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An ERP Selection Combination Model under Uncertainty: A Grey-BSC-AHP-Entropy Model

M. H. Kamfiroozi[1,*], **A. Bonyadi Naeini**[2]

[1] Department of Industrial Enginering, Iran University of Science and Technology, Tehran, Iran.

[2] School of management and progress engineering, Iran University of Science and Technology, Tehran, Iran.

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A B S T R A C T

An enterprise resource planning (ERP) software can help organizations and firms in their activities like: production planning, purchase, human resource, finance, sales, inventory control and etc. Selection of an ERP is mentioned as a multi-criteria decision making (MCDM) problem. However, several MCDM-models are proposed to solve this, but many of them didn't consider uncertainty as an effective environmental factor. In this paper, a new model has designed which used three-parameter interval grey numbers concept that is derived from Grey-theory. These numbers can help for reducing the uncertainty of data. Besides, a combination model for weighting has planned by implementing AHP and Entropy methods that are used in order to reduce uncertainty. And last, a decision making method (Three-parameter grey interval incidence degree method) is used for ranking process. There is a case study at the end of this paper that shows how this model works..

1. Introduction

Today organizations operate in an economic environment where customer demands are continuously changing and increasing [1]. 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 coordination the supply and production effectively [2]. 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 finance [3]. An ERP system typically implements a common enterprise-wide database together with a range of application modules [4]. The offered ERP software packages cannot provide a once-for-all business model for every process of all industries. In other words, no single ERP packaged software can meet all company functionalities or all special business requirement s [5]. ERP software automates and integrates business processes and allows information sharing in different business functions. In addition that ERP software

*Corresponding author
E-mail address: mohammad.kamfirozi@iustn.ac.ir

supports the finance, human resource, operations and logistic, sale and market in functions through more effected and productive business processes. At the same time it improves the performance of organization's functions by controlling them [6].

ERP field was considered in many papers. Nikookar et al investigated and determined the competitive environment of ERP vendors implementing their product in Iranian context [7].Lopez and Salmeron studied the risks in ERP maintenance projects by using Fuzzy Cognitive Map (FCM)[8]. Ram et al built a conceptual model to investigate the relationship between critical success factors related to the implementation of ERP software and the goal of competitive advantage [9]. Rouhani and Ravasan discussed on the idea of predicting ERP post-implementation success based on organizational profiles. They developed an expert system by exploiting the Artificial Neural Network (ANN) method to articulate the relationships between some organizational factors and ERP success [10].Munir ahmad and Cuenca discussed on critical success factors for ERP implementation in SMEs [11].

Some other researchers developed models for selecting ERP software. They used fuzzy system, Balanced score card (BSC), AHP method, Goal programming and etc. Some of these studies is observable in Table 1.

Table 1. Literature review on ERP selection problem

Researcher(s)	Year	Model
Ertugrul Karsak ans Okan Özogul	2009	They develped a novel decision framework for ERP software selection based on quality function deployment (QFD), fuzzy linear regression and zero–one goal programming.[12]
Wei, Chien and Wang	2005	presented an ERP selection model based on AHP. They proposed two main attributes, suitable system and suitable salesman[5].
Cebeci	2009	He introduced a model to select an ERP system for textile industries with BSC approach[13].
Bernroider & Stix	2006	They used integrating of QFD, fuzzy linear regression and 0–1 goal programming to solve ERP selection problem [14].
Ravi et al	2005	They developed ANP model for ERP software selection problem with BSC approach[15].
Hakim and Hakim	2010	They have tried to provide a suitable and practical model for decision-makers to take precise steps in implementing ERP systems, through reviewing the intra- and extra-organizational limitations. Their model tested and simulated in Bahman motor company[16]
Khaled and Idrissi	2012	They proposed a semi-structured approach for ERP system selection. They used the approach consists of an iterative selection process model and an evaluation methodology based on 0-1 linear programming and MACBETH technique to elaborate multi-criteria performance expressions[17]
Kamfiroozi, Aliahmadi and Jafari	2012	They used SMARTER and Shannon Entropy methods and ELECTRE ranking method to select the best ERP[18].
Kamfiroozi and Bonyadi	2013	They used a hybrid grey-game-MCDM gethod for Selecting ERP[19].

