Human Systems Management 26 (2007) 139–152
IOS Press

A study on key failure factors for introducing enterprise resource planning

Yuan-Du Hsiao [a], Ching-Chow Yang [b], Wen-Tsann Lin [b,*] and Wei-Cheng Lee [a]

[a] *Department of Industrial Engineering and Management, National Chin-Yi University of Technology, Taiwan, R.O.C.*

[b] *Department of Industrial Engineering, Chung-Yuan Christian University, Taiwan, R.O.C.*

Abstract. ERP (enterprise resource planning) is a management information system that optimizes distribution of enterprise resources and helps a business to integrate all its resources for fast and effective application to improve its operational performance and enhance its competitiveness. Consequently, a failure evaluation model for introducing ERP, together with the factors and reasons for failures are presented in this research, acting as a reference for businesses when planning and making important decisions on ERP.

This study uses the DMAIC of the 6-Sigma approach and a failure evaluation model for introducing ERP that involves expert opinions, a questionnaire, V-shaped performance evaluation matrix (PEM), statistical methods, QFD & FMEA (quality function deployment & failure mode and effects analysis) methods, and QFD & AHP (quality function deployment & analytic hierarchy process) methods to find 6 key success factors and 8 key strategies for introducing ERP. The results of empirical application indicate that internal employee complaints were reduced, supply efficiency of chain suppliers was increased, and customer complaints about quality were decreased. Therefore, the approach presented in this paper is truly effective for business. It is hoped that these key factors can serve as references for other enterprises when introducing ERP.

Keywords: Enterprise resource planning (ERP), performance evaluation matrix (PEM), quality function deployment (QFD), failure mode and effects analysis (FMEA), analytic hierarchy process (AHP)

Yuan-Du Hsiao is an Associate Professor in the Department of Industrial Engineering and Management, National Chin-Yi University of Technology. His research interests include research method, experiment design, mechanical technology and manpower development. He is a member of the Quality Management Association, Fellow of the Manpower Resource Development, Taiwan. He is the author of a number of publications on Technology Management, Manpower Resource Development, Technological Vocational education and training.

Ching-Chow Yang is an Professor of Industrial Engineering Department at Chung-Yuan Christian University. He received the PhD degree in Management Science from National Chian-Tung University, Taiwan. In 1997, Dr. Yang was honored the Individual Award of the ROC National Quality Awards. He is the author of six books (including *Hoshin Management, Quality is the Best Strategy for Competition, Human Resource Management, and Service Quality, etc.*). His research interests include total quality management, strategy management, service quality, and Six-Sigma. He has published many papers in journals and conferences. He has also been a Senior Consultant for many famous companies in Taiwan and China.

Wen-Tsann Lin is a Professor at the Department of Industrial Engineering and Management, National Chin-Yi University of Technology. His research interests include performance management, management information systems, and service quality management. He has also published numerous journal articles and conference papers. He once served as an educational administration executive Chin-Yi University of Technology for 24 years. He honors remarkable contribution on quality management and performance evaluation of higher education.

*Corresponding author.

Wei-Cheng Lee is a Postgraduate at the Department of Industrial Engineering and Management, National Chin-Yi University of Technology. His research interests include quality management, service management, and operations management. He may be contacted as follows: Tel: +886-4-22153761; E-mail: weicheng1015@yahoo.com.tw

1. Introduction

Facing with internationalization, diversification and increasing competition within the same trade, businesses must cope with market changes; application of information technology seems to be extraordinarily important. As a result, ERP has received considerable attention. ERP is a management information system that optimizes distribution of enterprise resources and helps a business to integrate all its resources for fast and effective application to improve its operational performance and enhance its competitiveness.

Product life cycle is becoming shorter in the current times of "10X change", and businesses are confronted by urgent requirements for operational and organizational reformations in order to enhance their competitiveness via product data management (PDM). Hauck [1] and Ge et al. [2] considered the effect of reduced time required for product development on increasing productivity, higher prices, reduced risks and increased market share. However, Kay and Madden [3] considered that introducing ERP system has impacts because of the changes in current processes. Standish Group [4] found that among the causes of IT project failures, only 14% was due to incompetence of technologies, whereas management deficiencies accounting for the remaining 86%. Facing the impact and influence brought by introduction of ERP systems, businesses usually hold review meetings for problem solving, although this method can not have complete improvement. Consequently, introduction of ERP systems not only can not help businesses expedite product development, but also delays the time phase of product development, resulting in low efficiency or even failures in implementing ERP systems.

Consequently, this study uses the DMAIC of the 6-Sigma approach and a failure evaluation model for introducing ERP, together with the factors and reasons for failures presented.

In this study, this article has three purposes: (1) to develop priority of key success factors for introducing ERP; (2) to develop priority of key strategies for introducing ERP; and (3) to understand the results of empirical application. These key factors will be the most important elements when the ERP system is on-line in the future and act as a reference for businesses when planning and making important decisions on ERP.

