ERP System Gray-Fuzzy Comprehensive Evaluation Based on Balanced Scorecard Method

Xin Tian, Wei Dai  
School of Economics and Management, Hubei Polytechnic University, Huangshi  
435003, Hubei, China

Abstract
Based on the balanced scorecard method and applying the multilevel gray fuzzy evaluation method, the article compared the performance of ERP system. The index system is classified baht largely shows the main factors influencing of ERP system performance. In accordance with the mathematical model, the quantitative process of ERP evaluation is given and calculated. The article put forward that gray fuzzy comprehensive evaluation method can not only make whole of each evaluation indexes like customer, financial, internal processes and learning information, but also can describe the level of performance and does transverse comparison. This method has a wide range of practicality and good maneuverability, and the ERP system performance evaluation has reference value.

Keywords: Balanced Scorecard Method, ERP System, Gray Fuzzy Comprehensive Evaluation Method

1. INTRODUCTION
In recent years, many enterprises have taken more attention to the information technology under the impact of the global information. The core of enterprise management information is the enterprise resource planning (ERP). ERP integrated the enterprise's internal resources all-round, not only improving internal operating efficiency, significantly enhancing the market competitiveness of enterprises, so as a better way of dealing with the change of the market, but also promoting the enterprise staff management consciousness and levels. Every year, however, enterprises have to pay more attention to the strategy of the ERP investment returns, risk management, and other deep-seated problems, with huge sum and risk to the ERP. The focus of ERP has changed gradually from the initial construction of infrastructure to the deepening of ERP application and penetration stage. With ERP system application and implementation caused the change of enterprise management mode and business process re-engineering, it will be a profound influence on the operation of the enterprise in each link. ERP system performance evaluation of enterprise, on one hand, can fully understand and master the operating performance of ERP, help to make an information development match enterprise strategic goals, improve enterprises management, combined enterprise short-term interests and long-term goal effectively. On the other hand, it is to summarize the experiences of implementing project and to take the foundation for the subsequent IT project.

2. LITERATURE ABOUT ERP PERFORMANCE EVALUATION
2.1. Overseas Relevant Research Dynamic
Some American experts and scholars had puts forward evaluation indicators and methods of MRPII (Manufacturing Resource Planning) application performance, among them the most famous are Oliver Wight’s "ABCD performance evaluation" and Partner ERP project evaluation system, which have been widely learning and using for reference(Oliver, 2000).

ABCD evaluation method included strategic planning, human factors and the cooperation spirit, total quality management (TQM), new product research and development, planning and control process five parts. Each part has a brief qualitative description to explaining the main consideration question and the different qualitative characteristics of ABCD four levels. Partner, the standardization of the famous American institutions, focuses on the long-term benefits and implementation of the evaluation system of ERP project which included project driving factors, transaction processing index and critical success factors(Oliver, 2000).

Delone and Mclean put forward the six key index of IT project implementation on the research results. There ware system quality, information quality, system usage, customer satisfaction, employees effect and organization effect. On this basis, they had raised D&M model which introduced the connection between the key indexes. D&M model is a milestone in the IT project evaluation. From then on, many studies of IT evaluation are based on D&M model(William H. D, Ephraim R. M, 2003).

2.2. Domestic Relevant Research Dynamic
In the late 70s’, China was introduced the internationally accepted ERP project performance evaluation method. At present, the representative is the evaluation index system of Tsinghua University with
comprehensive benefit analysis, based on key success factors of the enterprise such as time, quality, cost, service and environment. In October 2002, in order to evaluate the Chinese enterprise informatization level correctly and objectively, and guide the enterprise information based on efficiency, the National Informatization Evaluation Center of China issued "The Chinese Structural Scheme of Enterprise Informatization Index System" and "The Information Benchmarking Selection Plan of Chinese enterprises ". Draw lessons from international general evaluation system of ERP project, the ERP system implementation effect evaluation is divided into two most: ERP basic evaluation index system and ERP performance evaluation index system (Luo and Yao, 2013).