In this paper an integrated model based on AHP-Entropy-Grey incidence method for three parameter interval grey numbers with BSC approach is presented. The combination of AHP-Entropy method is used to weight the Attributes in uncertain conditions. Besides, three parameter interval grey numbers that derived from Grey system theory is implemented to change linguistic variables to quantitative type. At last a case study is brought to show how this model works.

2. Preliminaries

2.1.Three parameter interval gray numbers

Grey system theory was first proposed by Deng [20, 21] and was extended by others [22]. If black represents the information that is completely unknown and white represents the data that is quite clear, gray is the other information that somewhat are clear and somewhat are unclear. A system which contains gray Information is called Gray-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, $\tilde{a}$ is center of gravity (the number has the highest possibility) and $\overline{a}$ is upper bound. When the center of gravity is not determined, we face with the typical gray-numbers.

2.1.1 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

$$a(\otimes) + b(\otimes) \in [\underline{a} + \underline{b}, \tilde{a} + \tilde{b}, \overline{a} + \overline{b}] \quad (1)$$

$$a(\otimes) / b(\otimes) \in [\min\{\underline{a}/\underline{b}, \underline{a}/\overline{b}, \overline{a}/\underline{b}, \overline{a}/\overline{b}\}, \tilde{a}/\tilde{b}, \max\{\underline{a}/\underline{b}, \underline{a}/\overline{b}, \overline{a}/\underline{b}, \overline{a}/\overline{b}\}] \quad (2)$$

2.1.2 Decision making matrix normalization

Assume our decision making matrix is like below:

$$S = \{u_{ij}(\otimes) \,|\, u_{ij}(\otimes) \in (\underline{u}_{ij}, \tilde{u}_{ij}, \overline{u}_{ij}), 0 \le \underline{u}_{ij} \le \tilde{u}_{ij} \le \overline{u}_{ij}, i = 1, 2, ..., n, \ j = 1, 2, ..., m\} \quad (3)$$

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

Desired value for efficiency

$$\overline{x}_{ij} = \frac{\overline{u}_{ij} - \underline{u}_j^{\nabla}}{\overline{u}_j^{*} - \underline{u}_j^{\nabla}} \qquad \tilde{x}_{ij} = \frac{\tilde{u}_{ij} - \underline{u}_j^{\nabla}}{\overline{u}_j^{*} - \underline{u}_j^{\nabla}} \qquad \underline{x}_{ij} = \frac{\underline{u}_{ij} - \underline{u}_j^{\nabla}}{\overline{u}_j^{*} - \underline{u}_j^{\nabla}} \quad (4)$$

Desired value for costing

$$\overline{x}_{ij} = \frac{\overline{u}_j^{*} - \underline{u}_{ij}}{\overline{u}_j^{*} - \underline{u}_j^{\nabla}} \qquad \tilde{x}_{ij} = \frac{\overline{u}_j^{*} - \tilde{u}_{ij}}{\overline{u}_j^{*} - \underline{u}_j^{\nabla}} \qquad \underline{x}_{ij} = \frac{\overline{u}_j^{*} - \overline{u}_{ij}}{\overline{u}_j^{*} - \underline{u}_j^{\nabla}} \quad (5)$$

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 parameter.

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

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

2.2.Three-parameter grey interval incidence degree method(GID Method)

This method was purposed by Dang [23].

Denote

$$\underline{x}_j^+ = \max_i\{\underline{x}_{ij}\}, \tilde{x}_j^+ = \max_i\{\tilde{x}_{ij}\}, \overline{x}_j^+ = \max_i\{\overline{x}_{ij}\}, \underline{x}_j^- = \min_i\{\underline{x}_{ij}\}, \tilde{x}_j^- = \min_i\{\tilde{x}_{ij}\}, \overline{x}_j^- = \min_i\{\overline{x}_{ij}\} \quad (6)$$

Definition1: Suppose evaluation vector of alternatives is denoted by

$$x_i(\otimes) = (x_{i1}(\otimes), x_{i2}(\otimes), ..., x_{im}(\otimes)), i = 1, 2, ..., n \quad (7)$$

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

$$x^+(\otimes) = (x_1^+(\otimes), x_2^+(\otimes), ..., x_m^+(\otimes)), i = 1, 2, ..., n \quad (8)$$

$$x^-(\otimes) = (x_1^-(\otimes), x_2^-(\otimes), ..., x_m^-(\otimes)), i = 1, 2, ..., n \quad (9)$$

Be called ideal optimal alternative evaluation vector and critical alternative evaluation vector, respectively, in which $x^+(\otimes) \in [\underline{x}_j^+, \tilde{x}_j^+, \overline{x}_j^+], x^-(\otimes) \in [\underline{x}_j^-, \tilde{x}_j^-, \overline{x}_j^-](j = 1, 2, ..., m)$.

