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STUDY OF VARIOUS PERFORMANCE MEASUREMENT INDICES OF ERP SYSTEM

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Abstract**:** *Enterprise Resource Planning (ERP) systems have been used in integrating information and accelerating information distribution across functions and departments with the aim to increase operational performance of organization. The implementation of an ERP system is not a goal but a continuous journey towards the goal. After successful implementation of ERP, the goal is to increase the utilization factor of the system used. The satisfaction of the users and the overall performance must be measured periodically to evaluate the success of the implementation and the overall objectives of the ERP system. The purpose of this paper is to study various comprehensive frameworks for measuring the performance of an ERP system.*

Index Terms— Enterprise Resource Planning, Performance measurement, Performance indicator, Triangular fuzzy number

INTRODUCTION

Enterprise Resource Planning is a complex information system designed to integrate and optimize the business processes and transactions to automate the flow of material, information and financial resources among all the functions within a corporation[1, 2]. ERP synchronizes numerous functional areas in an integrated fashion, attempting to automate operations from supply chain management, inventory control, manufacturing, scheduling, production, sales, support, customer relationship management, financial and cost accounting, human resources and almost any other data oriented management process[3].

I. Literature Review

Several methods have been proposed for measuring the performance of the ERP systems. Financial performance metrics such as return on investment, net present value, or payback period were used by Kivijarvi and Saarinen (1995), Murphy and Simon (2001). Performance measurement based on the system and data assessment of information system were studied by Delone and Mclean (1992), Palvin et. al. (2001), Lee et.al. (2002). IS performance based on the user satisfaction war developed by Wu et. al.(2002) . Performance measurement based on data envelopment analysis was proposed by Stensrud and Myrtveit (2003). Performance measurement based on the balanced score card was proposed by Michel and jens (1999), Hagood and Friedmen (2002). The performance measurement based on the analytical hierarchy process was used by chan et. al. (2006), chen and kumar (2007)[12].

II. ERP Performance measurement

The term “Performance Measurement” means the creation and use of usually several indicators of various dimensions (e.g., cost, time, quality, innovation capacity, customer satisfaction), which are used to assess effectiveness and efficiency of the performance and performance potentials of different objects in the enterprise [4].

ERP implementation is a complex, uncertain, difficult and a risky project [5, 6, 7, 8]. ERP systems consists of major managerial tool and technology that requires the multidisciplinary attention of operations management, information system, finance, marketing, organizational behavior and human resources field [9]. Literature identifies that 66 to 70 percent ERP implementation projects fails to achieve their implementation objectives [7]. In failure, faulty technology is often blamed but eight out of nine times ERP problems are performance related [6]. To better understand the causes of problems and higher failure rate it is important to study various ERP performance measurement indices [7]. Each step in the implementation process requires analysis, to determine which factors will promote effective implementation [10]. The performance of the preceding stage is input for the succeeding stage, so it is important to measure performance at each stage during ERP implementation to ensure success [11]. After successful implementation, it is needed to carefully examine all related factors to increase the operational efficiency [5]. How much organization is dependent on the System is one of the key factors used to analyze the performance of the system [12]. To identify the impact of the system and operation strategies ERP performance measurement is necessary [13]. ERP performance measurement provides an opportunity to managers to devote their time, resources and leadership to areas that have better contribution to

performance outcome [14]. ERP performance measurement helps to understand which parts of their ERP system need improvement which eventually helps in decision making [1].

III. Some methods of ERP Performance measurement

A. Evaluating the performance measurement of an ERP system based on the knowledge of ERP implementation objectives

This method proposed by chun-chin wei in 2007. A comprehensive framework for measuring the performance of an implemented ERP system was proposed. This framework identifies the appropriate ERP performance indicators and constructs the Performance Indicator(PI) structure based on the knowledge of ERP implementation objectives. Consistent evaluation standards are set up for facilitating the complex ERP performance measurement process. The framework focuses on the process of ERP and PIs development to link the performance measurement contents with the ERP system implementation objectives. In this framework the objectives of the ERP implementation project extended into suitable PIs and used to evaluate whether those objectives have been achieved. The PIs are specified to provide detailed guidance for the ERP system performance assessment. The proposed methodology can be used to verify that the ERP performance evaluation process is in line with the goals of the organization. The framework also guides the strategic plan for the ERP system improvement. A case study of the method was done in a company of taiwan with a business of modular microwave communication system design, manufacturing, repair and service to demonstrate the practical viability of the proposed method [1].

