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An ERP system performance assessment model development based on the balanced scorecard approach

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Abstract Previously completed research has not been significant when regarding the aspect of deriving a model for measuring the performance of an Enterprise Resource Planning (ERP) system. Therefore, this research attempts to present an objective and quantitative assessment model based on the Balance Scorecard approach for the purpose of appraising the performance of the ERP system. The methodology used in this research involves the Grounded Theory, Expert Questionnaire, the Analytic Hierarchy Process, and the Fuzzy Theory to filter out and develop the KPIs for the ERP system performance assessment model. It is expected that such a model may be used by enterprises to assess the efficiency of the ERP system during the various stages of management and support within the system. Finally, this assessment model is verified in a case company through the examination of its unbiased and quantifiable assessment approach. This result allows us to further understand authentic efficiency, and explore if enterprises have fulfilled their proposed objectives after the introduction of the ERP system.

Keywords Grounded theory · Analytic hierarchy process · Fuzzy theory · Enterprise resources planning (ERP) · Balanced scorecard

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1 Introduction

In light of technical limitations and considerations of management structure, the introduction of enterprise information systems in the past was mostly constructed according to functional areas needs. Although the needs for the internal operations of each department might be supported by an independent information system, different information technology systems were adopted by all departments. Likewise, different operating systems and hardware were used, and issues on overall enterprise and cross-department information integration were ignored. Because of this, each department became an isolated information island. The internal information in the enterprise cannot be exchanged or reconciled through computer systems. Furthermore, the overlapping input tasks also considerably affected the efficiency of such information systems.

The emergence of the Enterprise Resource Planning (ERP) system solves the problem described above because it acts as a management system, integrating all the information of the enterprise, including the marketing, sales, and planning process. This helps enterprise managers to generate the best decisions. The ERP system is a single software, which can integrate all departments and functions within the enterprise (Umble et al. 2003). It can also be regarded as a software module family where each module shares a database and closely connects with each other in

order to support the operational procedure of the enterprise (Hammer 2002).

The introduction of the ERP system is not a simple process. Enterprises must first have a clear prospect of available resources and future visions. They also must understand what effects and values will emerge once the ERP is introduced, and consider if these outputs will match future visions and goals. If necessary, enterprises also need to conduct business process reengineering to achieve such benefits. Therefore, the process of introducing the ERP system is relatively complex and extremely risky especially since implementation failures are sometimes reported (Bingi et al. 2001; Aloini et al. 2007). With respect to the capital investment, the introduction of the ERP system is considered an investment project that entails an enormous amount of capital. The cost of such a system could range from hundreds of thousands up to several million dollars. Other investments involved in the ERP project such as labor force, hardware, database, users' training, and enterprise reform management are all considered as necessary costs. It is estimated that enterprises around the world spend about 1 billion dollars on ERP systems every year (Yusuf et al. 2004). In addition, McHugh (2000) cited a survey in March 2000 of executives in charge of the ERP system's introduction in 100 American enterprises revealed that merely 1/3 of the executives made a positive evaluation, and only 37% of the respondents could identify the tangible effects of the system on the business' finances.

The introduction of the ERP system is relatively risky, and its efficiency might not be obvious. Thus, after enterprises swarm to introduce the ERP system, the major issue is how to effectively manage the system in order to allow it to fully accomplish the expected performance (Hunton et al. 2003). According to Kaplan and Norton (1996), if one cannot measure it (i.e. the ERP system) then one cannot handle it. Therefore, for enterprises intending to better manage and measure its IS/ERP system performance, it is wise to start measuring from the start of the system introduction/use so that they would have a better knowledge of their enterprise performance and can evaluate whether the IS/ERP system actually produces its intended benefits. Moreover, the management and performance appraisal of information technology differ from those involved in other financial investment projects, in which the relationship between purpose and effectiveness is mostly simple, clear, and quantifiable. The effectiveness of the enterprise brought on by investment in information technology includes many invisible manifestations of effectiveness (Brynjolfsson and Hitt 2000). The difficulty of performance appraisal and the management of information technology investments cannot be measured by the traditional accounting performance assessment method.

Although the academe has presented various studies (see (Norris et al. 2000; Poston and Grabski 2001; Nicolaou 2004)) with respect to the effectiveness of the ERP system's introduction, the studies tended to focus on the verification or categorization of effectiveness, sometimes using a case company to validate the effectiveness generalized by past literature. There is apparently a lack of complete, objective, and measurable effectiveness assessment models and appraisal methods. Thus, enterprises that have already utilized the ERP system could not recognize if the project's introduction was efficient.

Therefore, the main objective of this research is to generalize the collected previous literature related to the effectiveness of the ERP system's introduction, and use the Balanced Scorecard to design a complete effectiveness measurement method for the ERP system, which is validated using a real case. The goal is for enterprises to use an objective and quantitative method to clearly examine the benefits associated with the system's introduction and avoid high risks involved in the process.

The subsequent paper consists of five sections. First section contains the discussions on ERP system management and the Performance Appraisal Theory. In the second section, the methods used in this research are explained, and an in-depth description of the process on how the model in this research is established is given; and in third section, data related to the case company is used to validate the model. The fourth section summarizes the study and provides the research conclusions.

2 Theoretical background and discussion

2.1 ERP system management

Akkermans et al. (2003) believed that the ERP can offer the following functions. First, it can replace outdated, old systems by using integration, the latest technology, and a maintainable software. Second, the system offers enterprises a framework of transaction, and allows specific operational procedures for projects within the enterprise scale to be closely connected with each other. Third, the ERP system can also help transform a function-oriented organization into an operation-oriented one. It mainly accomplishes these assignments through financial, manufacturing, logistics support, distribution, and human resource modules. These five major modules can operate independently for implementing specific functions of an enterprise as well as connect with each other. Therefore, the ERP system can execute the original function as well as fulfill the goal of integrating the internal data of the enterprise through data exchanges among the modules in order to accomplish the daily operations, which are

considerably significant for the enterprise (Umble et al. 2003).

According to the collection and reorganization of the previous literature related to the effectiveness of introducing the ERP system, the reasons for enterprises' introduction of such a system included, but was not limited to, global operational management, close connection of each functional data system, reduction of operational costs, upgrades of enterprise operational efficiency, enhancement of enterprise decision-making quality and management efficiency (Reinhard and Bergamaschi 2001). These are mostly intended to solve problems with data integration and increase the enterprise's competitiveness. However, can the ERP system, with its powerful functions, really solve these problems and bring huge benefits for enterprises? According to some local and overseas literature, once an enterprise introduces the ERP system it can realize the benefits associated with it. These benefits include the ease of saving and receiving of data, integration of operational processes, visibility of data, and increase in overall enterprise operational activities quality (Olhager and Selldin 2003). The ERP can also integrate corporate information and reach the corporate goals of rapid delivery of goods, lower costs, internationalization, and improvement of the whole enterprise's performance (Yen et al. 2002).

Based on the study of Deloitte, the benefits of ERP's include reduction of stocks, trimming of labor force, increase of output, improvement of order management, reduction of IT and purchasing costs, improvement of cash flow management, increase of profits, reduction of transportation and logistics costs, reduction of system maintenance requirements, improvement of the ratio for immediate goods delivery, reinforcement of the visibility of corporate information, offering of the latest or best operational procedure, improvement of response time to customers' needs, reduction of costs out of expectation, close connection among the systems, increase of flexibility, data sharing in the whole company, solution of the Y2K problem, and finally, improvement of overall corporate efficiency (Majed et al. 2003).

Other benefits of the ERP system suggested by Yusuf et al. (2004) include the improvement of supply chain management through e-communication and e-commerce, reducing operational costs, offering the information needed by the clients, and management's ability to treat external suppliers, corporate alliances, and clients as a virtual enterprise.

2.2 Performance appraisal theory

Performance appraisal is an initial and critical part of management (Evans et al. 1996), as it can clearly describe the past and current situations, and function as the reference for future management (Stadtler and Kilger 2000). Therefore, in order to manage the ERP system well, the enterprise must initially have a proper performance appraisal model to assess its ERP system.