2. Literature review

Davenport [5] indicated that ERP was one set that combined the suit software of all information inside enterprises closely, including Sales Management, Material Management, Human Resource Management, Production Management, Quality Management, Financial Accounting, Supply Chain Management, Customer Relation Management etc. It can offer all information inside enterprises in an efficient way and carries on the commerce.

Speculation on the future development and success of enterprise resource planning (ERP) has been the focus of many popular press articles [6], and in fact, many SMEs are turning to ERP to provide custom solutions [7]. This is in response to the fact that enterprises are facing increasing competition in the coming knowledge economy era of internationalization and globalization [8]. Furthermore, the potential for fads and fashions in management research is well established [9].

ERP systems emphasize the possible disintermediation of management accountants from their traditional roles and jurisdictions [10,11]. More specifically, ERP systems can help organizations manage their key resources: money, staff, products, customers and suppliers more effectively [12–15].

Although the ERP implementation phase can be a major obstacle [16,17], it can also produce significantly re-engineered and improved enterprises [18–20]. After implementation, proper use of ERP systems can further increase the competitiveness of an organization [21–23].

The use of ERP systems in the manufacturing industry is already widespread [19,24–26]. The benefits that can be gained from ERP use include the following [17, 24,27–29]:

1. Transformative implications for the nature of organizational integration and control.
2. Improve business operation, process integrations, and process standardization.

3. Improve material and inventory management.
4. Improve customer choice by flexibility and customization.
5. Improve production planning, preparation, controlling, and follow-up.
6. Increase marketplace transparency and global negotiation power.
7. Improve overall financial performance through increased revenue, cost reduction, labor savings, and overall profitability.

Many ERP implementations have been considered as failures because they did not achieve predetermined corporate goals [17]. Thus, ERP implementation raises several critical issues [30,31].

The 6-Sigma projects for continuous process improvement are led, from concept to completion, through five project management steps or phases named DMAIC (define, measure, analyze, improve, control) [32]. The 6-Sigma system emphasizes an intelligent blending of the wisdom of an organization with proven statistical tools to improve both the efficiency and effectiveness of the organization in meeting customer needs. The ultimate goal is not simply improvement for improvement's sake, but rather the creation of economic wealth for the customer and provider alike. This does not imply that Six Sigma replaces existing and ongoing quality initiatives in an organization, but rather that senior management focuses on those processes identified as critical-to-quality in the eyes of customers. Those critical systems are then the subject of intense scrutiny and improvement efforts, using the most powerful soft and hard skills the organization can bring to bear [33].

3. Methodology

This study uses the DMAIC of the 6-Sigma approach [34] in Fig. 1 as follows:

3.1. Define

3.1.1. Define the performance index

The evaluation system of ERP includes making of the performance index, the evaluation method and carry out step. A good evaluation system can inspire the correct idea of administrator to adopt better decision, and it may be even more important than the evaluation method to evaluate the index in performance [35].

Problems are presented at internal ERP review meetings and 48 failure factors are located using expert opinions. Means of severity μ_s, occurrence μ_o and controllability μ_c of 48 failure factors for ERP system introduction failures are calculated and converted to indices P_S, P_O and P_C by equations (1), (2) and (3). Indices of severity P_S, occurrence P_O and controllability P_C of failure factors are marked in the performance matrix defined in this article. A k-scale is used to evaluate the severity, occurrence and controllability of each failure factor for introducing the ERP system. Indices of severity, occurrence and controllability are defined and expressed as follows:

$$P_S = \frac{\mu_s - \min}{R}, \tag{1}$$

$$P_O = \frac{\mu_o - \min}{R}, \tag{2}$$

$$P_C = \frac{\mu_c - \min}{R}, \tag{3}$$

P_S: index of severity; P_O: index of occurrence; P_C: index of controllability; μ_s: mean of severity; μ_o: mean of occurrence; μ_c: mean of controllability; min: minimum of k-scale; R: range of k-scale.

3.1.2. Define the V-shaped performance evaluation matrix

Matrix management began in the 1960's as an organizational means to meet the needs of aerospace industries [36]. Managers of other industries and academics will also benefit from a discussion of additional project management research needs in the areas of matrix structures, organizational performance and performance evaluation matrix [37]. The product-process matrix needs some modifications to guide researchers and practitioners [38].

