluation vector and critical alternative evaluation vector, respectively, in which

$$x^+(\otimes) \in [\underline{x}_j^+, \tilde{x}_j^+, \overline{x}_j^+], x^-(\otimes) \in [\underline{x}_j^-, \tilde{x}_j^-, \overline{x}_j^-] \text{for } j = (1, 2, \ldots, m)$$

For the sake of simplicity, the normalized evaluation vector of A by (1) can be rewritten as the following decision making matrix

$$x^+(\otimes) = (x^+_{kj})_{3\times m} = \begin{bmatrix} x^+_{11} & x^+_{12} & \cdots & x^+_{1m} \\ x^+_{21} & x^+_{22} & \cdots & x^+_{2m} \\ x^+_{31} & x^+_{32} & \cdots & x^+_{3m} \end{bmatrix} \quad (2)$$

$$x^-(\otimes) = (x^-_{kj})_{3\times m} = \begin{bmatrix} x^-_{11} & x^-_{12} & \cdots & x^-_{1m} \\ x^-_{21} & x^-_{22} & \cdots & x^-_{2m} \\ x^-_{31} & x^-_{32} & \cdots & x^-_{3m} \end{bmatrix} \quad (3)$$

Which

$$x^+_{ij} = \underline{x}^+_j, x^+_{2j} = \tilde{x}^+_j, x^+_{3j} = \overline{x}^+_j, x^-_{1j} = \underline{x}^-_j, x^-_{2j} = \tilde{x}^-_j, x^-_{3j} = \overline{x}^-_j, j = 1,2,\dots,m$$

Assume $w_j (j = 1,2,...,m)$ are weights of attributes, for any i=1,2,…,n, denote

(4)

$$z(i)^-_1 = \sum_{j=1}^{m} w_j (x_{i1j} - x^-_{1j})^2, z(i)^-_2 = \sum_{j=1}^{m} w_j (x_{i2j} - x^-_{2j})^2, z(i)^-_3 = \sum_{j=1}^{m} w_j (x_{i3j} - x^-_{3j})^2$$

$$z(i)^+_1 = \sum_{j=1}^{m} w_j (x_{i1j} - x^+_{1j})^2, z(i)^+_2 = \sum_{j=1}^{m} w_j (x_{i2j} - x^+_{2j})^2, z(i)^+_3 = \sum_{j=1}^{m} w_j (x_{i3j} - x^+_{3j})^2$$

Definition: Suppose standard evaluation vectors for any alternative, ideal optimal alternative and critical alternative are given by (2) and (3), $Z(i)^-_k, Z(i)^+_k (i = 1,2,..,n; k = 1,2,3)$ are given by (4), denote

$$z(\acute{\imath}) = [(1 \acute{-} \varepsilon) z(i)^-_1 + z(i)^-_2 + z(i)^-_3]^{1/2} + [(1 \acute{-} \varepsilon) z(i)^+_1 + z(i)^+_2 + z(i)^+_3]^{1/2}$$

Then

$$z(i) = \frac{[(1 \acute{-} \varepsilon) z(i)^-_1 + z(i)^-_2 + z(i)^-_3]^{\frac{1}{2}}}{\acute{z}(i)} \quad i = (1,2,\dots,m)$$

is called projection function value of evaluation vector $x_i(\otimes)$, in which $\varepsilon \in [0,1]$ is preference coefficient. The projection function value $Z(i)$ characterizes the relative closeness of evaluation vectors between $x_i(\otimes)$ for alternative $A(i)$ and $x^+(\otimes)$ (ideal optimal alternative) and for alternative $A(i)$ and $x^-(\otimes)$ (critical alternative) (Dang, 2009).

RESEARCH METHODO

In this section the method that used in this paper is explained.

At the beginning, the goals are allocated to perspectives of BSC. Then linguistic variables are changed to three parameter interval grey numbers. Next each perspectives weight is obtained by Shapley method and these values are used as objective weights in Entropy method. Then the final weights of each perspective come from Entropy method. At the end, projection attribute function method is used to rank and select the best ERP system. This methodology is depicted in figure 3.

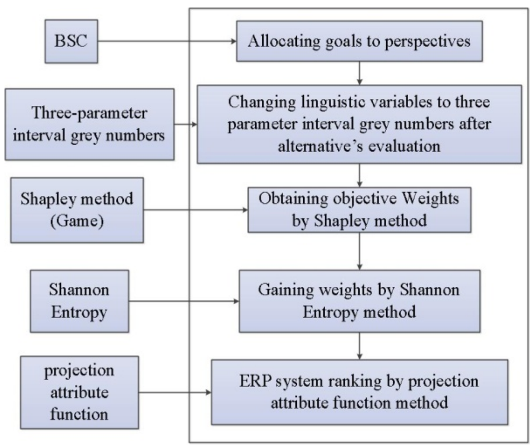

Figure 3: Research method

Case Study and Results

One of the manufactures in I.R. Iran would purchase an ERP system. This decision was made in order to satisfy some goals. Goals and their own perspectives are shown in table 1.

The alternatives and their values are gathered by consultation with 31 information systems experts. These are showed in table 2.

Linguistic variables were changed to three parameter interval grey numbers by table 3.

Table 1: Goals and their own perspectives

Aspects	Goals
Financial	Efficiency Increasing
	Costs Optimizing
	Achive to Competetive Price
Customer	Costomer Satisfaction
	Customer Holding
	Comfortable Access
	New Market Recognition
Internal business process	Adoptability
	Flexibility
	Standard of Production
	Quality Increasing
	Safety and Security
Learning and growth	Supporting
	Traning
	Knowledge Based Process

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

Table 3: Linguistic variables and their equal three parameter interval grey numbers

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)

The weight of every aspect from coalition values (table 4) was obtained by Shapley method. These weights were used as objective weights in Entropy method.

Every aspect's weights were calculated by Entropy method (table 5).

Then the alternatives ranks were gained by projection attribute function method. This is shown in table 6.

CONCLUSION

In this paper a new model was presented for ERP software selection. Enterprise resource planning (ERP) software selection is known as a multi-criteria decision making (MCDM) problem. The proposed model considers uncertainty with the use of three-parameter interval grey numbers and a weighting hybrid model. This hybrid model that is the result of Shapley (cooperative game) and Entropy combination can reduce uncertainty that comes from decision making model. Projection attribute function method is used in order to rank alternatives. This method is a new one that used over three-parameter interval grey numbers. An industrial case study was presented at the end to show how this model can work.

Table 4: Coalition values

V({})=V({Financial})=V({Customer})=V({Internal business process })=V({Learning and growth })=0
V({Financial,Customer})=0.15,V({Financial, Internal business process })=0.18,V({Financial, Learning and growth })=0.24,V({Customer, Internal business process})=0.22,V({Customer, Learning and growth})=0.27,V({Internal business process, Learning and growth })=0.29
V({Financial, Customer, Internal business process })=0.35,V({Financial, Customer, Learning and growth})=0.43,V({Financial, Internal business process, Learning and growth})=0.47,V({Customer, Internal business process, Learning and growth})=0.42
V({Financial, Customer, Internal business process, Learning and growth})=1

Table 5: Shapley weights and entropy weights

	Financial	Customer	Internal business process	Learning and growth
Shapley	0.23	0.23	0.25	0.29
Entropy Weights	0.0690	0.2853	0.4782	0.1675

Table 6: Projection function values and rank of each alternative

Alternative	projection function value	Rank
Oracle	0.6387	2
Sage	0.6410	1
MFG	0.3536	3

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