Practice shows that the ERP project performance evaluation is a systematic concept, involving multiple levels and multiple factors, uncertainty and complexity. In practice, some indicators are quantified easily; however, other individual indicators can't be quantitative description or cannot be directly compared between indicators at the same time. Because of various reasons, evaluation can only make judgments on the basis of experience and knowledge. It is difficult to achieve the goal of overall optimal and to make effective performance evaluation separately with quantitative or qualitative method. This paper adopts the combination of qualitative and quantitative methods to analyze the performance of the enterprise implement ERP project.

3. ERP SYSTEM EVALUATION INDEX BASED ON THE BALANCED SCORECARD

Fuzzy comprehensive evaluation method is a systematic analysis method based on the fuzzy set theory. Its advantages is to solve the quantify problem of the qualitative evaluation index reasonable. In the application of gray comprehensive evaluation method to evaluate the ERP project performance, should first establish the ERP project performance evaluation index system. Correcting analysis of the factors affecting ERP project performance, establishing a reasonable evaluation index system and the classification standard are warrants for the evaluation success. Balanced scorecard (BSC) from a strategic height, based on management, by adopting the idea of comprehensive balance, through the relationship between each other and mutual penetration, builds a three-dimensional and network structure. Fuzzy comprehensive evaluation method builds up the strict, scientific and complete evaluation system structure, fully embodies the full cycle from the strategy into action, it can effectively connected relationship between strategy, performance management and performance evaluation, and put the strategy into measurable indicators (L.A.Z soon, 1965; Robert Kaplan, 1993; Sui, 2008).

From these four perspectives “financial, customer, internal processes, and growth and learning”, the balanced scorecard provides a method of examination of value creation strategy. This is a list of long-term value and competition performance driving factors, overcome the limitation of simple performance management by financial means. ERP is a huge system, the main function modules including manufacturing module (master production plan, capacity requirements planning, bill of material, workshop management and quality management), supply chain management module (purchasing management, inventory management, sales management and inventory accounting), financial management module (accounting and financial management), customer relationship management module, human resources management module, decision support system module and business intelligent module. Being established a mapping relationship between function modules of the ERP, the four aspects of BSC is shown in figure 1.

It can be seen from the figure 1, the financial management module including the general ledger, accounts receivable, accounts payable, cashier cash management and profitability analysis is corresponding BSC. Manufacturing module and supply chain management module belong to the internal production and operation process of each link in an enterprise, therefore, which are the corresponding internal processes of BSC. Sales management is not only corresponding internal processes, but also corresponding to the clients. Inventory accounting is corresponding financial too. Decision support system module and the business intelligence module are correspond to grow and learn, and corresponds to the customer, the financial aspect. In this way, the implementation effect of each module of ERP system and enterprise performance of each department can get a comprehensive evaluation through the four aspects of the balanced scorecard. Similarly, in the implementation of the balanced scorecard, the performance evaluation indicators tend to involve the enterprise's financial data, the cost, quality and production plan data in the process of manufacturing, sales, profit and employee information, etc. (Andreas I, 2006).

Each evaluation index is mostly on the basis of large amounts of data statistics. Therefore, the balanced scorecard demands integration with management information system, and realize data sharing. Using the balanced scorecard performance evaluation in ERP environment, relevant data can be read from the module of ERP, so that the ERP system can realize the organic integration of the balanced scorecard system. Based on this, we combine with the target system of the ERP system, the elements of performance evaluation and the problem characteristics of the research focus on current related evaluation, and propose the performance evaluation index system of ERP method balanced scorecard as the core in this paper (seen in table1) (Alavi, Leidner, 2001; Xian, 2005).
Table 1. ERP system performance evaluation indicators based on the balanced scorecard

<table>
<thead>
<tr>
<th>Indicators of the first layer</th>
<th>Indicators of the second layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finance ( M_1 )</td>
<td>Return on assets ( M_{11} )</td>
</tr>
<tr>
<td></td>
<td>Return on equity ( M_{12} )</td>
</tr>
<tr>
<td></td>
<td>Capital turnover rate ( M_{13} )</td>
</tr>
<tr>
<td></td>
<td>Profit growth rate ( M_{14} )</td>
</tr>
<tr>
<td></td>
<td>Accounts receivable turnover ( M_{15} )</td>
</tr>
<tr>
<td>Customer ( M_2 )</td>
<td>Market share ( M_{21} )</td>
</tr>
<tr>
<td></td>
<td>Customer satisfaction ( M_{22} )</td>
</tr>
<tr>
<td></td>
<td>Customer loyalty ( M_{23} )</td>
</tr>
</tbody>
</table>