The Performance Evaluation Matrix (PEM) proposed by Lambert and Sharma [39] using as a strategy for performance improvement and modified by Lin et al. [40] is used in this research. A V-shaped matrix composed of severity vs. controllability and severity vs. occurrence will be applied for explanation (Fig. 2). Different coordinates of performance indices $[P_O, P_S]$ and $[P_D, P_S]$ result in different areas, which will be computed via Eq. (4). According to the Koch's 80/20 rule (80% of the problems are found in 20% of the items to be implemented) [41], a ± 2 standard deviation was used to establish the upper control line (UCL) and the lower control line (LCL) presented as follows:

$$\rho_i = |(y_i - x_i)|_\times (y_j - x_i). \tag{4}$$

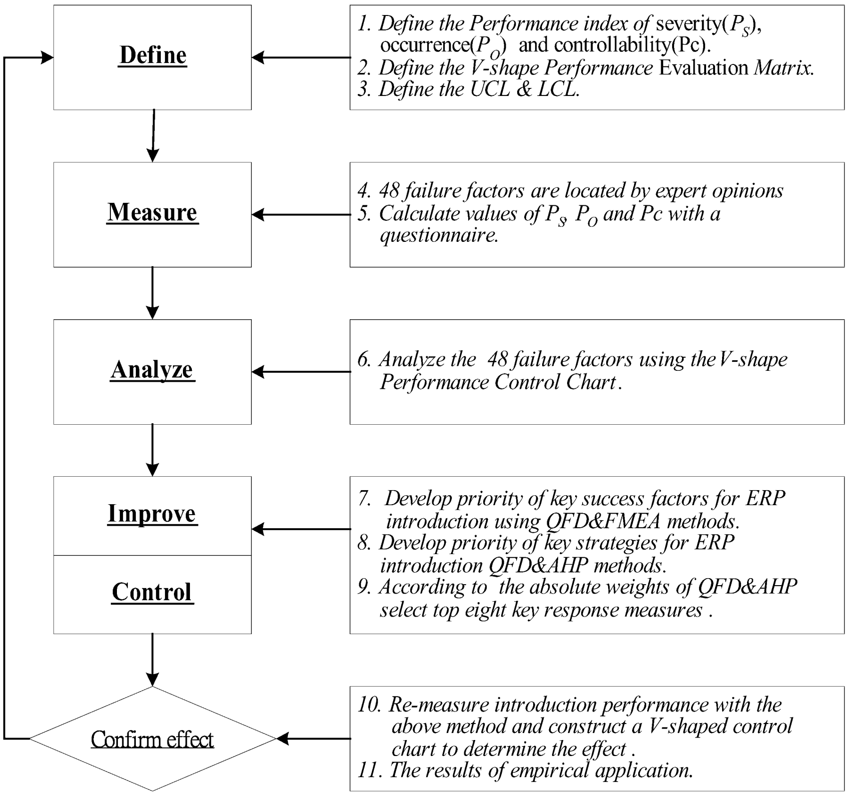

Fig. 1. DMAIC flow chart.

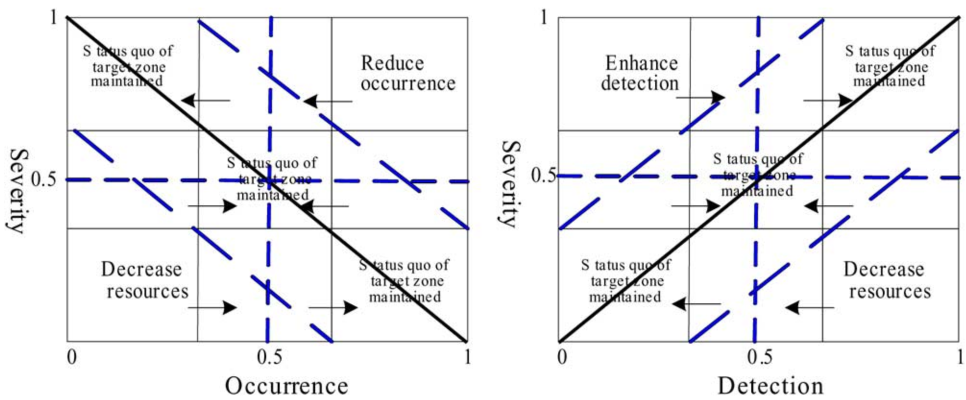

Fig. 2. V-shaped performance evaluation matrix.

Upper Control Line (UCL)

$$\mathrm{UCL} = \sqrt{\frac{\sum_{i=1}^{n}(R_i)^2}{n} - \mu_\rho^2} + 2\sigma. \tag{5}$$

Target Value of Center Line T = 0

Lower Control Line (LCL)

$$\mathrm{LCL} = -\sqrt{\frac{\sum_{i=1}^{n}(R_i)^2}{n} - \mu_\rho^2} + 2\sigma. \tag{6}$$

3.2. Measure

3.2.1. Tools

3.2.1.1 QFD & FMEA methods. After PEM analysis, the QFD approach is used to locate the key failure factors and their corresponding strategies.

Table 1
Weights scale

Estimate items	Absolutely important	Very important	More important	Slightly important	Important	Slightly unimportant	Unimportant	Very unimportant	Absolutely unimportant
Weights	9	8	7	6	5	4	3	2	1

Since the original QFD weights were from expert opinions and seemed to be less objective, they were replaced by the risk priority number (RPN) of FMEA. It is because the FMEA method can indicate failure factors of systems or devices. When a certain machine or part of a system fails, this approach may not only analyze the impact of the failure upon the system, but also specify the machine or part having the most significant influence. The analysis level in FMEA is bottom up and the most common risk evaluation method in the FMEA is Risk Priority Number (RPN) expressed in Eq. (7) as follows:

$$\text{RPN}j = Sj \times Oj \times Cj, \tag{7}$$

Sj: Severity of factor j; Oj: Occurrence of factor j; Cj: Controllability of factor j; j: FMEA factor ($j = 1 \sim m$).

