Applying Balanced Scorecard Approach in Performance Evaluation of Enterprise Resource Planning Project

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Abstract. The case company of this research is a well-known enterprise in manufacturing precision locknuts in Taiwan. Due to the demand of enterprise application integration, the case company plan to implement enterprise resource planning (ERP) system. In order to realize the effectiveness of ERP introduction, this study applied balanced scorecard (BSC) approach to evaluate the critical performance of ERP project. The BSC model used a "four perspectives" approach, i.e., financial, customer, internal business process, and learning and growth, to identify what measures to use to track the implementation of strategy. The preliminary key performance indicators (KPIs) of each department are firstly induced based on the articles published. The KPIs are formed as a questionnaire and then submitted to the key users to determine the primary KPIs for departments. The final KPIs and their corresponding weights for ERP system evaluation are defined by fuzzy analysis hierarchy process (FAHP) and are regard as a framework of performance evaluation for ERP implementation. Finally, the proposed framework for ERP system evaluation is used as a guideline for case company to improve daily operations. In this manner, the efficiency of the operations is improved and the overall competitiveness of the enterprise is moved up.

Keywords: enterprise resource planning, balanced scorecard, key performance indicators, fuzzy analysis hierarchy process

1. INTRODUCTION

Owing to the rising awareness of global environmental protection, it continues to toward the high value-added and precision products in fabricated metal products manufacturing. The values of fastener industry within Taiwan have reached almost 130.9 billion NT dollars; and the number of small and medium enterprises (SMEs) as the fastener company has already more than 1,000 in 2014. The locknuts are the largest fastener market and the estimated value is 8.29 billion NT dollars in 2016.

The case company was established in 1989. And now it concentrates on the key precision nuts of high-speed machine tools. The goal of company is to intensify accuracy and stability when locking spindle by precision lock nuts to reduce the defect rate.

Due to the increases of customers demand, the case company has implemented recently several intelligent plants. In order to quickly respond to customer needs and on-time delivery, the process management that connects with situation of production functioning via proper information system is necessary. Therefore, the purpose of this paper is to evaluate the critical performance of enterprise resource planning (ERP) project via systematic approach.

The well-known Gartner Group in America proposed the concepts of Enterprise Resource Planning (ERP) in 1990s. The ERP can integrate internal business processes and increase economic effects. First, this study applied balanced scorecard (BSC) model which used a "four perspectives" approach, i.e., financial, customer, internal business process, and learning and growth, to identify what measures to use to track the implementation of strategy. The indicators aggregating from literature review was defined first by using inductive reasoning method, and then submitted to the key users of case company with questionnaire to retained the important ones. Secondly, using fuzzy analysis hierarchy process (FAHP) to calculate the weight of each factor and find out the key performance indicators (KPIs). Finally, the

proposed framework for ERP system evaluation is used as a guideline for case company to improve daily operations.

2. LITERATURE REVIEW

Many firms around the world have shifted their information technology (IT) strategy from developing information systems in-house to purchasing application software such as enterprise resource planning (ERP) systems (Hong and Kim, 2002). The concepts of ERP was proposed by the famous management consulting firm Gartner Group in 1990s. Success or failure of an information system has been an important issue for enterprise. Cebeci (2009) proposed that according to the success of the implementation of ERP system; companies can obtain a competitive advantage in the global market rapidly. There are evidences that ERP enables to achieve benefits for organization, such as improved knowledge processing (Jones, 2006), the broader research focus on IT investments and market value (Ranganathan, 2006).

Due to traditional management systems having a serious deficiency about unabling to link a company's long-term strategy with its short term actions, Kaplan and Norton (1992), creators of the balanced scorecard (BSC), have found that no single measure can provide a clear performance target or focus attention on the critical areas of the business. BSC can measure the progress between the vision and strategy to promote the enterprise's development (Kaplan and Norton, 1996).

Business performance should be evaluated both using financial indicators and considering non-financial indicators (Yüksel and Dağdeviren, 2010). Kaplan and Norton proposed four important perspectives which include financial perspective, customer perspective, internal perspective, innovation and learning perspective as Figure 1. The descriptions are shown as follows (Kaplan and Norton, 1992, 2001).