*Figure 1*. The mapping relationships between ERP system module and BSC scorecard
4. ESTABLISHMENT GREY ASSESSMENT MODEL OF THE ERP SYSTEM PERFORMANCE

For the performance evaluation of ERP system implementation, we adopt the multi-level fuzzy evaluation because there are many related influence factors that is easily weakened evaluation weight using the single factor to evaluate. According to the index system in Table 1, ERP system performance evaluation can be divided into three levels, the overall target layer M, it indicates the ERP system performance evaluation which is primary evaluation index of a collection of the first layer evaluation index M={ M1, M2, M3, M4}. Mij is secondary evaluation index of a collection of notes for Mij = {Mij1, Mij2, Mij3, Mij4}. The specific steps of grey-evaluation are as follows:

4.1. Determine Factors Set

According to the relationship of each factor in the system, evaluation indexes are divided into different levels, then, the hierarchy structure model is established. The index set of factor indexes, with M, according to the M={M1, M2, M3, M4}, M1={M11, M12, M13, M14, M15}, similarly to the M2 - M4, symbolic meanings are shown in Table 1

4.2. Determine Index Weights of the Performance Evaluation

Weight is also called the weight or the weighted coefficient, and is showed quantitative distribution based the important degree. It can reflect the relative importance of the indicators. In multi-level evaluation, the importance of evaluation indexes is usually different. Whether reasonable and scientific to the weight determination directly affects the accuracy of the evaluation. The meaning of the weight of each index as the index in this level is important degree relative to other indicators. The weight of each index is N={N1, N2, N3, N4} respectively, which are determined by expert investigation method or used Analytic Hierarchy Process (AHP) to get the weight of N= {N1, N2, N3, N4}.

The using AHP, there are five steps:
Step1. Establish the system-level model;
Step2. Tectonic binary comparison judgment matrix; (positive reciprocal matrix)
Step3. Calculate the maximum eigen value λ max of judgment matrix and corresponding eigen values;
Step4. Calculate consistency index CI, RI, CR and do consistency test. As a general rule, the relative consistency index is smaller, the consistency of judgment matrix is better. When the relative consistency index less than 0.1, we can say that the judgment matrix is satisfied. Otherwise, return to the step2, to adjust or fixed the valuation of comparative judgment matrix;
Step5. Determine the weight of each single index in the lowest layer of the hierarchical structure model (Xian 2005; Guo 2005).

4.3. Determine grade value of evaluation

Grade value of evaluation is various kinds of evaluation results made by evaluate for evaluation objects, and convert the qualitative indicators to quantitative indicators, should be assigned to each index accordingly.
In accordance with the principle of ten-point scale, the four rating scores were excellent, good, qualified and unqualified. Index levels in between the corresponding score for each value represented as R=\{R_1, R_2, \ldots, R_n\}.

4.4. Building the Grey One-way Evaluation Model

According to the hierarchical structure model, the judgment matrix is established. In the judgment matrix, the fuzzy evaluation matrix Di of two factors is assigned according to the data analysis, questionnaire, expert opinion and analysts’ cognition after the comprehensive. The grey single-tier mathematical evaluation model is Mi = Ni · R, where R means evaluation results of the r-th factor, and Ni is weights allocation matrix for the r-th evaluation index. The fuzzy comprehensive evaluation of the operator is chosen S(,,\ldots,\oplus).

\[ s_k = \min \left( 1, \sum_{j=1}^{m} \mu_j r_{jk} \right), \quad k = 1, 2, \ldots, n \]

4.5. Setting up Gray Multi-level Comprehensive Evaluation Model

Multi-level evaluation model based on the single level evaluation model, the basic idea is: first of all, the comprehensive evaluation is done on the base layer of the hierarchy system, then put the evaluation results Mi. (\(M_1 = N_1 \cdot R\)) of this level as a hierarchy of original indexes, repeated again on a single evaluation, and so on to the top.

\[ M = W \cdot R = \left( \mu_1, \mu_2, \ldots, \mu_n \right) \cdot \left( \begin{array}{cccc} t_{11} & t_{12} & \cdots & t_{1n} \\ t_{21} & t_{22} & \cdots & t_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ t_{n1} & t_{n2} & \cdots & t_{nn} \end{array} \right) = \left( M_1, M_2, \ldots, M_n \right) \]

\(\text{“} \oplus \text{”}\)is the fuzzy synthesis operator.