After obtaining the RPN, the correlation weight coefficient is specified by expert opinions. The correlation weighted coefficient (W_{ij}) is measured by a 5-point scale, in which Point 5 stands for extremely strong correlation, and 1 for extremely weak correlation. After this coefficient is determined, it is multiplied by ρ, corresponding to the abnormal index. The absolute weight (T_j) of key ERP implementation strategies can be obtained using Eq. (8).

$$T_i = W_i \times C_i T_j. \tag{8}$$

3.2.1.2 QFD&AHP methods. Satty [42] developed the Analytic Hierarchy Process (AHP) to enable decision makers to represent the interaction of multiple factors in complex situations and it has been applied to R&D project selection [43]. Subsequently a new approach based on Satty's AHP method was developed to assist in multi-criteria decision-making problems [44]. Using earlier AHP techniques helps reduce the occurrence of accidental events [45]. Through the AHP technique, the benefits of risk reduction [46] and improving organizational "fit" of the system should outweigh the costs [47].

Upon locating key failure factors, matrix analysis will be conducted once more to select the key success factors. The AHP method is used to locate weights of QFD and subjective expert opinions are based for determination of pair-wise judgment matrices. Assuming there are m strategic dimensions with interaction outside the performance matrix (Xi; $i = 1, 2, \ldots, m$) and they are compared individually according to the correlations of each key factor. Upon completion of deciding the correlations of strategic dimensions on the first tier, strategic items on the second tier will be subsequently judged as well. The X_{overall} containing all targets on each tier will be used to construct a pair-wise comparison and judgment matrix $Y'h$, $e.\ q$, wherein, p and q mean the set of m key targets, obtained r key targets with interaction and 1 X_{overall}; h_{pq} stands for the hth expert's judgment of the relationship between sets p and q; conversion is based on the weights listed in Table 1.

$$\begin{array}{cccccccc}
 & & 1 & 2 & p & q & \ldots & v \\
 & 1 & h_{11} & h_{12} & h_{1p} & h_{1q} & \ldots & h_{1v} \\
 & 2 & h_{21} & h_{22} & h_{2p} & h_{2q} & \ldots & h_{2v} \\
Y_h & p & h_{p1} & h_{p2} & h_{pp} & h_{pq} & \ldots & h_{pv} \\
 & q & h_{q1} & h_{q2} & h_{qp} & h_{pp} & \ldots & h_{qv} \\
 & & \ldots & \ldots & \ldots & \ldots & \ldots & \ldots \\
 & v & h_{v1} & h_{v2} & h_{vp} & h_{vq} & \ldots & h_{vv}
\end{array}$$

$$Y'h = [h_{pq}] \quad h_{pq} = \frac{1}{h_{qp}} \quad p, q = 1, 2, \ldots, v,$$

$$v = m + r + 1. \tag{9}$$

The maximum eigenvalue and the maximum eigenvector of the key targets in the experts' judgment matrix are calculated by use of Expert Choice software. The maximum eigenvector serves as the weight for the key target in this research.

The measured weight of each key target set determined by the hth expert is computed by Expert Choice and expressed by W_h as follows:

$$W_h = (W_{h1}, W_{h2}, \ldots, W_{hv})$$

$$v = m + r + 1. \tag{10}$$

The overall weight W_{overall} of each key target judged by N experts can be integrated via the following equation:

$$W_{\text{overall}} = \left(\prod_{h=1}^{N} Wh \right)^{\frac{1}{N}}. \quad (11)$$

The AHP is divided into three levels in this research. An analytic hierarchy questionnaire is adopted for levels 2 and 3. The simple weighted method is applied to the first level. Weighted performance values H_i are added to the denominator and divided by each weight so that the sum will be 1 for the AHP method, which is defined as follows:

$$P_i(H_i) = \frac{H_i}{H_1 + H_2 + \cdots + H_n}. \quad (12)$$

3.2.2. The issues of ERP systems

Actual examples of businesses introducing ERP systems are examined. First, the failure mode and effects analysis (FMEA) is used to analyze the ERP systems. Next, issues of ERP systems will be presented via internal ERP review meetings. A total of 48 failure factors are located by expert opinions, as shown in Table 2. A questionnaire based on the known failure factors is thus designed and delivered for completion of departments related to ERP implementation.