(1) Financial: the strategy for growth, profitability, and risk viewed from the perspective of the shareholder.
(2) Customer: the strategy for creating value and differentiation from the perspective of the customer.
(3) Internal business processes: the strategic priorities for various business processes that create customer and shareholder satisfaction.
(4) Learning and growth: the priorities to create a climate that supports organizational change, innovation, and growth.

The BSC approach not only enables strategies of a business in terms of performance indicators, but also ensures establishment of the framework required for strategic measurement and management system (Yüksel and Dağdeviren, 2010). The long-term goal of strategy should be guiding and recapitulative which must have a clearly vision of the future for formulating company strategy.

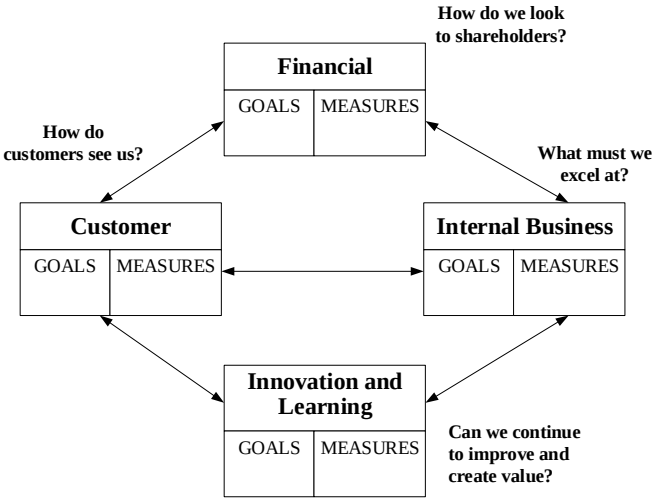

Figure 1: BSC links performance measures

Cardinaels and van Veen-Dirks (2010) applied BSC approach on how variations and influence of the performance differences are contained in the financial or non-financial categories. Chand et al. (2005) proposed comprehensive ERP scorecard to value the strategic impacts by a major international aircraft engine manufacturing and service organization as a case company. Asosheh et al. (2010) combined data envelopment analysis (DEA) and BSC to propose a new approach for IT project evaluation as well as selection. In summary, the BSC was one of the main methods that were used frequently in many literatures to analyze strategy for achieving goals.

The measurement should be specific; it will be beneficial for evaluation and assessment for the final goal. Because the performance measurement is fundamental principle of management, key performance indicators (KPIs) must be carefully selected and identified precisely where to take action to improve performance (Weber et al., 2005). KPIs are a quantitative management can be aggregated and disaggregated throughout the organization. They have capable of providing an integrated and complete view of company's performance.

The selection of KPIs is a complex decision making process which must be correct while the focus shift to reflect enterprise strategy content. Chan and Chan (2004) developed a framework for measuring success of construction projects. The set of KPIs collected from a comprehensive literature review is both objective and subjective. The validity of the proposed KPIs is also tested by three case studies. Michalska (2005) introduces the usage of the BSC in one of Polish enterprise of metallurgic industry for the measurement of overall enterprise's effectiveness. Besides, Kronz (2006) proposed that collecting and analyzing performance-related key performance indicators is the first prerequisite for holistic process management.

Saaty (1980) introduced analytic hierarchy process (AHP) approach which had been used widely for the problems of multi-criteria decision. When we make a decision, we do it without thinking or looking at all the influences, we need a tool for the tradeoffs and choices could be measure. Saaty (2004) explained the discussion involves individual and group decisions both with the independence of the criteria from the alternatives as in the AHP, it combined with examples to introduce some detail the mathematical foundations.

Ghodsypour (1998) applied an integrated AHP and linear programming for supplier selection. It is multi-criteria problem which include both qualitative and quantitative factors. Boran and Goztepe (2010) used a fuzzy set theory offers various methods to convert the qualitative judgment of the experts or decision makers to quantitative data. Recently, many studies applied fuzzy sets with AHP (FAHP) to analyze. For example, Cebeci (2009) presented a FAHP, which was a decision support system to select a suitable ERP system for textile industry. Liao et al. (2016) considered that evaluation carefully and selection were important for ERP importing, thus, they evaluated the fitness of ERP systems by FAHP and find out important assessment criteria as the locknuts case company to reference. Salmeron (2010) also applied the FAHP to analyze the risks factors identified after ERP implementation.