According to the most power principle of evaluation target M, evaluation of grey class level is determined. If R = max \{R_1, R_2, \ldots, R_n\}, then the value of the evaluation is the I class. Sometimes, the evaluation will lose effect because of dropping out too much information in accordance with the most power principle especially R cannot be directly used to rank and select for the evaluation object. Thus, we should do further processing with the gray comprehensive evaluation vector, so that make R with uniform and calculate V value of the comprehensive evaluation. IF all gray class level were assigned according to the gray level, then, we can get each gray evaluation class hierarchical vector U = \(\langle U_1, U_2, \ldots, U_i \rangle\), calculate the comprehensive evaluation value \(V = R \times U_T\), and sort evaluation object by the value V.

From the above description of the multilevel gray comprehensive evaluation method as you can see, the main characteristic is to describe different evaluation vector of gray classes using the scatter multiple evaluate information. Then uniform zing this vector, when there are many participants in the evaluation, the result can also been used for sorting selection according to the gray comprehensive evaluation value.

5. THE EMPIRICAL ANALYSIS

There is an electrical incorporated company A which is a large state-owned B shares listed company in China. In September 2004, the company had built EFLY ERP system successfully and the implement ERP systems including financial, supply chain management, manufacturing and other 20 modules and a set of Easy Flow of work-flow software. The overall objectives of the enterprise information construction are to reach the information integration among the company internal departments, suppliers and customers, to reach the research and development, production, management and service sharing resources, information and knowledge, and to improve enterprise's market reaction ability, innovation ability and customer satisfaction comprehensively. Through interviews and field survey with relevant personnel to understand the status of the whole system running, we adopted the questionnaire to answer questions, to obtain basic information of the evaluation. The results are shown in table 2(E= Excellent, W=Well, Q= Qualified, D= Disqualified).

<table>
<thead>
<tr>
<th>Table2</th>
<th>Performance evaluation data of the ERP system</th>
</tr>
</thead>
<tbody>
<tr>
<td>First layer</td>
<td>Weight</td>
</tr>
<tr>
<td>M_1</td>
<td>0.40</td>
</tr>
</tbody>
</table>
5.1. Determine the Weights of ERP Performance Evaluation

The index weights of ERP performance evaluation is calculated by using the Analytic Hierarchy Process method (AHP). The first layer index $M_i$ (i = 1, 2, 3, 4), whose weight vector is $M = \{0.25, 0.25, 0.25, 0.25\}$. The second index $M_{ij}$ (j = 1, 2, 3, 4, 5), whose weight vector is $M_{i} = \{0.30, 0.30, 0.13, 0.13, 0.14\}$.

5.2. Dividing the evaluation level

Rating standards as shown in table 3:

<table>
<thead>
<tr>
<th>Grade</th>
<th>$0.9 &lt; R_i \leq 0.6$</th>
<th>$0.6 &lt; R_i \leq 0.4$</th>
<th>$0.4 &lt; R_i \leq 0.2$</th>
<th>$0.2 &lt; R_i \leq 0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>Excellent</td>
<td>Well</td>
<td>Qualified</td>
<td>Disqualified</td>
</tr>
</tbody>
</table>

5.3. Building Evaluation Factor Matrix

According to the evaluation factors, to determine the membership of each factor and establish the evaluation matrix. The sample matrix can be divided into financial index $R_1$, customer index $R_2$, internal process index $R_3$, learning and growth index $R_4$. Evaluation grade level is got by the evaluation standard, which have filled in the corresponding mark sheets. According to the expert assessment, the sample matrix $R_i$ is made after processing.

The maximum characteristic root of the judgment matrix $R$ was calculated by the Mathematical software. The mean random consistency index $RI = 1.12$. The Random consistency ratio:

$$ CR = \frac{CI}{RI} = \frac{0.004725}{1.12} = 0.00422 < 0.10 $$

It is proposed that the hierarchical analysis sorting result was satisfactory consistency, namely the weights allocation is reasonable.