Definition2: Suppose three-parameter grey interval incidence degree of normalized evaluation vector $x_i(\otimes)$ with respect to ideal optimal alternative evaluation vector $x^+(\otimes)$ be $G(x^+(\otimes), x_i(\otimes))$, be $G(x^-(\otimes), x_i(\otimes))$ with respect to critical alternative evaluation vector $x^-(\otimes)$, and weight of two grey incidence degree are β_1, $\beta_2(\beta_1 + \beta_2 = 1)$, then call

$$G(x_i(\otimes)) = \beta_1 G(x^+(\otimes), x_i(\otimes)) + \beta_2\left[1 - G(x^-(\otimes), x_i(\otimes))\right], i = 1, 2, ..., n \quad (10)$$

The three-parameter grey interval incidence linear degree of $x_i(\otimes)$, and call

$$G(x_i(\otimes)) = G(x^+(\otimes), x_i(\otimes))^{\beta_1} . \left[1 - G(x^-(\otimes), x_i(\otimes))\right]^{\beta_2}, i = 1, 2, ..., n \quad (11)$$

The three-parameter grey interval incidence product degree of $x_i(\otimes)$

Above equations are arithmetic mean and geometric mean, respectively, when $\beta_1 = \beta_2 = 0.5$.

Denote

$$\underline{\Delta}_{ij}^+ = |\underline{x}_j^+ - \underline{x}_{ij}|, \tilde{\Delta}_{ij}^+ = |\tilde{x}_j^+ - \tilde{x}_{ij}|, \overline{\Delta}_{ij}^+ = |\overline{x}_j^+ - \overline{x}_{ij}|, i = 1, 2, ..., n; j = 1, 2, ..., m \quad (12)$$

$$\underline{m}^+ = \min_{i,j} \underline{\Delta}_{ij}^+, \underline{M}^+ = \max_{i,j} \underline{\Delta}_{ij}^+, \tilde{m}^+ = \min_{i,j} \tilde{\Delta}_{ij}^+, \tilde{M}^+ = \max_{i,j} \tilde{\Delta}_{ij}^+, \overline{m}^+ = \min_{i,j} \overline{\Delta}_{ij}^+, \overline{M}^+ = \max_{i,j} \overline{\Delta}_{ij}^+ \quad (13)$$

Definition3: Suppose normalized alternative evaluation vectors and ideal optimal alternative evaluation vectors are given by defenition1, weights of attributes are denoted by $W=(w_1,w_2,...,w_m)$, then

$$r_{ij}^{+}=\frac{1}{2}\left[(1-\alpha)\frac{\underline{m}^{+}+\lambda\underline{M}^{+}}{\underline{\Delta}_{ij}^{+}+\lambda\underline{M}^{+}}+\frac{\tilde{m}^{+}+\lambda\tilde{M}^{+}}{\tilde{\Delta}_{ij}^{+}+\lambda\tilde{M}^{+}}+\alpha\frac{\overline{m}^{+}+\lambda\overline{M}^{+}}{\overline{m}^{+}+\lambda\overline{M}^{+}}\right] \quad (14)$$

is called three-parameter grey interval incidence degree of sub-factor $x_{ij}(\otimes)$ with respect to ideal factor $x_j^{+}(\otimes)(i=1,2,...,n;\ j=1,2,...,m)$, in which $\lambda\in(0,1)$ is the differentiate coefficient, and $\alpha\in[0,1]$ is the preference coefficient.

$$G(x^{+}(\otimes),x_i(\otimes))=\sum_{j=1}^{n}w_j r_{ij}^{+},\ i=1,2,...,n \quad (15)$$

is called three-parameter grey interval incidence degree of evaluation vector with respect to ideal optimal alternative evaluation vector $x^{+}(\otimes)$.