A triangular fuzzy number (TFN) as shown in Figure 2, which is used frequently to express the importance of performance indicator. For the reason, this study uses TFN to represents the relative important of between every element.

The mathematical expression (membership function) of TFN is expressed in the equation (1):

$$\mu_{\tilde{S}}(x)=\begin{cases}(x-l)/(m-l), & l\le x\le m,\\ (u-x)/(u-m), & m\le x\le u,\\ 0, & \text{otherwise}\end{cases} \quad (1)$$

3. RESEARCH METHODOLOGY

The proposed methodology combined BSC with FAHP to develop an approach to find out the key performance indicators of ERP system and assess the important weights. The research steps are shown as follows.

Step1: Determine questions and model construction. According to the four important perspectives of BSC, this study reviews the related literatures of the performance evaluation for ERP implementation, and assign the factors of performance evaluation to a related specific perspective. The AHP model for the case company is then constructed as shown in Figure 3.

Step 2: Aggregate the opinions of managers and key users, and construct the pairwise comparison matrices. First, questionnaire design is according to the AHP model in Figure 3. The managers and key users of the case company are questioned the questionnaires. Afterwards, every questionnaire must be confirm the consistency of the comparison matrix by using the Super Decisions software. The consistency index (C.I.) and the random index (R.I.) are shown as formula (2) and Table 1, respectively. And the consistency ratio (C.R.) is shown as formula (3).

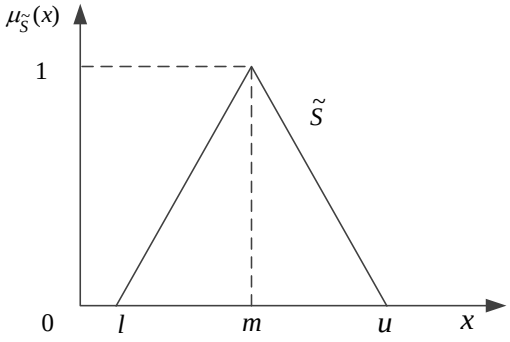

Figure 2: Triangular fuzzy number

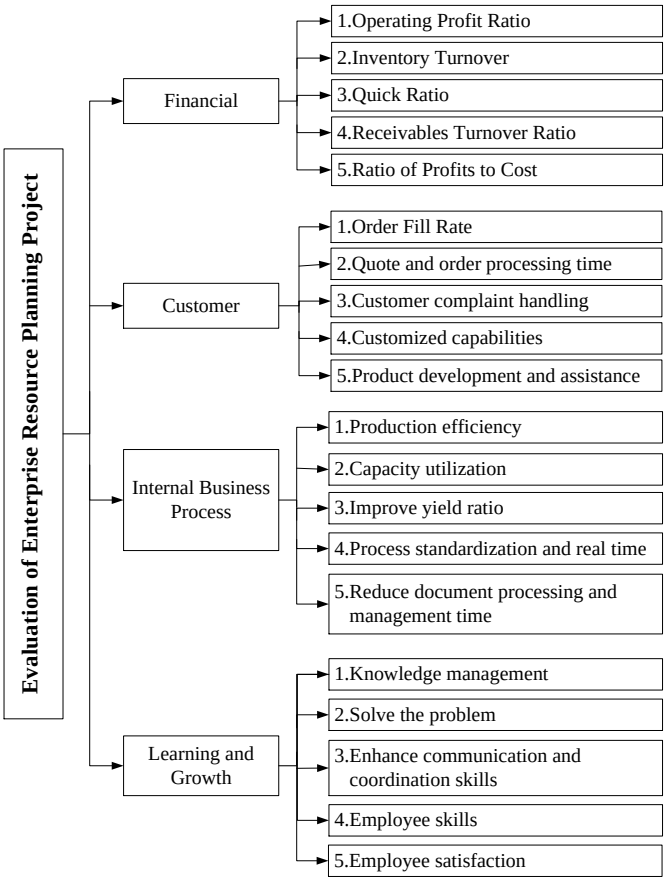

Figure 3: AHP model of performance evaluation for ERP implementation

$$\text{C.I.} = \frac{\lambda_{\max} - n}{n-1} \tag{2}$$

where $\lambda_{\max} = 1/n\sum_{i=1}^{n}(AW)_i / w_i$.