Procedure to evaluate ERP performance measurement in this method:

STEP-1 To Form an ERP PI content development team

A team involving critical managers, user representatives, and ERP system experts from different departments is selected [1].

STEP-2 To Expanding the ERP implementation objectives to suitable ERP PIs

The team members need to transform fundamental objectives into some appropriate PIs. These PIs link the input factors of ERP implementation with the output factors of ERP execution and recognize the gap between what the users want and what the system performs. A systematic ERP PI discussion process is employed. The team starts the discussion with a nearest means-objective of a bottom-level fundamental objective in the ERP implementation objective structure to discuss, "Whether the means objective can be used as a suitable ERP performance indicator?" If the means-objective is an appropriate PI, then it is added to the PI set. If it is not suitable, the team can further discuss, "How to evaluate whether this means-objective has been achieved?" The answers reveal more detailed and new PIs, which can be incorporated into the PI set [1].

STEP-3 To add other appropriate PIs on the ERP output view based on survey

A survey "quantitative content validity method" is organized to modify the PI set in which each member is asked to rate each PI using three point scale of "not relevant" (value 1), "important but not essential" (2), and "essential" (3) . Then content validity ratio is calculated for each PI by following formula

$$CVR = (n - N/2) / (N/2)$$

Where N denotes the numbers of team members and n is the number of team members who give the PI a value of 2 or 3.

A significant level of CVR is decided by the team. All the PIs having CVR less than significant level is eliminated from the PI set [1].

STEP-4 To Construct the PI structure

A PI structure was constructed from the remaining PIs. The ERP PI structure comprised five levels. Level 1 reveals the ultimate mission for assessing the performance of the ERP system. Level 2 consists of main PI categories. Level 3 contains the major objectives. Level 4 describes the basic fundamental objectives .The level 5 comprises the associated PIs which used to measure the performance of the ERP system. The relative weights of ERP PIs and fundamental objectives were determined by using AHP method. The paired comparisons process was repeated for each PI by all decision makers and converted to a numerical scale to give weightage. The ERP PI structure and corresponding weights used in the case study are shown in the figure 1[1].

STEP-5 To develop the detailed performance evaluation method

The team members investigate how to measure the PIs and what data need to collect and how to collect the data for evaluating the each PI. The detailed evaluation guidance and an assessment form for each PI were developed. All measured values of qualitative and quantitative PIs can be translated into the score of 0-100 [1].

STEP-6 To Develop the detailed performance evaluation method

The average scores of the ratings of all decision makers were obtained. The score of the each fundamental objective is calculated as following:
Score of fundamental objectives = ∑ (weight of the PI * score of the PI)

After calculating the score of each fundamental objective, score of the major objective is calculated as following:
Score of the major objective = ∑ (weight of the fundamental objective * score of the same)