3.2.3. Calculate the performance matrix values

3.2.3.1 Sample. Actual examples of businesses introducing ERP systems are the participants. The R&D Department and the Factory Affairs Department provided the population for this questionnaire survey. The targets were high-level supervisors in the R&D Department, personnel at the Product Specifications Group and staff related to ERP system operation. The questionnaire was delivered by mail. Recommend sampling number system reference Doctor Wen [48], using Stein (1945) and Cox (1952) formula:

$$n = \left(\frac{Z_\alpha}{e} \right)^2 \times p \times (1 - p), \quad (13)$$

n: number of effective sample; Z_α: Coefficient of confidence interval; e: error; p: maximum confidence probability.

According to the formula above, defined $\alpha = 0.1$, error $= 10\%$ and $p = 0.5$, so we can estimate the effective sample $n = 75$.

In this study, 100 questionnaires were issued and 79 returned, 2 of which were invalid, representing a feedback percentage of 77%.

3.2.3.2 Reliability analysis. Reliability is the consistency or stability of results based on the measurement tools. Several items are included on one measurement scale, and these items must be measured using the same construct. Thus, each item should be consistent on the same scale, which means that each item should have "internal consistency".

In this study, the overall reliability coefficient was 0.9751. In principle, a greater Cronbach's α (the following formula) means higher reliability of a questionnaire.

Cronbach α formula:

$$\alpha = \frac{I}{I-1} \left(1 - \frac{\sum Si^2}{S^2} \right), \quad (14)$$

I: test items, Si^2: variation for each testing, S^2: variation for total testing.

Nunnally [49] considered that a reliability coefficient greater than 0.5 indicated a minimum acceptable reliability, and that a coefficient above 0.7 was fair. Thus, the reliability of the results from the questionnaires is highly stable and consistent.

3.2.3.3 Calculate the performance matrix values. Next, means of severity μ_{s}, occurrence μ_{o} and controllability μ_D of the 48 failure factors were calculated and converted to indices P_S, P_O and P_D and areas by Eqs (1), (2), (3), (4) and (5), as shown in Table 3.

The UCL and LCL of ± 2 standard deviation can be obtained via equation (5), as shown in Table 4.

3.3. Analysis

The 48 failure factors are mapped by Maple 8 in the V-shaped Performance Control Chart, as shown in Fig. 3. After mapping performance control lines, abnormal coordinates outside UCL and LCL can be located and arranged as in Table 5.

QFD & FMEA methods are used next, and failure factors and key success factors of introducing ERP systems are deployed by QFD Capture 4.0 Software. According to Table 5, it can be seen that there are 19 factors beyond the control lines. Their risk priority numbers calculated by equation (7) are listed in Table 6. The correlation weight coefficient (W_{ij}) specified by expert opinions and multiplied by the ρ corresponding to the abnormal index. The absolute weights of key ERP implementation strategies are obtained by equation (8) and shown in Fig. 3.

Table 2
48 failure factors

Issues of ERP systems	ERP Model	failure factors
	Sales Management (SM)	1. Material: Incorrect salesman information
		2. Man: Inadequate salesman quality
		3. Method: Wrong marketing system
		4. Machine: Computer and network can not cooperate
	Material/Purchasing Management	5. Material: Incorrect purchasing information
		6. Man: Inadequate purchasing personnel quality
		7. Method: Material supplies not purchased appropriately
		8. Machine: Purchasing equipment is bad
	Human Resource Management (HR)	9. Material: Insufficient staff understanding
		10. Man: Staff have inadequate experience to manage
		11. Method: Staff practices bad
		12. Machine: Inappropriate implementation ability
	Production Management/Planning (PP)	13. Material: Not carried out according to the production manual
		14. Man: Producer can not meet the request
		15. Method: Production line planned improperly
		16. Machine: Production allocated improperly
	Quality Management (QM)	17. Material: Incorrect quality information
		18. Man: QC officer's general ability is insufficient
		19. Method: QC method is not clear
		20. Machine: Ineffective QM equipment
	Project Management (PM)	21. Material: Lack of project satisfaction not proper
		22. Man: Insufficient planning personnel quality
		23. Method: Lack of planning innovation
		24. Machine: Ineffective planning method
	Cost Control (CC)	25. Material: Cost quotes mistaken
		26. Man: Personnel quality insufficient
		27. Method: Cost analysis mistakes
		28. Machine: Use of the wrong cost control tools
	Financial Accounting (FA)	29. Material: Incorrect financial news
		30. Man: Personnel quality insufficient
		31. Method: Inappropriate financial administration procedures
		32. Machine: Inappropriate financial administration tools
	Business Strategy (BS)	33. Material: The strategy can not be implemented
		34. Man: Improper leader
		35. Method: Wrong style of leadership
		36. Machine: The insufficient equipment
	Apply Technology (AT)	37. Material: Wrong information
		38. Man: Wrong customer relation system
		39. Method: Wrong method
		40. Machine: Wrong equipment
	Supply Chain Management (SCM)	41. Material: Wrong SCM information
		42. Man: Incompetent staff
		43. Method: SCM can not obtain the expect result
		44. Machine: Wrong software system
	Customer Relation Management (CRM)	45. Material: Customer information is mistaken
		46. Man: Inadequate experience in salesman
		47. Method: Wrong customer's relation system
		48. Machine: Insufficient customer's information transmission