Table 1: Random index

Num.	1	2	3	4	5	6	7	8
R.I.	N.A.	N.A	0.58	0.90	1.12	1.24	1.32	1.41

$$\text{C.R.} = \frac{\text{C.I.}}{\text{R.I.}} \tag{3}$$

After aggregating the conformance of data, TFN method is use to construct the FAHP evaluate scale (shown as Table 2). A TFN has two linear functions on either sides of the peak; among them that (l, m, u) represents lower bound, mean bound, and the upper bound (Kumar and Maiti, 2012). And the positive reciprocal triangular fuzzy number is $(1/u, 1/m, 1/l)$.

In this research, we use geometric average approach as the model for the TFN.

Table 2: Triangular fuzzy numbers

Scale	Linguistic	Fuzzy AHP scale* (l, m, u)
1	Equally important	(1,1,1)
3	Weakly more important	(2,3,4)
5	Important	(4,5,6)
7	Very important	(6,7,8)
9	Extremely important	(8,9,9)
2,4,6,8	Intermediate value between two adjacent	$(x-1, x, x+1)$

The geometric average approach was defined by following equations (4)-(7).

$$\tilde{\mathbf{A}} = \left\{\tilde{S}_{ij}\right\}_{n\times n}, \text{ where } \tilde{S}_{ij} = (l_{ij}, m_{ij}, u_{ij}), \tag{4}$$

$$l_{ij} = \min\left(B_{ijk}\right), \tag{5}$$

$$m_{ij} = \sqrt[n]{\prod_{k=1}^{n} B_{ijk}}, \tag{6}$$

$$u_{ij} = \max\left(B_{ijk}\right) \tag{7}$$

where B_{ijk} represents a judgment of expert k for the relative importance of criteria i and j.

The fuzzy aggregated pairwise comparison matrix is constructed as following matrix.

$$\tilde{\mathbf{A}} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \cdots & \cdots & \cdots & \tilde{a}_{1n} \\ \vdots & 1 & \cdots & \cdots & \cdots & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & 1 & \cdots & \cdots & \cdots & \cdots \\ \vdots & \vdots & \vdots & 1 & \tilde{a}_{ij} & \cdots & \cdots \\ \vdots & \vdots & \vdots & 1/\tilde{a}_{ij} & 1 & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & 1 & \cdots \\ 1/\tilde{a}_{n1} & 1/\tilde{a}_{n2} & \cdots & \cdots & \cdots & \cdots & 1 \end{bmatrix} \tag{8}$$

where $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij}) = \left(\tilde{a}_{i1} \otimes \tilde{a}_{i2} \otimes \cdots \otimes \tilde{a}_{in}\right)^{1/n}$

Step 3: Calculate the priority vector of fuzzy synthetic extent and compare with them. The steps of fuzzy extent analysis method are described as follows (Chang, 1996):use of the extent analysis method for the synthetic extent value Si of the pairwise comparison.

(1) Compute the normalized value of row sums, and the fuzzy arithmetic operation is shown as equation (9).

$$\begin{aligned} \tilde{S}_i = (l_i, m_i, u_i) &= \sum_{j=1}^{n} \tilde{a}_{ij} \otimes \left[\sum_{k=1}^{n}\sum_{j=1}^{n} \tilde{a}_{kj}\right]^{-1} \\ &\approx \left(\frac{\sum_{j=1}^{n} l_{ij}}{\sum_{k=1}^{n}\sum_{j=1}^{n} u_{ij}}, \frac{\sum_{j=1}^{n} m_{ij}}{\sum_{k=1}^{n}\sum_{j=1}^{n} m_{ij}}, \frac{\sum_{j=1}^{n} u_{ij}}{\sum_{k=1}^{n}\sum_{j=1}^{n} l_{ij}}\right) \end{aligned} \tag{9}$$

(2) Calculate the degree of possibility of $\tilde{S}_i \geq \tilde{S}_j$, $i \neq j$, where *i* and *j* denote distinct criteria.