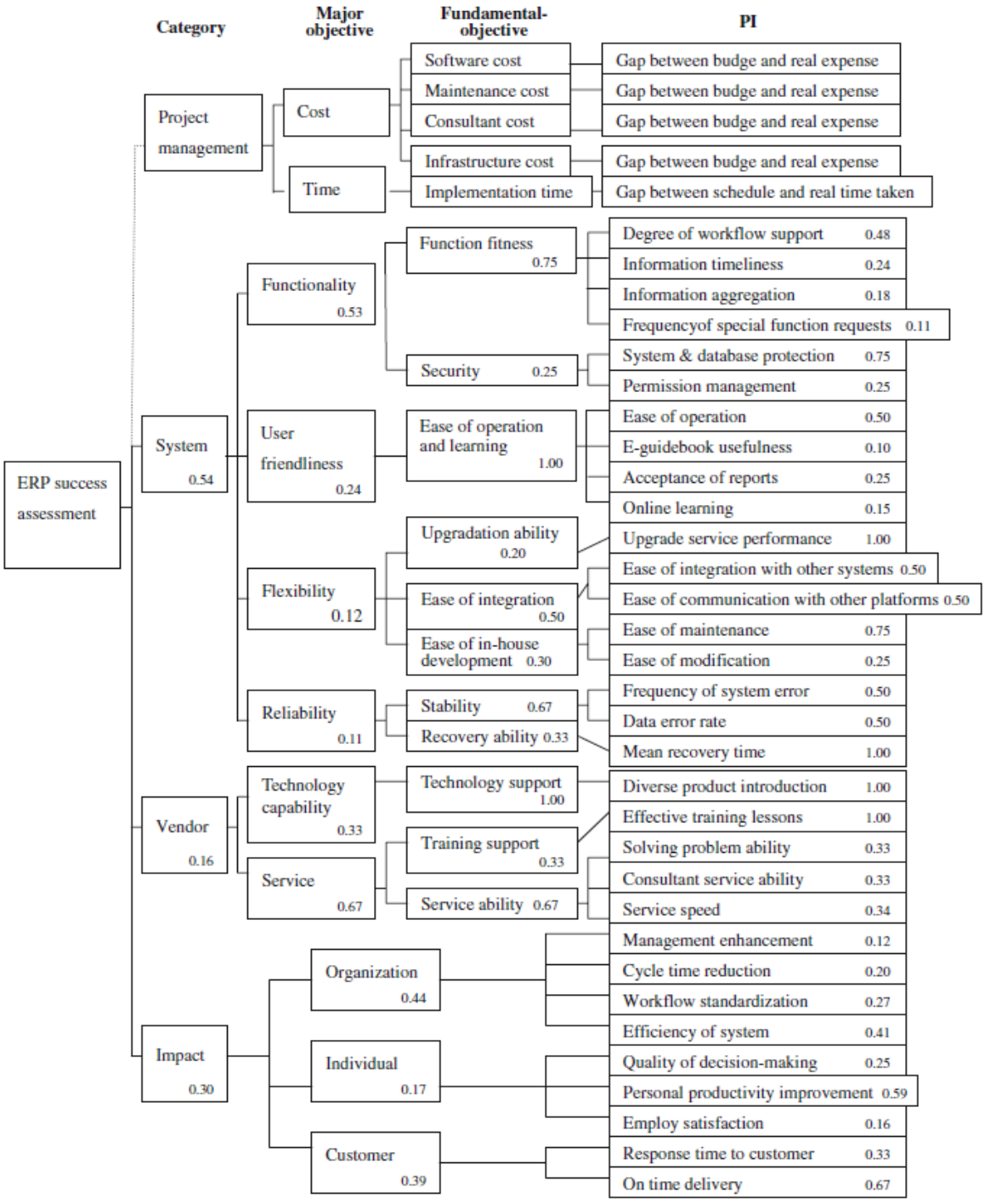

Fig 1 – ERP PI structure and corresponding weights [chun-chin wei 2007]

After calculating the score of each major objective, score of the category is calculated as following:

Score of category = ∑ (weight of the major objective * score of the major objective)

After calculating the score of each category, score of the overall ERP system is calculated as following:

Score of the ERP system = ∑ (weight of the category * score of the category) [1]

PIs taken in the case study related to cost are gap between the various budget and real expenses, related to time are gap between schedule and real time taken , related to functionality are degree of workflow, information timeliness, information aggregation, frequency of special function requests, system and database protection, permission management, related to user friendliness are ease of operation, E-guidebook usefulness, acceptance of reports, online learning, related to flexibility are upgrade service performance, ease of integration with other systems, ease of communication with other platforms, ease of maintenance, ease of modification, related to reliability are frequency of system error, data error rate, mean recovery time, related to technology capability are diverse product introduction, related to service are solving problem ability, consultant service ability, service speed, related to organization are management enhancement, cycle time reduction, workflow standardization, efficiency of system, related to individual are quality of decision making , personal productivity improvement, employ satisfaction, related to customer are response time to customer, on time delivery. Some PIs are in direct relation in system performance. As the score of the direct PIs increase system performance is better. Some PIs are in inverse relation in system performance. As the score of the indirect PIs increases system performance will poor. The score of the overall performance of the ERP system is more than the ERP system is performing better.