After collecting and consolidating the past literature pertaining to performance appraisal, it was discovered that the performance appraisal theory has been consistently evolving since its inception. In the beginning, it was conceived of as Univariate Effectiveness Measures; however, Steers (1977) indicated that Univariate Effectiveness Measures tended to merely assess one facet of performance and could not reveal the whole situation. Besides, it was difficult to define and select, but very easy to be affected by individual researchers' subjective factors. Thus, the theory evolved into Multivariate Effectiveness Measures. However, Steers still point out that Multivariate Effectiveness Measures usually lack mutual indicators. In addition, there was also no mutual principle for selecting performance appraisal indicators, which tended to be difficult to quantify and define in terms of relative weighting. In addition, the position of assessors would also affect the selection of indicators.

The theory further evolved to include financial statement analysis. However, Booth (1996) believed that this method focused on short-term assessment instead of long-term appraisal. Enterprises would tend to sacrifice long-term competitive advantages for short-term benefits, and it would be easy for them to neglect other critical information when their only focus was the financial aspect. This assessment system merely stressed the performance of the departments instead of satisfying customers' needs. The theory was thus turned into overall analysis. Although overall analysis considered all aspects of the enterprise, it could not usually convert the enterprise's overall strategies and goals into performance appraisal indicators.

Epstein and Manzoni (1997) indicated that there will be three major trends with respect to the development of a prospective performance system. One, future performance systems established by the enterprise will support the implementation of strategies. Two, future performance systems must include non-financial indicators in order to replenish financial indicators, and three; these systems must be promoted to the departments or districts, which actually create the performance for the organization.

According to the study of Gaiss (1998), the performance system developed by modern organizations must connect with the prospective strategic goals of the organizations. Thus, the overall analysis evolved into the strategic performance assessment. Kaplan and Norton proposed the concept of the Balanced Scorecard in 1992, which included four facets: learning and growth, customers, internal process, and finance. These not only involved overall performance assessment, but also combined corporate

vision and strategies. It has become an emerging tool for enterprises to properly evaluate overall performance.

Milis and Mercken (2004) organized and compared traditional capital investment assessment mechanisms, such as payback period, ARR (Accounting Rate of Return), ROI (Return on Investment), IRR (Internal Rate of Return), NPV (Net Present Value), and other emerging methods and techniques in their article. They indicated that these mechanisms were difficult to use to explain the associated intangible costs and benefits before and after the IT solutions. In addition, Clemons and Weber (1990) pointed out that most of these mechanisms were at the stage of conceptualization and could not yet be accepted by the public. Therefore, Milis and Mercken (2004) finally and enthusiastically recommended the use of the Balanced Scorecard as the proper assessment mechanism to evaluate the investment project of information technology.

3 Research method and the construction of the ERP performance assessment model

3.1 The research method and design

This research adopts a series of research methods, tools and approaches to collect and analyze data, and to propose an ERP effectiveness assessment model. The research methods and approaches used are the Grounded Theory, and case study, whereas the research tools utilized are the balanced scorecard, analytical hierarchy analysis and fuzzy logic. The flow chart of this research is as shown in Fig. 1.

The descriptions of the flow in Fig. 1 are given as below.

3.1.1 Stage 1–2: Grounded theory and balanced scorecard—synthesizing the list of effectiveness of ERP system

Grounded theory is a research method which allows the investigator(s) to play the role as the primary instrument of data collection and analysis. Its end result is a theory emerging from (or is "grounded" in) the data; and it is useful to practice, has its referent specific, everyday world situation (Merriam 1998).

In order to construct the Effectiveness Assessment Model for the ERP System's introduction, the Grounded Theory is used because no theory is assumed in advance in this study. Instead, they allowed the theory to be presented through the data. The Grounded Theory uses the statements and concepts in the original data and applies the methods of reorganization, analysis, constant comparison, and coding. The stage of open coding is used to analyze, examine, compare the data, and further name the phenomenon. The same phenomenon can be categorized into one group. The phase of axial coding is done to connect the subcategory and the main category according to their respective characteristics through deduction and generalization, and allows them to be correlated with each other. Therefore, the Grounded Theory collects and analyzes data through a systematic method, and is considered to be a critical means to reorganize qualitative data (Strauss and Corbin 1990). It can also be the most scientific and rational method among the different qualitative methodologies (Hammersley 1989).

This research analyzed the meaning of different kinds of effectiveness concepts reported in the use of the ERP system, then combined those with similar concepts, and refined them into a single intuitive concept of effectiveness of the ERP system. Similarly, the authors subsequently analyze, evaluate, and simplify all other effectiveness concepts and group the same concept into the same category.

The introduction of the ERP system should be combined with the existing corporate vision framework, organizational procedure, and strategic principles. The Balanced Scorecard can manage overall performance evaluations and combine the vision and strategies of the enterprise.

The Balanced Scorecard (BSC) is a performance management and measurement tool; it is a concept for measuring whether the micro operational activities of a company are aligned with its macro objectives in terms of vision and strategy. Its underlying rationale is that measuring an organization's performance mainly based on the financial perspective is not sufficient as this effort cannot directly influence financial outcomes (Kaplan and Norton 1992). It proposes that managers to select measures from three additional categories or perspectives: customer, internal business processes and learning and growth (Kaplan and Norton 1992). This stage also focuses on the four major facets of the Balanced Scorecard, and allocates each category found from the Grounded Theory stage to these four facets according to their respective characteristics in order to construct the effectiveness framework of ERP system introduction, which is mainly based upon the Balanced Scorecard.

3.1.2 Stage 3–5: Questionnaire, analytical hierarchy process and fuzzy theory—designing and refining the performance assessment indicators

Performance assessment indicators of different effectiveness facets extracted from the previous literature related to performance indicators could have been incorporated with subjective views. Therefore, we administered the questionnaire to collect the opinions of professionals from the academe, industry circles, and government agencies, which can filter out and improve these performance indicators. After calculating the Content Validity Ratio (CVR) of each performance indicator using the Analytic Hierarchy Process (AHP), we

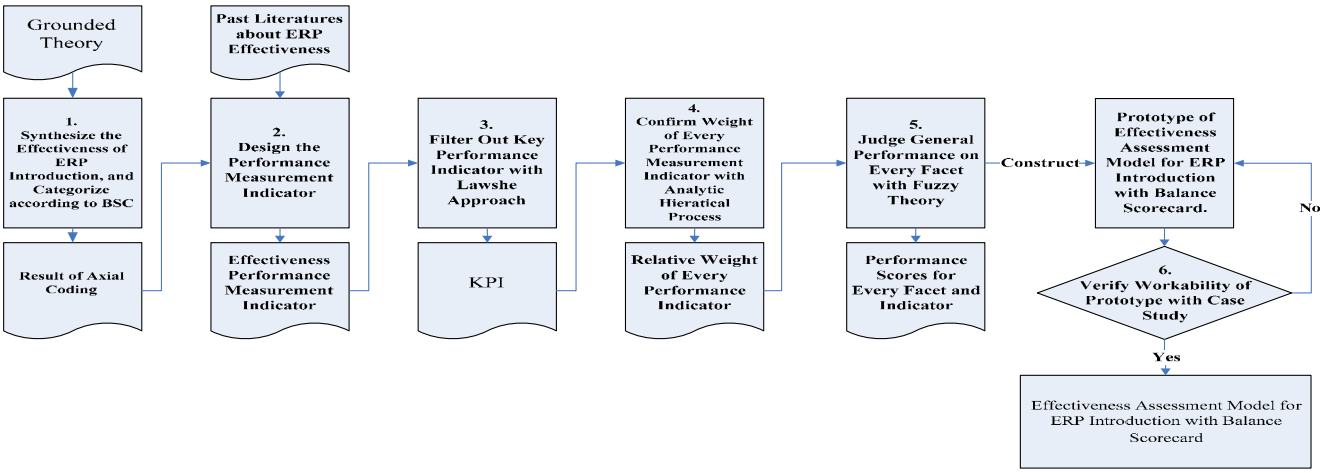

Fig. 1 Flow chart of the research

can obtain the salient performance evaluation indicators as the base for judging the performance of each facet.

The Analytic Hierarchy Process (AHP) is a mathematically based theory method for selecting competing solutions/ activities using distinct criteria, which can be quantitative or qualitative (Marakas 1998). The AHP offers a systematic way to weight multiple criteria aim to achieve the organizational goals by evaluating alternative solutions. The AHP can solve non-structural problems and is mainly applied to support decision making. Since different enterprises have different views when it comes to the significance of each performance indicator, this research adopts the AHP method in order to calculate the relative weight of each performance indicator.