Let $\tilde{S}_i = (l_i, m_i, u_i), \tilde{S}_j = (l_j, m_j, u_j)$, then $V\left(\tilde{S}_i \geq \tilde{S}_j\right)$ is shown as equations (10) and (11), and the graphic expression in Figure 4.

$$V\left(\tilde{S}_i \geq \tilde{S}_j\right) = 1 \quad \text{iff } m_i \geq m_j \tag{10}$$

$$V\left(\tilde{S}_i \geq \tilde{S}_j\right) = \text{hgt}\left(\tilde{S}_i \cap \tilde{S}_j\right)$$

$$= \begin{cases} 1, & \text{if } m_i \geq m_j \\ (u_i - l_j)/\left[(u_i - m_i) - (m_j - l_j)\right], & \text{if } u_i \geq l_j \\ 0, & \text{otherwise} \end{cases} \tag{11}$$

(3) Compute the weight vector and normalize it.

The degree of possibility of $\tilde{S}_i$, $i = 1,2,...,n$ can be defined as equation (12).

$$d'(A_i) = \min V(S_i \geq S_k), \ k = 1,2,\ldots,n, k \neq i, \tag{12}$$

The weight vector is given by following equation.

$$\mathbf{W}' = \left(d'(A_1), d'(A_2), \ldots d'(A_n)\right)^{\mathrm{T}} \tag{13}$$

where $A_i, i = 1,2,\ldots,n$ is *i*th element.

Obtain the normalized weight vector that can be defined as follows via normalization.

$$\mathbf{W} = \left(d(A_1), d(A_2), \ldots d(A_n)\right)^{\mathrm{T}} \tag{14}$$

where the elements of W are all non-fuzzy number.

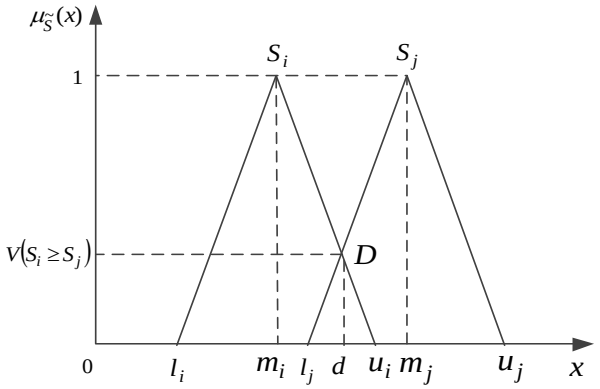

Figure 4: degree of possibility of $\tilde{S}_i \geq \tilde{S}_j$

Step 4: Obtain the final weights of the indicators for the goal. Use Super Decision software to determine the weight of each indicator and select the higher indicators as main reference ones.

4. COMPUTATIONAL RESULTS

This section is divided into three parts to introduce. The part one is a comparison result between criteria that is based on goal; Result and influence of interdependence pairwise comparison between the criteria and criteria is part two; The relative importance among the factors of their criteria is be shown in finally. As following we use the "four perspectives" i.e., financial (A1), customer (A2), internal business process (A3), and learning and growth (A4) to explain the process.

There are 30 questionnaires were sent out for managers and key users of the case company, and 25 questionnaires were returned. Each criteria and each factor are compared each other, and 22 out of 25 questionnaires have verified the data consistency, i.e. $C.I. \leq 0.1$ and $C.R. \leq 0.1$.

The priority weights of ERP systems performance evaluation are obtained by using the pair-wise comparison matrix combine with TFN methods. The result is shown in Table 3.