B. ***An ERP performance measurement framework using a fuzzy integral approach***

This method proposes a comprehensive framework for measuring the performance of an ERP system using a fuzzy integral approach. A fuzzy ERP performance index is used to account for the ambiguities involved in evaluating the performance of the ERP system. The fuzzy ERP performance index can be translated first into simple scores and then back to linguistic terms. The performance measurement results can represent the achievement of objectives and the directions for improving the implemented ERP system. A case study of the method is done in a company of taiwan to demonstrate the practical viability of the proposed method [12].

A step by step procedure is described to evaluate ERP performance measurement in this method.

STEP-1 To extend the objectives of the ERP implementation project to appropriate PIs

An ERP performance measurement project team involving critical managers, user representatives, system experts and consultants are made to transform the objectives into the suitable ERP PIs to link up the input factors of an ERP implementation project with the output performance factors and indicate the gap between what the user want and what the ERP system performs [12].

STEP-2 To add other crucial PIs into the PI set

The original PI set which are extracted from objectives does not involve all the PIs which are necessary for ERP system performance measurement. The team members should survey some proper PIs based on the output performance aspects of ERP system execution. Then, these critical PIs can be added into the PI set [12].

STEP-3 Construct the PI structure

The PIs structure was constructed including all the PIs. The PI structure comprises 4 levels. Level 1 reveals the ultimate mission for assessing the performance of the adopted ERP system. Level 2 consists of main PI categories. Level 3 contains the fundamental objectives. Level 4 comprises the associated PIs that were used to measure the performance of the ERP system [12].

STEP- 4 To develop the detailed performance measurement guidance

After developing the detailed performance measurement guidance of PIs, weightings associated with PIs can be assigning by direct assignment or indirect pairwise comparisons like the AHP. Then, a weighting vector W is obtained. The values in vector W have the domain range (0, 1) [12].

STEP-5 To assess the PIs

The quantitative indicators are evaluated using marginal value function in terms of direct and inverse linear relationship. A baseline of each PI which the team members hope to achieve can be set and by this baseline, members are capable to analyze the gap between what the ERP is performing and what the user want from ERP.

$$r_i = \frac{(v_i - v_i^0)}{(v_i^* - v_i^0)}.$$

Where

v_i = The value of PI i which the current ERP system is performing

v_i^0 = The worst value of PI i which the team believes the ERP system should perform
V_i^* = maximum value of PI i which the team expects the best possible performance that the ERP system might achieve.

r_i ($0 \leq r_i \leq 1$) = a dimensionless value compatible with the linguistic ratings of the qualitative PIs (if the crisp rating of the r_i is r, its triangular fuzzy number (TFN) is (r, r, r).

The members can assess the qualitative PIs using a simple rating questionnaire or form to rate each PI. Subjective assessments are given in linguistic terms to determine the degree of the adopted ERP system performing against qualitative PIs. Then, linguistic terms is transformed into fuzzy numbers by using appropriate conversion scale. The values of the quantitative PIs are converted into dimensionless ratings; the ratings are compatible with the ratings of the qualitative PIs. A fuzzy vector R of PI ratings can be obtained combined the both quantitative and qualitative indicators. TFNs for the linguistic values used in case study are shown in Table 1 [12].

Rating	TFN
Very poor	(0,0,0.3)
Poor	(0,0.3,0.5)
Fair	(0.2,0.5,0.8)
Good	(0.5,0.7,1.0)
Very good	(0.7,1.0,1.0)

Table1. Linguistic variables describing values of rating (chun-chin wei et.al. 2007)

STEP-6 To aggregate the assessments to determine the fuzzy ERP performance index
Score vector S is calculated for each fundamental objectives by following equation

$$\tilde{S} = \tilde{R} \otimes W^T$$

The values in the fuzzy vector S are in TFNs. After obtaining fuzzy performance index for each fundamental objectives and then, roll them into the fuzzy performance index of each main category and the entire system using above equation [12].