Through administering questionnaires, this research gives understanding to the enterprises' perceptual differences with regard to assessment indicator levels, and uses the Fuzzy Theory (Zadeh 1965). Fuzzy theory permits the gradual assessment of the membership of elements (in the real unit interval [0, 1]) in a set (Zadeh 1965). It makes use of approximate reasoning rather than strict rule for set membership, and modeling how humans obtain information from imprecise information and vague phenomena. A major goal is to simulate normal human reasoning, knowledge and experience in a way that can allow the computers to behave less precisely and logically than the traditional computer methods require (Turban and Aronson 2001). Fuzzy theory uses the fuzzy inference logic in order to solve for factors of uncertainty in human thoughts to transform qualitative data into quantitative data for calculating the effectiveness of the ERP system introduction.

3.1.3 Stage 6: Case study—validating the proposed model

A case study acts as an empirical inquiry under realistic conditions and applies the observed evidence to obtain the conclusion. It is not only a method to collect data or a design feature, but it is a considerably complete research method that includes design logic and specific data collection as well as analysis (Yin 1994). The method mainly accesses the incidents, personnel affairs, and activities of research targets through the perspectives of actual participants (Gall et al. 1996). Thus, it allows people to evaluate realistic situations and is also an extremely valuable scientific research method, helping researchers obtain more practical data for constructing theories (McCutcheon and Meredith 1993). In order to ensure the quality of a case study, Yin (1994) suggested that it is necessary to consider the following four measurement standards (see Table 1).

In summary, this study utilizes an integrated approach to investigate the research problem of ERP system performance assessment model. The grounded theory is used because no theory is assumed in advance in this study. This method is used to analyze, examine and compare the data found in the previous literature. These performance indicator data are then categorized based on the four Balanced scorecard (BSC) perspectives. BSC is used as the performance measurement tool because it can provide overall performance evaluations and combine the vision and strategies of the enterprise. Subsequently, the Analytic Hierarchy Process (AHP) is used to calculate the relative weight of each performance indicator. The fuzzy theory is adopted to transform qualitative data into quantitative data for calculating the effectiveness or performance of the ERP system introduction. The glossary for the terms and jargons used in this study is given in the Appendix Table 19.

3.2 The construction of the ERP performance assessment model

3.2.1 Analytical result of the grounded theory

Since there are various reports on the effectiveness of the ERP's system introduction in academia, this research first

Table 1 The case study method dealing with four research design tests Yin (1994)

Evaluation	Strategies of case study	Stage of strategic application
Construct Validity	Using multiple information sources for constructing the proof chain so that the data providers can examine the draft of the case report	Data collection
		Data collection
		Report writing
Internal Validity	Using the type comparison method	Data analysis
	Using the explanatory construct method	Data analysis
	Using time sequence analysis	Data analysis
External Validity	Using repetitive logic with multiple cases	Research design
Reliability	Using case research agreement	Data collection
	Developing the database of the case	Data collection

collected previous literature, which mentioned the effectiveness of the ERP's system introduction, and then managed open coding in the Grounded Theory with respect to different effectiveness concepts in the existing literatures (Sharda et al. 1988; Appleton 1997; Poston and Grabski 2001; Gale 2002; Hunton et al. 2003; Nicolaou 2004; Matolcsy et al. 2005). One hundred sixty-three conceptualized results were identified and were transformed into 25 mutually exclusive items covering different perspectives. The detailed results of the 25 effectiveness are shown in Appendix Table 20.

Subsequently, this research allocated these 25 items of effectiveness into the four facets of the Balanced Scorecard and constructed the effectiveness framework for the ERP's system introduction. Kaplan and Norton (1992) indicate that financial facet includes some index used to indicate whether an organization's business operations are resulting in improvement of the bottom line. Customer facet consists of index that can be used to measure an organization's performance from the customer perspective. Internal process facet focuses on the core competencies. Learning and growth facet contains index for evaluating an organization continuous business improvement. Hence, this study employed these criteria and allocated each item to suitable facet according to its characteristics. For example, in the internal process facet, the internal operations in the enterprise are stressed; and the critical additional value activities, which can result in the supply chain performance improvement and reinforce shareholders' value, are also particularly emphasized. Improving the performance of the operational procedure (the 10th component of effectiveness) is certainly part of the internal operation of any enterprise, and better operational effectiveness (the 17th component of effectiveness) implies better stakeholders and shareholders value. Thus, these two items of effectiveness can be allocated within the internal process facet. The detailed results of coding are shown in Table 2.

According to the data reorganization and analytical results, there were more items of effectiveness allocated in the learning and growth facets than for the financial and internal process facets. This means that enterprises' introduction of the ERP system is not only beneficial in the sense that it can upgrade current corporate performance with common investment projects, but it is also more beneficial for the future growth and competitiveness of the enterprises.

Based on the analysis of individual effectiveness, it is determined that once enterprises introduce the ERP system, assistance in e-dealing procedures will not only considerably reduce operational costs but will also improve the performance of operational processes. The response time to customers will also be reduced. In addition to providing information for decision-making, the ERP system allows the information to be more accurate and timely. The ERP system, which emphasizes cross-department information system integration, also makes information-sharing among departments easier and connections among the departments better. As to corporate productivity, the business volume and profits also increase due to the effectiveness of the system.

3.2.2 Designing the performance assessment indicators according to the grounded theory result

In terms of literatures related to performance indicators, this research developed 43 items for effectiveness measures (or performance indicators) of the ERP's introduction based on effectiveness (Kaplan and Norton 1996; Booth 2000; Lipe and Salterio 2000; Banker et al. 2004; Milis and Mercken 2004; Dilla and Steinbart 2005). For example, "reducing the time to react" in the customer's facet can be measured by the duration of "response time to customers' needs" and the "ratio of immediately responding to customers' inquiries". Meanwhile, "offering more accurate and immediate

Table 2 Result of axial coding

Facet	Effectiveness	Frequency	Facet	Effectiveness	Frequency
Financial facets	Reducing costs	12	Customer	Enhancing the level of customer satisfaction and loyalty	3
	Increasing business volume and profits	10		Reducing the time to react	10
	Increasing the inventory turnover rate	9		More immediate delivery	4
	Reducing the financial pay-up cycle	7		Improving product quality	4
	Reducing the costs of information techniques	3	Learning and growth	Offering more accurate and immediate information for decision making	12
	Reducing the total cycle time	3		Enhancing the connection among departments through information sharing	8
Facet of internal procedure	Improving the performance in operational procedure	10		Increasing organizational productivity	10
	Better operational efficiency	5		Increasing enterprise competitive advantages	2
	Improving the performance of the supply chain	3		Reduction of personnel	2
	Reducing the time to enter the market	1		Improving the information system framework	2
	Reducing repetitive operations	3		Enhancing employees' sense of achievement	1
	Reducing work complexity	1		Helping monitor the global operation environment	1
				Enhancing information system functions	1

Table 3 Key performance indicators of the effectiveness of the ERP system's introduction

Facets	Performance/measure indicator	Description
Financial matters	1. gross margin	Current term gross margin/net sales
	2. net profit ratio	Current term net profit/ net sales
	3. revenue growth ratio	(current term sales-prior term sales)/prior term sales
	4. profit growth ratio	(Net profit/-prior term net profit)/ prior term net profit
	5. inventory turnover rate	Sales cost/[(ending inventory + initial inventory)/2]
	6. reduction rate of inventory level	(ending inventory-initial inventory)/ initial inventory
	7. receivables turnover rate	Net credit/[(ending receivables + initial receivables)/2]
	8. cash conversion cycle	Period from material purchase to shipment and cash receiving
	9. business cycle	365/inventory turnover rate + 365/receivables turnover rate
Customers	10. response time required by customers	Measuring the speed of the enterprise in dealing with customers' needs
	11. ratio of immediately responding to customers' concerns	Times of immediately responding to customer inquiry/total times of customer inquiry
	12. accurate delivery rate	Accurate delivery times/total delivery times
	13. customer reject rate	Current term reject times/total times of current term shipment
Internal process	14. reduction percentage of unexpected shutdown time	(unexpected shutdown time before constructing ERP-unexpected shutdown time after constructing ERP)/unexpected shutdown time before constructing ERP from receiving orders to delivering the goods to customers
	15. order dealing time	
	16. product manufacture time	Average time to produce uni-product
	17. capacity to cope with provisional orders	Time from receiving to finishing one provisional order
Learning and growth	18. accurate information ratio	Time to generate accurate information by the system/total time to generate information
	19. information dealing time	Time to generate information by the system
	20. information delivery time among departments	Average document delivery time
	21. database integration rate	Measuring corporate information system integration level