Table 3
Consistency performance evaluation of failure factors

failure factors	P_S	P_O	P_D	severity V.S. occurrence	severity V.S. controllability	Total weight of index areas (C_i)
1	0.5	0.3846	0.3269	0.0133	0.0300	0.0433
2	0.5769	0.5384	0.4615	0.0015	0.0133	0.0148
3	0.5384	0.4807	0.5	0.0033	0.0015	0.0048
4	0.4807	0.5384	0.3653	0.0033	0.0133	0.0166
5	0.5576	0.4230	0.3461	0.0181	0.0448	0.0629
6	0.5576	0.5192	0.4423	0.0015	0.0133	7.5339
7	0.5	0.5384	0.4038	0.0015	0.0092	8.4529
8	0.5384	0.5769	0.4038	0.0015	0.0181	0.0206
9	0.6730	0.6923	0.3846	0.0004	0.0832	0.0836
10	0.7115	0.5576	0.5	0.0237	0.0447	11.8375
11	0.6153	0.5769	0.5384	0.0015	0.0059	12.738
12	0.5192	0.5576	0.4615	0.0015	0.0033	13.5431
13	0.5192	0.5384	0.4807	0.0004	0.0015	14.5402
14	0.5382	0.5192	0.4038	0.0004	0.0181	15.4797
15	0.5382	0.4807	0.4038	0.0033	0.0181	16.4441
16	0.4850	0.4615	0.3846	0.0004	0.0093	17.3408
17	0.5763	0.5769	0.4230	0.0000	0.0237	18.5999
18	0.5384	0.5384	0.4423	0.0000	0.0093	19.5284
19	0.5384	0.5	0.4423	0.0015	0.0093	20.4915
20	0.5	0.4807	0.5192	0.0004	0.0004	21.5007
21	0.5362	0.5382	0.4615	0.0000	0.0059	22.5418
22	0.5146	0.5578	0.4807	0.0015	0.0015	23.5561
23	0.6546	0.5769	0.5576	0.0059	0.0092	24.8042
24	0.315	0.4230	0.4230	0.0015	0.0015	25.164
25	0.5	0.5	0.4807	0.0000	0.0004	26.4811
26	0.5362	0.4807	0.4423	0.0033	0.0093	27.4718
27	0.6185	0.6538	0.5384	0.0015	0.0059	28.8181
28	0.4408	0.5961	0.4807	0.0237	0.0015	29.5428
29	0.5329	0.4230	0.5192	0.0133	0.0004	30.4888
30	0.5627	0.5	0.4423	0.0015	0.0093	31.5158
31	0.5	0.4807	0.4038	0.0004	0.0092	32.3941
32	0.5362	0.4807	0.4423	0.0033	0.0093	33.4718
33	0.4638	0.4615	0.4038	0.0000	0.0033	34.3324
34	0.6315	0.5576	0.5192	0.0059	0.0133	35.7275
35	0.6585	0.6153	0.5769	0.0000	0.0015	36.8522
36	0.6615	0.5384	0.5	0.0092	0.0181	37.7272
37	0.4538	0.4423	0.4230	0.0004	0.0015	38.321
38	0.5384	0.6153	0.4615	0.0033	0.0059	39.6244
39	0.5384	0.5576	0.5192	0.0181	0.0004	40.6337
40	0.5	0.5576	0.5	0.0033	0.0000	41.5609
41	0.5384	0.4038	0.5362	0.0015	0.0000	42.4799
42	0.5384	0.5961	0.5	0.0004	0.0015	43.6364
43	0.4807	0.4423	0.4615	0.0015	0.0004	44.3864
44	0.5192	0.5769	0.4807	0.0059	0.0015	45.5842
45	0.4230	0.4423	0.4615	0.0004	0.0015	46.3287
46	0.4423	0.4807	0.4615	0.0015	0.0004	47.3864
47	0.4615	0.5384	0.4038	0.0059	0.0033	48.4129
48	0.4230	0.4038	0.3461	0.0004	0.0059	49.1792

Table 4
Coordinates and indices corresponding to the PEM

Index & Coordinate V-shaped Performance Matrix	population standard deviation (σ)	UCL ($+2\sigma$)	LCL (-2σ)	UCL interval	LCL interval
Severity V.S. occurrence	0.0060	0.0119	−0.0119	[0.8909, 1]	[1, 0.8909]
				[0, 0.1091]	[0.1091, 0]
Severity V.S. controllability	0.0147	0.0294	−0.0294	[0, 0.1715]	[0.1715, 0]
				[0.8285, 1]	[1, 0.8285]

Table 5
Performance matrix evaluation table

Performance matrix	Description of failure factor	Failure factor	Suggestion
Severity/controllability	Low severity/high controllability	Factors 1, 2, 4, 5, 6, 8, 9, 10, 14, 15, 17, 18, 19, 26, 32, 34 & 36	Reduce the proportion of the controllability factor
Severity/occurrence	Low severity/High occurrence	Factor 28	Reduce the proportion of the occurrence Factor
	High severity/Low occurrence	Factors 1, 5, 10 & 29	Reduce the proportion of the severity Factor