Suppose the fuzzy performance index of a fundamental objective or the entire system is c with the left membership function f_c^L and the right membership function f_c^R . Then,
The left integral value of c is defined as:

$$I_L(C) = \int_0^1 g_c^L(y)dy$$

The right integral value of c is defined as:

$$I_R(C) = \int_0^1 g_c^R(y)dy$$

Where, g_c^L and g_c^R are the inverse functions of f_c^L and f_c^R respectively.
Then, the total integral value with an optimism index θ is defined as:

$$I_T^\theta(C) = \theta I_R(C) + (1-\theta)\, I_L(C),\ \theta \in [0,1]$$

Calculation for finding fuzzy performance index and total integral value for fundamental objective function fitness is following (used in case study)

$$\begin{bmatrix} (0.5,0.7,1.0) \\ (0.5,0.7,1.0) \\ (0.2,0.5,0.8) \\ (0.7234,0.7234,0.7234) \end{bmatrix} \otimes [0.48,0.24,0.18,0.11] = [0.4756,0.6736,0.9436].$$

The fuzzy performance index of "function fitness" was (0.4756, 0.6736, 0.9436). then c = (0.4756,0.6736, 0.9436). then its membership function is:

$$f_{\tilde{c}}(x) = \begin{cases} \frac{x-0.4756}{0.1980}, 0.4756 \le x \le 0.6736 \\ 1, \quad x = 0.6736 \\ \frac{x-0.9436}{-0.2700}, 0.6736 \le x \le 0.9436 \\ 0, \quad \text{otherwise} \end{cases}$$

The left integral value of c is defined as:

$I_L(c) = \int_0^1 0.198y + 0.4756dy = 0.5746$

The right integral value of c is defined as :

$I_R^c(c) = \int_0^1 -0.27y + 0.9436dy = 0.8086$

Then, the total integral value of the fuzzy performance index obtained by the fuzzy integral value method

$I_T^{0.5}(c) = 0.5*0.5746 + 0.5*0.8086 = 0.6916$

Where (θ= 0.5)

0.6916 represents the performance score of the "function fitness" linguistic terms can express the condition of the ERP system against each fundamental-objective and main category and the decision in a better way so the team members can translate the results into linguistic terms[12].

STEP-7 To analyze the results and improve the ERP system

The results of the ERP performance measurement are analyzed and the objective where ERP is performing poor is determined. The Periodic ERP performance measurement should be undertaken to provide a basis for the practice of continuous improvement [12].

The PIs used in the case study are system completion, global task performance , degree of workflow support, information timeliness, information aggregation, frequency of special function requests, system and database protection , permission management, User friendliness, E- guidebook usefulness, acceptance of reports, online learning, upgrade service performance, ease of integration with other systems, ease of communication with other platforms, ease of maintenance, ease of modification, frequency of system error, data error rate, mean recovery time, diverse product introduction, effective training lessons, solving problem ability, solving problem ability, consultant service ability, service speed, management enhancement, cycle time reduction, workflow standardization, efficiency of the system, quality of the decision making, personal productivity improvement, employ satisfaction, response time to customer, on time delivery . The integral value of the fuzzy performance index is more means ERP system performs better.

The evaluation results obtained by this method can truly reflect the current situation of the ERP system and the accomplishment of the ERP implementation objectives. The linguistic results provide a semantic and impressionable description about the current condition of the ERP system [12]

IV. CONCLUSION

An ERP system implementation project needs to invest enormous money, labor, and time for a company. One need to understand what benefits the system will contribute and how system will get improved. A very significant challenge faced during implementation is to justify the value-added contribution of ERP systems. Without the ability of assessing the performance of the ERP system, one cannot evaluate its status and monitor its improvement. Performance evaluation process enables the organization to make proper improvement. An ERP performance measurement framework should establish a feedback mechanism between the desired objectives of ERP adoption and the substantial effects of ERP execution.

Two frameworks for performance measurement of an ERP system are discussed in the current paper. First framework is based on the knowledge of implementation objectives of the ERP system and the second is based on a fuzzy integral approach. Both the framework allows managers to extend the objectives of the ERP implementation project into suitable PI's and to evaluate whether those objectives have been achieved. The evaluation results can truly reflect the current situation of the adopted ERP system and the accomplishment of the expected objectives. This can help in recognizing the directions of ERP system improvement and the strategies of corporate information system in the future.

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