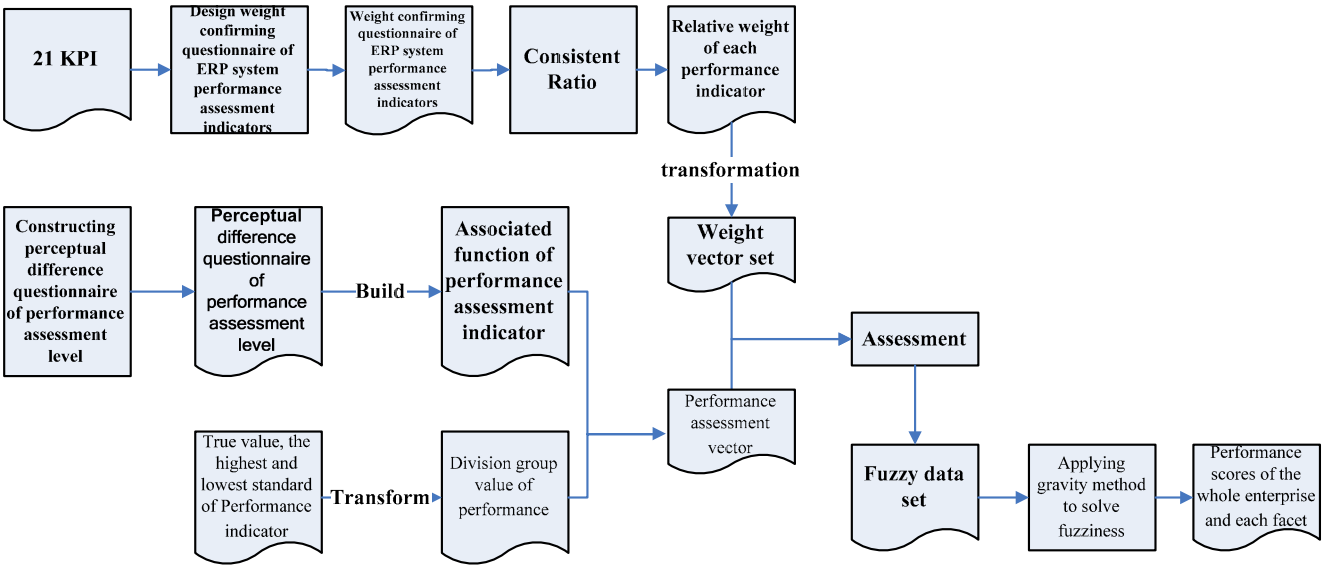

Fig. 2 Application steps figure of the assessment model

information for decision making" in the learning and growth facet can be measured by the "information accuracy ratio" and the "information dealing time". The detailed information is shown in Appendix Table 21 below.

3.2.3 Refining the performance indicators through the expert questionnaire

The Expert Questionnaires were distributed to the pioneers of the academe, industry circles, and governmental units related to ERP. We filed and filtered out the 43 performance assessment indicators generated from the previous stage. This stage is intended to find the key performance indicators, which the scholars and experts agreed upon to be used for the evaluation of the effectiveness of the ERP system's introduction. There were 20 questionnaires distributed and nine valid returns, resulting in a 45% rate of return. The nine experts include three professors and six top-level managers. Based on the order of importance for each measurement indicator from the experts, this study employed the Content Validity Ratio (CVR) to check whether the indicator is critical. As there are nine experts in this study, the CVR should be greater than 0.78 in order to be selected (Lawshe 1975). The formula to compute the CVR is: CVR = (n-N/2)/(N/2). The symbol "n" indicates the key factors considered important, but not absolutely relevant by the experts. The symbol "N" represents the number of experts.

Based on the responses made in the abovementioned questionnaire, this research finally filtered out 21 key performance indicators of effectiveness as agreed upon by the experts and scholars. As to the financial facet, the researcher filtered out nine items including gross margin, net profit ratio, and revenue growth ratio, to name a few. Customer facet includes four items, for example the response time required by customers and the ratio of immediately responding to customers' inquiries. The internal process facet involves four items such as reduction percentage of unexpected shutdown time and order dealing time. Finally, for the learning and growth facet, the researcher filtered out four items including accurate information ratio and information dealing time. The definitions of each performance indicator are described in Table 3.

Table 4 Pairwise comparisons of the weight (importance) of the four facets of Balanced Scorecard ERP system performance assessment indicators

X	X more important									Equal	Y more important								Y
Financial	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	Customer
	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	Internal process
	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	Learning and growth
Customer	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	Internal process
	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	Learning and growth
Internal process	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	Learning and growth

Table 5 Pairwise comparisons of the weight (importance) of the nine performance assessment indicators of the financial-facet

X	X more important									Equal	Y more important								Y
1.Gross margin	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	2.Net profit ratio
	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	3.Revenue growth ratio
	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	4.Profit growth ratio
	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	….
	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	9.Business cycle
2.Net profit ratio	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	3.Revenue growth ratio
…	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	…
8.Cash conversion cycle	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	9.Business cycle

3.2.4 The prototype of the ERP performance assessment model

Finally, based on the 21 filtered KPIs and on the knowledge of the AHP and Fuzzy Theory, the research constructed a prototype of the assessment model for the effectiveness of the ERP system's introduction. The prototype includes five steps as shown in Fig. 2. The detailed description is as follows:

Step 1 Based on 21 KPIs reorganized and generalized by this study, the researchers must modify the operational definitions of indicators and the duration of data according to the characteristics and actual situations of different industries and enterprises. We designed a "Weight confirming questionnaire of the ERP system's performance assessment indicators", in the format as shown in Tables 4, 5, 6, 7 and 8, in order to get accurate data about the internal enterprise's views toward the relative significance of each performance indicator. Based on the returned questionnaire, the authors enter the relative importance of each facet and its sub-criteria into the Expert Choice or other similar software to compute the Consistency Ratio (CR value must ≤0.1), and calculate the relative weight of each performance assessment indicator. For the step by step details on how to use the Expert Choice system or AHP approach can be obtained from this website: http://en.wikipedia.org/wiki/Analytic_Hierarchy_Process. The computed weight for each indicator (KPI) forms the basis for vector A.

Step 2 In the same survey instrument as in Step 1, we designed a "questionnaire of perceptual "differences for performance assessment indicator levels of enterprise' introduction of the ERP system" to understand the enterprises' views on the perceptual differences of each performance assessment indicator level, as well as construct its membership functions. In order to take care of the potential fuzziness in the data provided by respondents, we further partition each assessment level into two halves as illustrated in Table 9. It is assumed that the respondents indicated that the performance assessment level of gross margin is excellent, and should fall between good and excellent performance. Thus, a line is drawn between these two zones, as shown in Table 10.

As for the membership function, it is set up based the relative frequency of each of the 10-part (as in Table 9) for each KPI, using the formula of X/N, where N is the total number of questionnaires and X is the number of times a group (for a KPI) was selected.

Table 6 Pairwise comparisons of the weight (importance) of the four performance assessment indicators of the customer-facet

X	X more important									Equal	Y more important								Y
10.Response time required	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	11. Ratio of immediate response
	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	12. Accurate delivery rate
	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	13.Customer reject rate
…	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	…
12. Accurate delivery rate	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	13.Customer reject rate

Table 7 Pairwise comparisons of the weight (importance) of the four performance assessment indicators of the internal process-facet

X	X more important									Equal	Y more important								Y
14.Reduction % of unexpected shutdown time	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	15.Order dealing time
	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	16. Product manufacture time
	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	17.Capacity to cope with orders
…	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	…
16. Product manufacture time	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	17.Capacity to cope with orders

Step 3 Also in the same survey instrument as in Step 1 and 2, the true value, highest standard and lowest standard of each KPI are collected. By using these three measures, the performance division group value for each KPI is calculated based on the following formula:

$$\text{Performance division group value} = \frac{\text{true value} - \text{lowest standard}}{\text{highest standard} - \text{lowest standard}} \times 10$$

Step 4 We can now construct the performance assessment set R by referring the performance division group value$\tilde{}$ of a KPI (obtained from Step 3) to the KPI membership function (obtained from Step 2),.