5.4. One-way Evaluation Respectively

First, calculate the comprehensive evaluation of $M_1$, the evaluation result is $V_1$ based on $V_j = M_1 \cdot R_j$. 

<table>
<thead>
<tr>
<th></th>
<th>$M_{12}$</th>
<th>$M_{13}$</th>
<th>$M_{14}$</th>
<th>$M_{15}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.30</td>
<td>0.13</td>
<td>0.13</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>0.4</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>0.3</td>
<td>0.3</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>0.1</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>0.1</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$M_{21}$</th>
<th>$M_{22}$</th>
<th>$M_{23}$</th>
<th>$M_{24}$</th>
<th>$M_{25}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.09</td>
<td>0.27</td>
<td>0.27</td>
<td>0.28</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>0.4</td>
<td>0.6</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>0.3</td>
<td>0.3</td>
<td>0.2</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$M_{31}$</th>
<th>$M_{32}$</th>
<th>$M_{33}$</th>
<th>$M_{34}$</th>
<th>$M_{35}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.23</td>
<td>0.23</td>
<td>0.23</td>
<td>0.11</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>0.3</td>
<td>0.4</td>
<td>0.7</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>0.3</td>
<td>0.2</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$M_{41}$</th>
<th>$M_{42}$</th>
<th>$M_{43}$</th>
<th>$M_{44}$</th>
<th>$M_{45}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.30</td>
<td>0.30</td>
<td>0.13</td>
<td>0.13</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>0.7</td>
<td>0.4</td>
<td>0.5</td>
<td>0.3</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>0.1</td>
<td>0.0</td>
<td>0.1</td>
<td>0.0</td>
<td>0.1</td>
</tr>
</tbody>
</table>

82
5.5. The Comprehensive Evaluation

\[ M = \sum w_i s_i = 0.4845 \times 40\% + 0.283 \times 30\% + 0.184 \times 20\% + 0.029 \times 10\% = 0.318 \]

From the above, the performance grade of a company ERP system implementation is showed by the evaluation classification standard in the table 3. The evaluation result of "Financial indicators" is the "Well" and "customer indicators" is "Qualified". According to the indicators score, the rating can be sorted. The evaluation of "internal process indicators" and "learning and growth indicators" is a little lower than other indicators.

It means that the enterprise information management is still in the early stages of the integration application. DM(database mining) and providing information for business decisions is the highlight in the future work, including knowledge management, technological innovation. The purpose of ERP performance is to make the enterprise information management to achieve the stage of data integration management (Guo 2005; Tian, 2013).

6. CONCLUSIONS

Different companies have different background, the strategic target and the business operation strategy. Each ERP system also has its characteristics, and each ERP system performance indexes will be different. So, ERP system performance evaluation index system in the actual assessment should be appropriately increase or decrease according to actual situation. ERP performance evaluation is broad, requires many basic data. Therefore, it is suggested that the company establish a special performance evaluation system with a special indicators database for data collection, sorting and processing. The enterprise may consider using other advanced information technology to evaluate when their technical force is abundant. For example, using business intelligence (BI) technology can process data with making the performance evaluation indicators database connected with ERP system, saving a large amount of data collection time, so as to improve the efficiency of performance evaluation. Using the "dashboard" visualization technology can display real-time performance evaluation of data.

The purpose of the ERP system gray-fuzzy comprehensive evaluation is to understand a comprehensive of the effect in ERP system operation, grasp the implementation of enterprise strategy, guide the enterprise's information construction and the management control, provide the basis for the system maintenance upgrade, while studying the effort level of the person in charge of the ERP system to fully arouse the enthusiasm of employees and improve the work efficiency.

Acknowledgments

This work was supported by National Natural Science Foundation of China (NO:71473074).

REFERENCES


L.A.Zadeh (1965)“Fuzzy sets”, Information and Control, 8, pp.338-353.

OliverWight (2000) The Oliver Wight ABCD Checklist for Operational Excellence. (The Oliver Wight Companies), Publisher: Wiley.


Xian F. (2005) “Using a spreadsheet (Excel) to achieve the level of analysis method (AHP) of the simple calculation”, China’s scientific and technological papers online.