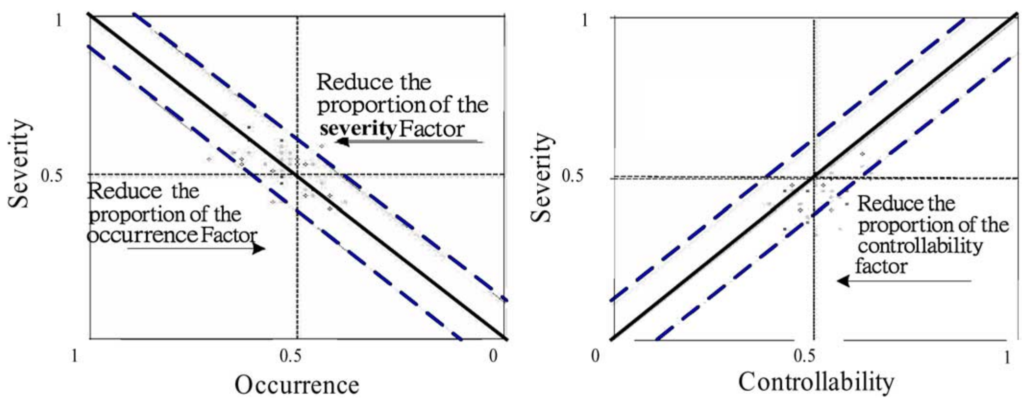

Fig. 3. V-shaped performance control chart.

3.4. Improvement and control

3.4.1. Develop priority of key success factors for introducing ERP

Upon completion of QFD & FMEA methods, the priority will be sorted in accordance with the absolute weights in Fig. 4. Based on the conclusions derived from the aforesaid evaluation model and Koch's 80/20 rule (80% of the problems are found in 20% of the items to be implemented) [38], the top 6 key success factors are selected as follows: Cost Control in factor 7, Sales Management in factor 1, Production Management/Planning in factor 4, Financial Accounting in factor 8, Material/Purchasing Management in factor 2 and Project Management in factor 6.

3.4.2. Develop priority of key strategies for ERP introduction

Measures in response to the 16 key success factors are presented via 6 internal expert opinions (listed in Table 7). Next, EXPERT CHOICE is used to compute the key correlation weight in the overlapped matrices of QFD & AHP methods. The correlation weight coefficient is specified by expert opinions. After that, the absolute weights of key ERP implementation strate-

Weight Definition **Very important 5** **More Important 4** **important 3** **Slightly Unimportant 2** **Unimportant 1**	RPN	Sale Management (SM)	Material / Purchasing Management	Human Resource Management (HR)	Production Management/Planning (PP)	Quality Management (QM)	Project Management (PM)	Cost Control (CC)	Financial Accounting (FA)	Business Strategy (BS)	Apply Technology (AT)	Supply Chain Management (SCM)	Customer Relation Management (CRM)
1. Incorrect salesman information	10	5	4	3	4	4	3	4	5	3	3	3	4
2. Inadequate salesman quality	36	5	2	5	4	4	4	4	5	4	3	2	4
4. Computer and network can not cooperate	30	3	3	2	2	4	2	1	2	2	5	1	1
5. Incorrect purchasing information	27	3	5	4	3	3	2	5	4	2	2	3	2
6. Inadequate purchasing personnel quality	27	2	5	3	5	3	3	5	3	3	2	2	3
8. Purchasing equipment is bad	30	2	5	2	3	3	2	4	2	2	2	3	2
9. Insufficient staff comprehension	40	3	3	5	4	3	4	3	5	5	1	1	1
10. Staff have inadequate experience to manage	36	5	3	5	5	5	5	5	4	4	4	3	5
14. Producer can not meet the request	27	4	3	2	4	3	4	3	2	2	1	5	1
15. Production line planned improperly	24	5	4	1	5	4	4	4	3	5	1	4	1
17. Incorrect quality information	36	3	2	1	3	5	2	4	3	2	1	5	1
18. QC officer's general capacity insufficient	27	3	5	5	4	5	2	4	3	2	1	5	1
19. QC method is not clear	27	4	4	1	3	4	3	4	3	2	2	3	1
26. Personnel's quality insufficient	24	2	2	5	2	2	3	5	5	3	1	3	1
28. Use the wrong tool	30	1	1	1	1	1	1	1	1	1	5	1	1
29. Wrong financial news of financial affairs	32	4	3	1	2	1	4	5	5	3	1	3	1
32. Wrong financial administration tool	27	4	4	1	2	2	2	5	5	2	4	1	1
34. Improper leader	45	4	2	5	5	2	4	2	1	4	1	4	1
36. Insufficient tool equipment	40	2	2	2	2	2	4	2	2	5	3	4	1
Absolute Weights(Tj)		1684	1682	1479	1732	1606	1630	1872	1619	1585	1149	1595	784
Sort		3	4	10	2	7	5	1	6	9	11	8	12

Fig. 4. QFD & FMEA.