Step 5 Using the weighted vector set of Step 1 and the performance assessment level set in Step 4, we obtained the fuzzy evaluation set for overall KPIs performance using the following formula:

$$\underset{\sim}{A} \circ \underset{\sim}{R} = \underset{\sim}{B}$$

Where B is the overall performance fuzzy evaluation sets, and $\circ\tilde{}$ is the Composition Operator. The corresponding value in vector B for each set of performance score (e.g. see Table 11) is then$\tilde{}$ plotted in a graph. The areas, A*i*, under the graph are then computed. And, the gravity measure for each area, A*i*, is calculated using this gravity formula according to its shape.

Finally, we applied the operation of M (•, +) to obtain the performance scores of the whole enterprise for each facet, using this formula $\overline{X} = \frac{\sum \overline{X_i} \ A_i}{\sum A_i}$. Based on Table 11, the performance after the introduction of the ERP system can thus be recognized. For instance, if the score of performance is 65, then the situation of performance is "Good performance".

4 Case study

This research expected to construct an objective and quantifiable effectiveness assessment model for the ERP system's introduction. This assessment model is expected to not only be a theoretical research finding, but can also be applied to real and empirical circles. The prototype of this model is verified in a case company from the stainless steel secondary processing manufacture industry.

4.1 Background of the case company

The case company was established on Jan. 11, 1992 with a capital of 26 million New Taiwanese Dollars. At its inception, the company exclusively dealt with exports of stainless materials and other manufacturing transactions. It was later transformed to manage the business of manufactured stainless materials. In 1999, the company moved from Taichung Industrial Park to Changhua Chuan-Hsing Industrial Park. In 2000, it founded a stainless pipe professional manufacturing plant in Chang-pin Industrial Park, and

Table 8 Pairwise comparisons of the weight (importance) of the four performance assessment indicators of the learning and growth-facet

X	X more important									Equal	Y more important								Y
18.Accurate information ration	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	19.Information dealing time
	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	20.Information delivery time among dept.
	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	21.Database integration rate
…	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	…
20.Information delivery time among dept.	9	8	7	6	5	4	3	2	1		2	3	4	5	6	7	8	9	21.Database integration rate

Table 9 General format of the questionnaire of perceptual difference performance assessment level

Performance Assessment level	Excellent						
	Medium						
	Very bad						
		Very bad performance	Bad performance	Average performance	Good performance	Excellent performance	

became involved in the stainless pipe business. With the expansion, the case company continued to purchase advanced facilities to enhance its market competitiveness. The case company has been upholding the managerial ideas of "integrity, stability, growth, responsibility, and specialty" in the pursuit of corporate sustainable development and increases in client satisfaction. The company also expanded with a new scope of stainless materials, externally enhanced service quality and high competitiveness, internally reinforced working efficiency, and upgraded professional techniques. The company also passed the ISO9001:2000 edition of international quality system certification, and has established an image of maintaining excellent product quality.

By the end of 2004, the company's capital grew to 353 million New Taiwanese Dollars. Around that time, there were about 100 employees. The company's major clients included Chieh-mao, Chang-ching, Yu-lung, and Sheng-hsiang. The main suppliers were Yi-lien, Tang-jung, Tung-meng, Chian-hsin, and Asia Chemical. The major competitors were Hsin-kung, Chen-yu, Yun-chiang, etc. The business volume in 2004 was about 435 million, and the business objective for 2005 was sales of 60,000 tons of stainless materials.

The original information system of the case company was based on divisional stages to integrate corporate information. During the process of integration, it was inevitable to face differences in time and precision. Thus, in order to efficiently integrate corporate information, after assessing the factors of completeness of the software system, availability of human resources and introduction expenditure, and the suppliers' supports exclusively for the steel industry, the case company decided to use the WorkFlow ERP system of Data Systems, the largest local ERP vendor in Taiwan. This ERP system was introduced in 2002 and it provided stock management, order management, purchasing management, manufacturing, account receivables and payables, note capital, personnel affair management, and other special purpose module such as card zipping. The company expects to completely reduce the business errors of the personnel, and upgrade the accounting closing time with consistent speed.

The process of ERP system introduction to the company occurred through slow employees' education at the initial stage. At the phase of formal introduction, the company completely integrated to the ERP system and abandoned the old information system. During the introduction process, the top executives, such as the chairman, were all very supportive of the ERP system. The executives of each unit were also considerably cooperative and supportive.

With respect to effectiveness after introduction, the case company indicated that although the ERP system is a complete software set, they could not merely focus on certain modules. The precision of distribution module and reduction of human errors, were more prominently improved. Therefore, as to the financial facet, only account receivables and accounting management were further improved and the gross margin ratio or revenue was not as prominent. This revealed some reduction of errors and the precision of information offering. The non-financial facet showed a better effect, particularly with distribution operations. The company can rapidly reduce order-dealing time, create scheduling and delivery times, and improve client satisfaction. In addition, the employees' operational errors were also relatively reduced, and self-learning capacities were improved. The operational process of the case company was also improved, which reinforces the image of the company. Thus, competitiveness was strengthened with the introduction of the ERP system.

4.2 Preparation for obtaining the related assessment model data

After interviewing the case company three times, the definitions of assessment indicators and the duration of data were adjusted as given in Appendix Table 22. Different questionnaires were distributed according to the

Table 10 Perceptual difference assessment for Gross Margin

Performance Assessment level	Excellent						
	Medium						
	Very bad						
		Very bad performance	Bad performance	Average performance	Good performance	Excellent performance	

Table 11 Transformed relationship between performance scores and situations

Scores of performance	0~20	20~40	40~60	60~80	80~100
Situations of performance	Very bad performance	Bad performance	Average performance	Good performance	Excellent performance

departments based on their expertise, to their top and middle management. The main content of the questionnaire is divided into three parts: (1) understanding the respondents' views toward the relative significance of the ERP system performance assessment indicator (the first step of the assessment model), (2) understanding the respondents' views toward the evaluation level of each performance assessment indicator (excellent, medium and very bad) and their corresponding performance (the second step of the assessment model), and (3) understanding the respondents' views toward the performance indicators. Doing this required the respondents to reply by scoring and obtaining the true value of a qualitative indicator by means of the average (the third step of the assessment model). However, the options of each section are based upon the fields and experience of each department, and the options related to the four major facets of the Balanced Scorecard allocated in the questionnaire for each department.

Subsequently, the same group of personnel in the general manager's office was invited to provide their views toward organizational performance in another interview survey. The goal of this interview is to collect the subjective views of the corporate executives and use it to verify the result of our proposed assessment model. The measures were requested to evaluate their satisfaction level for the significance of the performance indicators at the case company (denoted as satisfaction) and their importance in comparison with its major competitors (denoted as importance) in each assessment indicator (this was measured through the five-point Likert scale, in which 1 refers to not very important/very unsatisfied and 5 means very important/very satisfied), see (Govindarajan 1988; Govindarajan and Fisher 1990). Finally, by multiplying the score of satisfaction and importance, the performance scores were obtained for this indicator. Because there are five indicators under each facet, the performance scores of all five performance indicators were then added to obtain the performance scores of the facet before standardization. The following formula was used to standardize the performance scores of the facet between 0 and 100 points.

$$\text{Performance score after standardization} = \frac{\text{performance scores before standardization} - 5}{120} \times 100$$

4.3 Results of the assessment model in the case company

The following describes the operational process of the assessment model in the case company:

4.3.1 Consistent ratio and weight of each performance indicator

This research used the Expert Choice 2000 software to compute the weight of each performance indicator. From the returned 24 questionnaires, 14 were found having the CR values to be less than or equal to 0.1.