Table 3: Comparison matrix of the ERP project evaluation

	A1	A2	A3	A4
A1	(1,1,1)	(1.30,1.64,1.99)	(0.83,1.05,1.35)	(1.42,1.77,2.26)
A2	(0.50,0.61,0.77)	(1,1,1)	(0.57,0.70,0.90)	(1.14,1.44,1.86)
A3	(0.74,0.95,1.20)	(1.11,1.43,1.77)	(1,1,1)	(1.54,2.02,2.55)
A4	(0.44,0.57,0.70)	(0.54,0.70,0.88)	(0.39,0.49,0.65)	(1,1,1)

Equations (10) and (11) are used to determine $\tilde{S}_i$, $i = 1,\ldots,4$, and the results are shown as follows.

$$\tilde{S}_1 = (4.55,5.45,6.60) \otimes \left(\frac{1}{20.88}, \frac{1}{17.36}, \frac{1}{14.52}\right) = (0.22,0.31,0.45)$$

$$\tilde{S}_2 = (3.21,3.75,4.53) \otimes \left(\frac{1}{20.88}, \frac{1}{17.36}, \frac{1}{14.52}\right) = (0.15,0.22,0.31)$$

$$\tilde{S}_3 = (4.39,5.41,6.53) \otimes \left(\frac{1}{20.88}, \frac{1}{17.36}, \frac{1}{14.52}\right) = (0.21,0,31,0.45)$$

$$\tilde{S}_4 = (2.37,2.76,3.23) \otimes \left(\frac{1}{20.88}, \frac{1}{17.36}, \frac{1}{14.52}\right) = (0.11,0.16,0.22)$$

Use the equation (13) to obtain $d'(A_i)$ which is the degree of possibility of $\tilde{S}_i$.

$$d'(A_1) = \min V(S_1 \geq S_2, S_3, S_4) = \min(1,1,1) = 1$$

$$d'(A_2) = \min V(S_2 \geq S_1, S_3, S_4) = \min(0.49,0.52,1) = 0.49$$

$$d'(A_3) = \min V(S_3 \geq S_1, S_2, S_4) = \min(0.99,1,1) = 0.99$$

$$d'(A_4) = \min V(S_4 \geq S_1, S_2, S_3) = \min(0.03,0.55,0.07) = 0.03$$

Fuzzy extent analysis method, equations (14) and (15), is applied obtain the super-matrix.

$$\mathbf{W}' = (1, 0.49, 0.99, 0.03)^{\mathrm{T}}$$

$$\mathbf{W} = (0.40, 0.20, 0.39, 0.01)^{\mathrm{T}}$$

The weights of four perspectives are 0.40, 0.20, 0.39, and 0.01, respectively. And the factors' weights of each perspective are shown in Table 4.

Table 4: The weights among the factors of their criteria

Perspectives	Factors	weight
Financial	Operating Profit Ratio	0.58
	Inventory Turnover	0
	Quick Ratio	0.42
	Receivables Turnover Ratio	0
	Ratio of Profits to Cost	0
Customer	Order Fill Rate	0.47
	Quote and order processing time	0.26
	Customer complaint handling	0.20
	Customized capabilities	0.07
	Product development and assistance	0
Internal business process	Production efficiency	0
	Capacity utilization	0.23
	Improve yield ratio	0.35
	Process standardization and real time	0.12
	Reduce document processing and management time	0.30
Learning and growth	Knowledge management	0.28
	Solve the problem	0
	Enhance communication and coordination skills	0.34
	Employee skills	0.34
	Employee satisfaction	0.04

5. CONCLUSIONS

This study focuses on the demand of ERP system for the case company, and uses inductive method of aggregating literatures review. An AHP model is constructed from questionnaire for managers and key users of case company. The major of performance indications are developed by combining BSC with AHP to determine each perspective and its factors' weights.

The results show that the weights of consideration of the factors for evaluating ERP system project are sequentially financial, internal business process, customer, learning and growth, which weights are 0.40, 0.39, 0.20, 0.01. The total important ratio of financial, internal business process and customer is 99%.

Furthermore, the most influence factors of financial and internal business process are operating profit ratio and improve yield ratio, respectively. The studied results mainly provide the weights of performance evaluation to case company to as a guideline on improving daily operations and move up the efficiency of the operations.

ACKNOWLEDGMENTS

This research is funded by the Ministry of Science and Technology of the Republic of China under Grants MOST104-2622-E-167-018-CC3. And special thanks to all who have helped to make this study.

REFERENCES

Asosheh, A., Nalchigar, S. and Jamporazmey M. (2010) Information technology project evaluation: An integrated data envelopment analysis and balanced scorecard approach. *Expert Systems with Applications*, **37**, 5931-5938.