Denote

$$\underline{\Delta}_{ij}^{-}=|\underline{x}_{ij}-\underline{x}_j^{-}|,\tilde{\Delta}_{ij}^{-}=|\tilde{x}_{ij}-\tilde{x}_j^{-}|,\overline{\Delta}_{ij}^{-}=|\overline{x}_{ij}-\overline{x}_j^{-}|,i=1,2,...,n;\ j=1,2,...,m \quad (16)$$

$$\underline{m}^{-}=\min_{i,j}\underline{\Delta}_{ij}^{-},\underline{M}^{-}=\max_{i,j}\underline{\Delta}_{ij}^{-},\tilde{m}^{-}=\min_{i,j}\tilde{\Delta}_{ij}^{-},\tilde{M}^{-}=\max_{i,j}\tilde{\Delta}_{ij}^{-},\overline{m}^{-}=\min_{i,j}\overline{\Delta}_{ij}^{-},\overline{M}^{-}=\max_{i,j}\overline{\Delta}_{ij}^{-} \quad (17)$$

Definition: suppose normalized alternative evaluation vectors and ideal optimal alternative evaluation vectors are given by (2) and (3), respectively, and weights of attributes are denoted by $W=(w_1,w_2,...,w_m)$ then

$$r_{ij}^{-}=\frac{1}{2}\left[(1-\tau)\frac{\underline{m}^{-}+\xi\underline{M}^{-}}{\underline{\Delta}_{ij}^{-}+\xi\underline{M}^{-}}+\frac{\tilde{m}^{-}+\xi\tilde{M}^{-}}{\tilde{\Delta}_{ij}^{-}+\xi\tilde{M}^{-}}+\tau\frac{\overline{m}^{-}+\xi\overline{M}^{-}}{\overline{m}^{-}+\xi\overline{M}^{-}}\right] \quad (18)$$

is called three-parameter grey interval incidence degree of evaluation vector $x_{ij}(\otimes)$ with respect to critical alternative evaluation vector $x^{-}(\otimes)$. $(i=1,2,...,n;\ j=1,2,...,m)$, in which $\xi\in(0,1)$ be differentiate coefficient, $\tau\in[0,1]$ be preference coefficient.

$$G(x^{-}(\otimes),x_i(\otimes))=\sum_{j=1}^{n}w_j r_{ij}^{-},i=1,2,...,n \quad (19)$$

is called three-parameter grey interval incidence degree of evaluation vector $x_i(\otimes)$ with respect to critical alternative evaluation vector $x^{-}(\otimes)$.

3. Research Methodology

In this part the method that was used in this paper is explained.

1. First the goals will be gathered under four aspects of BSC: The need for performance measurement systems at different levels of decision making, either in the industry or service contexts, is not something new undoubtedly [24] BSC have been proposed by Kaplan and Norton[25,26] This tool evaluates performance by four different perspectives: the financial, the internal business process, the customer, and the learning and growth [27].

Now, the BSC seems to serve as a control panel, pedals and steering wheel [28]. 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 [29].

2. Second, the linguistic variables will be changed to three parameter interval grey numbers by Table 2.

Table 2. 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)

3. Third, each aspect's weight will be obtained by AHP method: The analytic hierarchy process (AHP) was first proposed by Saaty in 1971. It is one of the methods which used for solving multi-criteria decision making (MCDM) problems in political, economic, social and management sciences [30].Through AHP, opinions and evaluations of decision makers can be integrated, and a complex problem can be devised into a simple hierarchy system with higher levels to lower ones[31]. Then the qualitative and quantitative factors can then be evaluated in a systematic manner. The application of AHP to a complex problem involves six essential steps [32] [33]:

- Defining the unstructured problem and stating the objectives and outcomes clearly.
- Decomposing the complex problem into a hierarchical structure with decision elements (criteria and alternatives).
- Employing pairwise comparisons among decision elements and forming comparison matrices.
- Using the eigenvalue method to estimate the relative weights of decision elements.
- Checking the consistency property of matrices to ensure that the judgments of decision makers are consistent.
- Aggregating the relative weights of decision elements to obtain an overall rating for the alternatives.