Table 12 Weight of each facet and each performance indicator

Facets or indicators	Hierarchical Weight	Overall weight	Facets or indicators	Hierarchical Weight	Overall weight
Financial	0.249	0.249	Response time required by customers	0.117	0.031
Customer	0.263	0.263	Level of immediate response to customers' consulting	0.200	0.053
Internal process	0.338	0.338	Accurate delivery level	0.388	0.102
Learning and growth	0.150	0.150	Frequency of customer rejects	0.295	0.078
Gross margin	0.360	0.090	Reduction level of times of unexpected work shutdown	0.059	0.020
Net profit ratio	0.263	0.065	Order dealing speed	0.171	0.058
Revenue growth ratio	0.126	0.031	Product manufacture speed	0.450	0.152
Profit growth ratio	0.060	0.015	Capacity to cope with provisional orders	0.321	0.108
Inventory turnover rate	0.048	0.012	Accurate information ratio	0.531	0.080
Reduction rate of inventory level	0.043	0.011	Information dealing speed	0.143	0.021
Receivables turnover rate	0.036	0.009	Information delivery speed among departments	0.174	0.026
Speed of cash turnover	0.032	0.008	Integration level of information system	0.152	0.023
Business cycle	0.032	0.008			

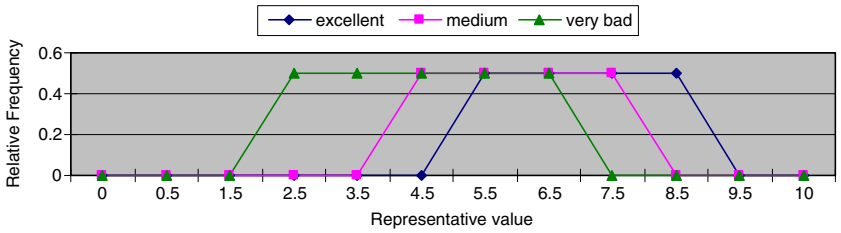

Fig. 3 Membership function of gross margin

These valid questionnaires were subsequently used to calculate the integrated pair-wise comparison matrix and to obtain the weighting for each facet and performance indicator. The results, which are automatically computed by the Expert Choice 2000 software, are shown in Table 12.

4.3.2 Construction of the associated function of the performance assessment indicators

Ten equal parts, ranging from "very bad performance", "bad performance", "average performance", "good performance", and "excellent performance" were provided in the questionnaire of perceptual differences of the performance assessment indicator evaluation level as the basis for group division. By using the statistics on the total number of questionnaires (N) and the number of times each group was selected (X), the relative frequency of each group (i.e. X/N) is then computed. This relative frequency refers to the level of membership. The authors then regarded the average value of each group as a representative value. The representative value refers to the x-coordinate, and relative frequency refers to the Y-axis. The authors drew these in a graph, connecting each point into a curve using the Richardson extrapolation method to expand the scale from 0 to 10 and from left to right. The curve obtained is called the membership function. The membership function of gross margin is shown here in Fig. 3.

4.3.3 Transformation of performance division group value

Using the formula as discussed in the Section 3.2.4, the division group value is calculated. As for the quantitative indicator, the financial information from 1999 to 2004 were obtained and the year 2004 was considered as the true value. The best and the worst financial performance of each indicator from 1999 to 2004 were then considered as the highest and lowest standards, respectively. With regard to qualitative indicators, the researcher used a questionnaire to obtain the respondents' subjective views on the performance of each indicator in 2004 as the true value, with 10 points as the highest and 0 as the lowest. The results are shown in Table 13.

4.3.4 Constructing the performance assessment sets $\underset{\sim}{R}$

This step used the division value and membership function of the performance indicators to map into the membership function value, as well as to collect all of the membership functions included in the performance evaluation set. For example, the division value of the gross margin is 5.88; and based on the membership function of gross margin shown

Table 13 Division group value of performance indicators

Performance indicators	Division group value	Performance indicators	Division group value
gross margin	5.88	response time required by customers	5.33
net profit ratio	6.04	level of immediate response to customers' inquiry	6.00
revenue growth ratio	10.00	accurate delivery level	6.00
profit growth ratio	0.52	frequency of customer rejects	5.67
inventory turnover rate	7.25	reduction level of times of unexpected work shutdown	7.67
reduction rate of the inventory level	4.22	order dealing speed	8.00
receivables turnover rate	10.00	product manufacture speed	7.33
cash turnover speed	7.00	capacity to cope with provisional orders	8.00
business cycle	10.00	information accuracy level	7.63
		information dealing speed	7.38
		information delivery speed among departments	7.00
		information system integration level	6.75

Table 14 Performance levels

Facets	Indicators	Very bad	Medium	Excellent
Financial matters	gross margin	0.5	0.5	0.5
	net profit ratio	0.23	0.5	0.5
	revenue growth ratio	0	0	0
	profit growth ratio	0	0	0
	inventory turnover rate	0.5	0.5	0.5
	reduction rate of the inventory level	0	0.36	0
	receivables turnover rate	0	0	0
	cash turnover speed	0.25	0.5	0.5
	business cycle	0	0	0
Customers	response time required by customers	0	0.7261	0.2739
	level of immediate response to customers' inquiry	0	0.335	0.33
	accurate delivery level	0	0.335	0.33
	frequency of customer rejects	0	0.5561	0.3878
Internal procedure	reduction level of times of unexpected work shutdown	0	0.2739	0.4439
	order dealing speed	0	0	0.835
	product manufacture speed	0	0	1
	capacity to cope with provisional orders	0	0	0.835
Learning and growth	information accuracy level	0	0.10875	0.5325
	information dealing speed	0	0.015	0.405
	information delivery speed among departments	0.0625	0.125	0.5625
	information system integration level	0	0.09375	0.6875

in Fig. 3, the corresponding membership function values to the three membership function curves (i.e. very bad, medium, and excellent) are, respectively, (0.5, 0.5, and 0.5). Thus, this performance assessment set became $\underset{\sim}{R} = \{0.5, 0.5, 0.5\}$. The same operation was also applied on the assessment set of the other performance indicators. Through this, all of the assessment sets were obtained.

$$\underset{\sim}{R} = \begin{Bmatrix} 0.5 & 0.5 & 0.5 \\ 0.23 & 0.5 & 0.5 \\ \dots & \dots & \dots \\ 0.0625 & 0.125 & 0.5625 \\ 0. & 0.09375 & 0.6875 \end{Bmatrix}$$

, detailed information is shown in Table 14.

4.3.5 Managing fuzzy judgment by using the gravity method

The following used overall performance as an example to describe the operational process of this step. Using the results of A and R, we calculated the overall performance fuzzy evaluation set B of the case company.

Overall weight sets $\underset{\sim}{A} = \{\, 0.09 \;\; 0.065 \;\; \dots \;\; 0.026 \;\; 0.023 \,\}$

Overall indicator assessment set $\underset{\sim}{R} = \begin{Bmatrix} 0.5 & 0.5 & 0.5 \\ 0.23 & 0.5 & 0.5 \\ \dots & \dots & \dots \\ 0.0625 & 0.125 & 0.5625 \\ 0 & 0.09375 & 0.6875 \end{Bmatrix}$

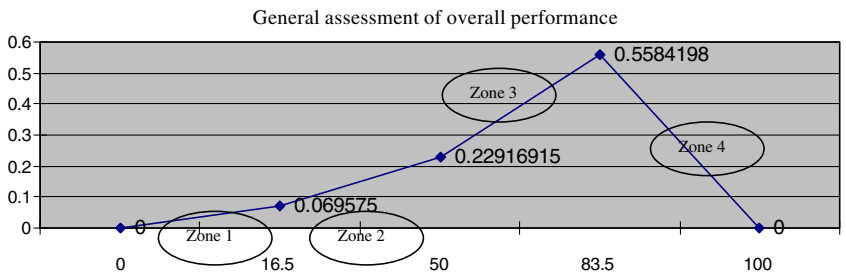

Fig. 4 General assessment diagram of overall performance

Table 15 Calculation process of the whole performance score

	Zone 1	Zone 2	Zone 3	Zone 4
Square measure A_i	0.574	5.004	13.192	4.607
Gravity $\overline{X_i}$	11.000	36.233	69.084	89.000
$\overline{X}$ = 64.55				

Overall performance fuzzy assessment set is:

$$\underset{\sim}{B} = \underset{\sim}{A} \circ \underset{\sim}{R} = \{0.069575 \quad 0.22916915 \quad 0.5584198\}$$

Three attributes of "very bad", "medium", and "excellent" levels were designated to represent the following range of performance facet scores: 0~33 points, 33~67 points, and 67~100 points respectively. The indicator assessment membership in the fuzzy assessment set for performance was considered as the Y-coordinate and the assessment equal part middle point (e.g. if excellent represents 67~100, so its middle point is (100-67)/2=83.5) as the X-axis. This was used to draw the indicator assessment for membership in the diagram. Each point was connected with straight lines and expanded externally to the zero point, i.e. (100, 0). A general performance assessment diagram was drawn. Figure 4 shows the overall general performance assessment diagram resulting from this process.