Boran, S. and Goztepe, K. (2010) Development of a fuzzy decision support system for commodity acquisition using fuzzy analytic network process. *Expert Systems with Applications*, **37**, 1939-1945.

Cardinaels, E. and van Veen-Dirks, P. (2010) Financial versus non-financial information: The impact of information organization and presentation in a Balanced Scorecard. *Accounting, Organizations and Society*, **35**, 565-578.

Cebeci, U. (2002) Fuzzy AHP-based decision support system for selecting ERP systems in textile industry by using balanced scorecard. *Expert Systems with Application*, **36**, 8900-8909.

Chan, A. and Chan, A. (2004) Key performance indicators for measuring construction success. *Benchmarking: An International Journal*, **11**, 2, 203-221.

Chand, D., Chand, G., Hunton, J., Owhoso, V. and Vasudevan, S. (2005) A balanced scorecard based framework for assessing the strategic impacts of ERP systems. *Computers in Industry*, **56**, 558-572.

Chang, D. (1996) Applications of the extent analysis method on fuzzy AHP. *European Journal of Operational Research*, **95**, 649-655.

Ghodsypour, S.H. and O'Brien, C. (1998) A decision support system for supplier selection using an integrated analytic hierarchy process and linear programming. *International Journal Production Economics*, **56-57**, 199-212.

Hong, K. and Kim Y. (2002) The critical success factors for ERP implementation: an organizational fit perspective. *Information & Management*, **40**, 25-40.

Jones, M.C., Cline, M., and Ryan, S. (2006) Exploring knowledge sharing in ERP implementation: an organizational culture framework. *Decision Support Systems*, **41**, 411-434.

Kaplan, R.S. and Norton, D.P. (1992) The Balanced Scorecard-Measures that Drive Performance. *Harvard Business Review*, 72-79.

Kaplan, R.S. and Norton, D.P. (1996) Using the Balanced Scorecard as a Strategic Management System. *Harvard Business Review*, 37-48.

Kaplan, R.S. and Norton, D.P. (2001) Transforming the Balanced Scorecard from Performance Measurement to Strategic Management: Part I. *Accounting Horizons*, 87-104.

Kronz, A. (2006) Managing of process key performance indicators as part of the ARIS methodology. *In Corporate performance management*, Berlin: Springer, 31-44.

Kumar, G. and Maiti, J. (2012) Modeling risk based maintenance using fuzzy analytic network process. *Expert Systems with Applications*, **39**, 9946-9954.

Liao, L., Huang, C. and Kang, P. (2016) Applying fuzzy-AHP and VIKOR method to evaluate the fitness of ERP systems. *Proceedings of the 2016 International Conference on Industrial Engineering and Operations Management*, Kuala Lumpur, Malaysia, March 8-10, 2016.

Michalska, J. (2005) The usage of The Balanced Scorecard for the estimation of the enterprise's effectiveness. *Journal of Materials Processing Technology*, **162-163**, 751-758.

Ranganathan, C. and Brown, C.V. (2006) ERP Investments and the Market Value of Firms: Toward an Understanding of Influential ERP Project Variables. *Information Systems Research*, **17**, 2, 145-161.

Saaty, T.L. (1980) The analytic hierarchy process: planning, priority setting, resource allocation. *McGraw Hill*, New York.

Saaty, T.L. (2004) Decision Making-The Analytic Hierarchy and Network Process (AHP/ANP). *Journal of Sustems Science and Systems Engineering*, **13**, 1, 1-35.

Salmeron, J.L. and Lopez, C. (2010) A multicriteria approach for risks assessment in ERP maintenance. *The Journal of Systems and Software*, **83**, 1941-1953.

Weber, A. and Thomas, R. (2005) Key Performance Indicators, Measuring and Managing the Maintenance Function. *Ivara Corporation, Burlington*.

Yüksel, İ. and Dağdeviren, M. (2010) Using the fuzzy analytic network process (ANP) for Balanced Scorecard (BSC): A case study for a manufacturing firm. *Expert Systems with Applications*, **37**, 1270-1278.