4. Forth, The weights that gained by AHP will be implemented as subjective weights in Entropy method: This measure of uncertainty is given by Shannon [34] as

$$E \approx S\{P_1, P_2, ..., P_n\} = -k \sum_{i=1}^{m} [P_i LnP_i] \qquad (20)$$

which K is a positive constant. When decision matrix is clearly explained, entropy can be used as a tool in criteria evaluation. Here the method is presented in an step-by-step approach [35]:

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

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

- The project outcomes of attribute j can be defined as

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{22}$$

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

$$E_j = -k \sum_{i=1}^{m} [p_{ij} Lnp_{ij}] \tag{23}$$

Where k is a constant as

$$k = \frac{1}{Ln(m)} \tag{24}$$

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

$$d_j = 1 - E_j \tag{25}$$

- Then the weights of attributes can be obtained by

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{26}$$

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

$$w'_j = \frac{\lambda_j w_j}{\sum_{j=1}^{n} \lambda_j w_j} \tag{27}$$

In this survey the weights of aspects is obtained from lower band, gravity and upper band matrix separately. Then the mean value of weights that outcomes from each matrix considered as weights of each attribute.

5. At final three-parameter grey interval incidence degree method will be used to rank and select the best ERP system.

This methodology is depicted at Figure 1.

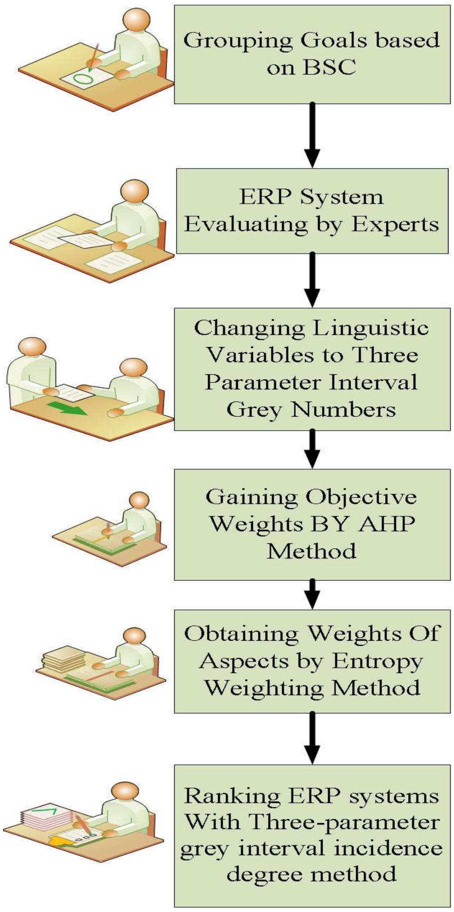

Figure 1. Research Methodology

4. Case Study

One of the manufactures in I.R. Iran wants to buy an ERP system. This decision is made in order to satisfy some goals. Goals and their own aspects are shown in Table 3.

Table 3. goals and their own aspects

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

There are Alternatives and their values which gathered by consultation with experts are shown at Table 4.

Table 4. 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 variables are changed to three parameter interval grey numbers by table (2).
We obtained the weight of each aspect by AHP method. Pairwise comparison matrix is shown in Table 5.

Table 5. pairwise comparison matrix

	Financial	Customer	Internal business process	Learning and growth
Financial	1	1.2	2	1
Customer		1	1.2	2
Internal business process			1	0.8
Learning and growth				1

Then we calculate every aspect's weights by Entropy method. AHP weights and final Entropy Weights is shown in Table 6.

Table 6. AHP and Entropy Weights

	Financial	Customer	Internal business process	Learning and growth
AHP Weights	0.302	0.293	0.186	0.219
Entropy Weights	0.0967	0.3881	0.3800	0.1351

5. Conclusion

In this paper a new model proposed for ERP software selection. Enterprise resource planning (ERP) software selection is known as a multi criteria decision making (MCDM) problem. The proposed model attends to uncertainty by three-parameter interval grey numbers. Also a weighting hybrid model is proposed that is result of AHP and Entropy combination. This combination method can reduce uncertainty that comes from decision making model. Three-parameter grey interval incidence degree method was ranking method that was used in this paper. This method that is a new method acts on three-parameter interval grey numbers. A case study was presented at the end, till shows how this model can work. The final results of model is observable in Table 7.

Table 7: alternatives grey incidence degree and their rank

Alternative	Three-parameter grey interval incidence degree	Rank
Oracle	0.4694	3
Sage	0.5789	1
MFG	0.4919	2

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