The diagram in Fig. 4 is then divided into four zones (where zone 1 and 4 are triangles, and zone 2 and 4 are trapezoid shapes) and applied the polygon square measure (or area) formula to obtain a measure of A_i and the individual gravity measure $\overline{X_i}$, where *i* is zone area. For example, square measure of A_1 is 0.574 (16.5× 0.069575÷2); A_2 is 5.004 [(0.069575+0.22916915)*(50–16.5) ÷2]; A_3 is 13.192 [(0.5584198+0.22916915)*(83.5–50) ÷2], and A_4 is 4.607 (16.5×0.5584198÷2). On the other hand, gravity measure of $\overline{X_1}$ is 11 [(0+16.5+16.5)/3]; gravity measure of $\overline{X_4}$ is 89 [(83.5×2+100)/3]. The formula of the whole gravity $\overline{X}$ is: $\overline{X} = \frac{\sum \overline{X_i} \quad A_i}{\sum A_i}$. The overall gravity position is the performance score. Table 15 shows the calculation process of the overall performance score.

Table 16 Reorganization of performance scores and the performance of the case company

The whole or facets	Performance scores	performance
General operational performance	64.55	Good performance
Financial	51.96	Average performance
Customer	60.10	Good performance
Internal process	77.17	Good performance
Learning and growth	71.70	Good performance

Thus, the overall performance score is 64.55, which is a "good performance" according to Table 5. The same operational process was also applied to the performance scores of each of the other four facets. The overall performance scores and the specific performance scores of each facet were then transformed into general performance scores using Table 5. The reorganization is shown in Table 16:

4.3.6 Result of case verification

In order to verify (1) whether the model actually matched the managerial subjective views toward the performance of the whole and each specific facet after the introduction of the ERP system, and (2) if the objectivity and quantification of this model replaces the past subjective assessment toward performance, this study compared the performance generated from the subjective assessments with the results of this model. Thus, another interview survey was distributed to the same sample group, who was the top and middle management of the case company in 2005 to collect their subjective views by rating their satisfactions with each performance indicator in 2004 and rating the importance of each performance indicator to the company. Each evaluation was based on 5-Likert-scale. Therefore, the final computed range of scores was between 1 and 25. After the questionnaires were returned, the performance scores of each facet were computed. The detailed information is shown in Table 17.

The authors compared Table 16 (performance scores and performance calculated through the assessment model) and Table 17 (performance scores and performance calculated through the subjective replies of top managers in the case company) and the result is reorganized as shown in Table 18.

According to the data found in Table 18, the performance scores questionnaire based on the manager's subjective responses in general are lower than the performance scores generated by the assessment model. However, the score of overall performance is not significant different.

With regard to each assessment facet, the performance scores of the internal process facet and the learning & growth facet, regardless generated from the model or from subjective views, take the first and second positions in the sequence of performance. The performance levels are labeled as "good performance", so it can be surmised that the performance of the case company was accurately obtained.

As to the performance scores of the financial facet, the financial facet calculated through the assessment model is lower than the subjective views. The reason might be that during the period of our collected data (from 1999 to 2004, i.e. before and after 2 years of the ERP system introduction), the rise and fall of performance was too extreme (for example, the highest profit growth ratio is 1939.78% and the lowest is −94.58%). As to the performance of the customer facet, although both are not at the same performance level, the

Table 17 Reorganization of performance scores of each attribute

Facets	Indicator	Average scores	Total scores	Facets	Indicator	Average scores	Total scores
Financial	gross margin	12.0	56.67	Internal process	Productivity utilization rate	18.0	66.25
	net profit ratio	13.0			Good ratio	16.0	
	revenue growth ratio	18.0			Level of investing new facilities	14.5	
	inventory turnover rate	18.0			Order dealing time	18.0	
	investment returns rate	12.0			Output rate	18.0	
Customer	Market share rate	16.0	55.83	Learning and growth	Employee productivity	22.5	60.83
	Customer satisfaction	10.0			Employee satisfaction	16.0	
	Customer returns rate	12.5			Employee techniques reinvention	11.5	
	Brand image	18.0			Employee flow rate	14.0	
	Customer reject rate	15.5			Personal organizational cooperation	14.0	
Scores of general performance: 59.90							

performance score calculated through the assessment model is 60.10 points, which is just above the threshold of the average performance level. This shows the difference is not enormous and can still be acceptable.

With regard to the whole performance, although the performance level is different, the performance score generated from the responses of the general manager-level executives is 59.90 points. This is very close to the threshold of "good performance", and is not so different from the 64.55 points calculated through the assessment model. Thus, the result is still pretty closed and acceptable.

5 Conclusions

This research applied the Grounded Theory to reorganize the coding of different effectiveness concepts mentioned in the literature, and found 163 items of effectiveness, which were distilled into 25 items. Based on this, 43 performance assessment indicators were designed for the 25 items of effectiveness but only 21 KPIs were confirmed through the Expert Questionnaire. Using these 21 KPIs, the balanced scorecard, AHP and the Fuzzy Theory were used to develop the prototype for the effectiveness assessment model of ERP system introduction.

Subsequently, a case study was used to verify this prototype. After comparing the research findings and the results generated from subjective view questionnaires, it was discovered that the difference between the two certainly exists since the measurements are different. However, the assessment model produced and applied in this research can generally compute the performance of the case company. The assessment model is scientific and all subjective aspects can be transformed into quantitative data. Thus, this model should be a better assessment model for evaluating the effectiveness of ERP system introduction in the future. When

Table 18 Comparison of the performance by different assessment methods

Output of assessment model				Output of subjective questionnaire			
Assessment facets	Scores of performance	performance	sequence	Assessment facets	Scores of performance	performance	sequence
Financial	51.96	Average performance	4	Financial	56.67	Average performance	3
Customer	60.10	Good performance	3	Customer	55.83	Average performance	4
Internal process	77.17	Good performance	1	Internal process	66.25	Good performance	1
Learning and growth	71.70	Good performance	2	Learning and growth	60.83	Good performance	2
Overall performance	64.55	Good performance		Overall performance	59.90	Average performance	

assessing the effectiveness of ERP system introduction, the prospective enterprises can apply this model to replace the past subjective and non-scientific evaluations. For academics, it is expected that this research would offer the basis for cross-case comparison studies on ERP system performance. Alternatively, they can do an in-depth study on real performance after the enterprise-initiated introduction of the ERP system, and explore if the enterprises have fulfilled their original performance goals after introducing the system.

In addition, due to restrictions in time, resource obtainment and sources of information, this research merely focused on one case to manage the verification of the model. In order to expand the generalizability of this assessment model, it can be further tested in different industries and companies to produce an effectiveness assessment model of ERP system introduction, which can be widely applied to all companies across different industries. In addition, future studies can conduct a thorough survey in an effort to develop a more comprehensive, objective and quantitative performance indicators to enhance the proposed effectiveness assessment model of ERP system introduction. Finally, future research can compare "Before ERP" and "After ERP" performance in the same way and provide case company an objective result to evaluate effectiveness of such IT implementation.

Appendix

Table 19 Glossary of the terms or jargons used in the text and their purposes

Term	Description	Purpose in this study
Grounded theory	Grounded theory is a research method which allows the investigator(s) to play the role as the primary instrument of data collection and analysis. Its end result is a theory emerging from (or is "grounded" in) the data; and it is useful to practice, has its referent specific, everyday world situation (Merriam 1998).	It is used because no theory is assumed in advance in this study. This method is used to analyze, examine, compare the data found in the previous literature, and categorizes the performance indicator data.
Balanced scorecard	The Balanced Scorecard (BSC) is a performance management and measurement tool; it is a concept for measuring whether the operational activities of a company are aligned with its objectives in terms of vision and strategy. Its underlying rationale is that managers should not measure an organization's performance mainly based on the financial perspective but also include measures from the customer, internal business processes and learning and growth perspectives (Kaplan and Norton 1992)	BSC is used as the performance measurement tool because it can provide overall performance evaluations and combine the vision and strategies of the enterprise.
Analytical hierarchy process	The Analytic Hierarchy Process (AHP) is a mathematically based theory method for selecting competing solutions/ activities using distinct criteria, which can be quantitative or qualitative (Marakas 1998). The AHP offers a systematic way to weight multiple criteria aim to achieve the organizational goals by evaluating alternative solutions.	It is used to calculate the relative weight of each performance indicator.
Fuzzy theory	Fuzzy theory permits the gradual assessment of the membership of elements (in the real unit interval [0, 1]) in a set (Zadeh 1965). It makes use of approximate reasoning rather than strict rule for set membership, and modeling how humans obtain information from imprecise information and vague phenomena.	It is used to transform qualitative data into quantitative data for calculating the effectiveness of the ERP system introduction
Fuzzy set or fuzzy assessment set	A set of membership of elements (in the real unit interval [0, 1]) representing the imprecise information and vague phenomena.	It is used to transform qualitative data into quantitative data for calculating the effectiveness of the ERP system introduction
Gravity method	The centre-of-gravity method is used to find a location which minimizes transportation costs. It is based on the idea that all possible location have value which is the sum of all transportation costs to and from that location. The best location, the one which minimizes costs, is represented by what in a physical analogy would be the weighted centre-of-gravity of all points to and from which goods are transported.	It is used to calculate the overall performance fuzzy evaluation set $\tilde{B}$ of the case company. This was used to draw the indicator assessment for membership in the diagram. Each point was connected with straight lines and expanded externally to the zero point, i.e. (100, 0). A general performance assessment diagram was drawn. Figure 4 shows the overall general performance assessment diagram resulting from this process.

Table 20 Results of open coding

Items	Effectiveness	Frequency	Items	Effectiveness	Frequency
1	Offering more accurate and immediate information for decision making	12	14	More immediate delivery	4
2	Enhancing connection among departments through information sharing	8	15	Improving the information system framework	2
3	Rising organizational productivity	10	16	Reducing the costs of information techniques	3
4	Reducing repetitive operations	3	17	Better operational efficiency	5
5	Reducing costs	12	18	Reducing the total cycle time	3
6	Increasing the inventory turnover rate	9	19	Improving the performance of the supply chain	3
7	Reducing the time to react	10	20	Reducing the time to enter the market	1
8	Enhancing the level of customer satisfaction and loyalty	3	21	Reducing work complexity	1
9	Increasing business volume and profits	10	22	Enhancing employees' sense of achievement	1
10	Improving the performance in operational procedure	10	23	Improving product quality	4
11	Increasing enterprise competitive advantages	2	24	Helping monitor the global operation environment	1
12	Reduction of personnel	2	25	Enhancing information system functions	1
13	Reducing the financial pay-up cycle	7			

Table 21 Performance appraisal indicators

Facets	Effectiveness	Measurement indicators
Financial matters	1. Reducing costs	1. gross margin
		2. net profit ratio
	2. Increasing the business volume and profits	3. revenue growth ratio
		4. profit growth ratio
	3. Increasing the inventory turnover rate	5. inventory turnover rate
		6. reduction ration of the inventory level
	4. Reducing the financial pay-up cycle	7. receivables turnover rate
		8. cash conversion cycle
	5. Reducing the costs of information techniques	9. IT investment expenditure
	6. Reducing the total cycle time	10. business cycle
Customers	7. Reducing the time to react	11. response time required by customers
		12. ratio of immediately responding to customers' concerns
	8. Enhancing the level of customer satisfaction and loyalty	13. times of customers' complaints
		14. customer continuity rate
		15. growth rate of numbers of customers
	9. More immediate delivery	16. on-time delivery rate
		17. accurate delivery rate
	10. Improving product quality	18. customer reject rate
Internal process	11. Improving the performance in operational procedure	19. reduction ratio of lead time
		20. reduction proportion of unexpected shutdown time
		21. order dealing time
	12. Better operational efficiency	22. product manufacture time
		23. capacity to cope with provisional orders
	13. Improving the performance of the supply chain	24. reduction rate of purchasing costs
	14. Reducing the time to enter the market	25. time of new products entering the market
		26. time of developing new products

Table 21 (continued)

Facets	Effectiveness	Measurement indicators
	15. Reducing repetitive operations	27. information key-in times
		28. times of repetitive operations
	16. Reducing work complexity	29. automation and computer popularity
		30. e-documents proportion
Learning and growth	17. Offering more accurate and immediate information for decision making	31. accurate information ratio
		32. information dealing time
	18. Enhancing the connection among departments through information sharing	33. information delivery time among departments
	19. Increasing organizational productivity	34. employee average profits
	20. Increasing enterprise competitive advantages	35. cash flow increase ratio
		36. market share rate
	21. Reduction of personnel	37. number of employees in the business organization
	22. Improving the information system framework	38. database integration rate
	23. Enhancing employees' sense of achievement	39. employee satisfaction
		40. employee flow rate
	24. Helping monitor the global operation environment	41. internet application ratio
	25. Enhancing information system functions	42. information workability rate
		43. time of obtaining information related to the production of products

Table 22 Renewal effectiveness assessment indicators

Facets	Performance indicators	Description	Duration of data
Financial matters	1. gross margin	Current term gross margin/net sales	Three fiscal years before and after the introduction of the system (not including the year of introduction)
	2. net profit ratio	Current term net profit/net sales	Three fiscal years before and after the introduction of the system (not including the year of introduction)
	3. revenue growth ratio	(current term sales—prior term sales)/prior term sales	Three fiscal years before and after the introduction of the system (not including the year of introduction)
	4. profit growth ratio	(current term net profit—prior term net profit)/prior term net profit	Three fiscal years before and after the introduction of the system (not including the year of introduction)
	5. inventory turnover rate	current term sales cost/[(ending inventory + initial inventory)/2]	Three fiscal years before and after the introduction of the system (not including the year of introduction)
	6. reduction rate of the inventory level	(ending inventory—initial inventory)/initial inventory	Three fiscal years before and after the introduction of the system (not including the year of introduction)
	7. receivables turnover rate	Current term net credit//[(ending receivables + initial receivables)/2]	Three fiscal years before and after the introduction of the system (not including the year of introduction)
	8. speed of cash turnover	Measuring the speed of the enterprise from material purchase to shipment and cash receiving	The third fiscal year after the introduction of the system
	9. business cycle	365/inventory turnover rate + 365/ receivables turnover rate	Three fiscal years before and after the introduction of the system (not including the year of introduction)

Table 22 (continued)

Facets	Performance indicators	Description	Duration of data
Customers	10. response time required by customers	Measuring the speed of the enterprise in dealing with customers' complaints	The third fiscal year after the introduction of the system
	11. level of immediate response to customers' inquiry	Measuring the enterprise's capacity to immediately respond to customers' inquiry after introducing the system	The third fiscal year after the introduction of the system
	12. accurate delivery level	Measuring the enterprise's capacity to accurately deliver the goods to the customers	The third fiscal year after the introduction of the system
	13. frequency of customer rejects	Measuring the frequency the enterprise is rejected by the customers	The third fiscal year after the introduction of the system
Internal procedure	14. reduction level of times of unexpected work shutdown	Measuring the reduction level of shutdown because of emergent situations arising from the process after the enterprise introduced the system	The third fiscal year after the introduction of the system
	15. order dealing speed	Measuring the speed of the production department of the enterprise in receiving orders, scheduling, finishing production, and stocking	The third fiscal year after the introduction of the system
	16. product manufacture speed	Measuring the speed of the enterprises to produce uni-product	The third fiscal year after the introduction of the system
	17. capacity to cope with provisional orders	Measuring the capacity of the production unit of the enterprise to change the schedule to meet customer needs when provisional orders are received	The third fiscal year after the introduction of the system
Learning and growth	18. information accuracy level	Measuring the accuracy level of information generated by the information system of the enterprise	The third fiscal year after the introduction of the system
	19. information dealing speed	Measuring the time spent by the information system in generating information	The third fiscal year after the introduction of the system
	20. information delivery speed among departments	Measuring the speed of enterprise information exchange among departments	The third fiscal year after the introduction of the system
	21. information system integration level	Measuring the ease-of-use level of the enterprise information system's operational display	The third fiscal year after the introduction of the system

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