Fig. 5. Key correlation weights.

Weight Definition Very important 5 More Important 4 Important 3 Slightly Unimportant 2 Unimportant 1		1. Dominance and promotion of high-level management	2. Adjustment of internal project organization	3. Establishment of ERP implementation strategies	4. Organizational flow reengineering	5. Increasing the quality of educational training	6. Examining the rationality of organizational implementation	7. Management by objectives (MBO)	8. Enhancing personnel cooperation	9. Enhancing system module capability and reducing system cost	10. Providing system flexibility and expansibility	11. Increasing compatibility between application structures and databases	12. Promoting cross-departmental and cross-regional applications	13. Inspecting service quality of suppliers	14. Examining professional expertise of consulting companies	15. Communication between consulting companies and enterprises	16. Inspecting service quality of consulting companies
	0.067	5	2	4	3	3	3	4	5	5	3	2	3	3	2	2	1
4. Production Management / Planning (PP)	0.081	5	4	5	4	3	4	4	3	3	2	2	4	2	2	2	2
1. Sale Management (SM)	0.079	4	4	4	5	2	4	3	5	3	3	3	2	3	2	3	1
2. Material/ Purchasing Management	0.091	3	3	3	3	3	3	3	3	4	2	2	4	2	2	3	2
6. Project Management (PM)	0.103	4	3	4	4	2	4	4	3	4	3	2	4	3	3	2	1
8. Financial Accounting (FA)	0.067	5	5	5	5	4	3	4	3	3	3	2	3	2	3	3	2
absolute weights (T_j)		2.076	1.691	2.009	1.94	1.349	1.73	1.782	1.756	1.792	1.292	1.055	1.66	1.225	1.146	1.21	0.727
Sort		1	8	2	3	10	7	5	6	4	11	15	9	12	14	13	16

Fig. 6. QFD & AHP.

gies are obtained as shown in Fig. 5. Finally, QFD is conducted on these six key success factors of introducing ERP systems and response strategies, as shown in Fig. 6.

3.4.3. Select key response measures

The absolute weights in Fig. 6 are sorted in order and the top eight key response measures are selected as follows: dominance and promotion of high-level management in factor 1, establishment of ERP implementation strategies in factor 3, organizational flow reengineering in factor 4, enhancing system module capability and reducing system cost in factor 9, management by objectives in factor 7, enhancing personnel cooperation in factor 8, examining the rationality of organizational implementation in factor 6 and adjustment of internal project organization in factor 2.

3.5. Confirm effect

(1) Re-measure introduction performance with the above method, and obtain the same eight key response measures, as listed in Table 8.
(2) The results of empirical application

These 8 key response measures will be the most important elements when the ERP system is on-line in the future.

The simple and easy-to-use evaluation process and model presented in this research may help systematically and effectively improve the performance of introducing the ERP system to the enterprises. The results of empirical application indicate that internal employee complaints were reduced from 23.54 to 6.31, supply efficiency of upstream and downstream suppliers increased from 46.35 to 73.68, and customer complaints about quality decreased from 18.74 to 7.35. Therefore, the approach presented in this paper is truly effective for business.

Table 6
Risk priority number (RPN)

Failure factors	Severity	Controllability	Occurrence	RPN
1	2	5	1	10
2	4	3	3	36
3	2	5	3	30
4	3	3	3	27
5	3	3	3	27
6	5	3	2	30
7	4	5	2	40
8	3	4	3	36
9	3	3	3	27
10	3	4	2	24
17	3	3	4	36
18	3	3	3	27
19	3	3	3	27
26	3	2	4	24
28	5	3	2	30
29	2	4	4	32
32	3	3	3	27
34	5	3	3	45
36	2	5	4	40

4. Conclusion

4.1. Conclusions

Confronted by the pressing requirements for operational and organizational reformations, comprehensive e-business is an inevitable trend. Problems like personnel rejection, effects on product development flow and difficult horizontal coordination at the beginning of ERP introduction usually occur. The failure mode and effects analysis integrated with performance matrix is proposed in this research to locate key success factors from cases and devise key response strategies. In addition, the simple evaluation process and model presented here can serve as a reference for businesses to systematically evaluate and improve their performance while introducing product data management systems.

In conclusion, three of these findings are worth demonstrating: (1) 6 key success factors for introducing ERP systems; (2) 8 key response strategies for introducing ERP systems; (3) the results of empirical application indicate that internal employee complaints were reduced, supply efficiency of chain suppliers was increased, and customer complaints about quality were decreased. Therefore, the approach presented in this paper is truly effective for business.

Table 7
Key response strategies for introducing ERP systems

Key strategy for introducing ERP systems	
1. Dominance and promotion of high-level management	9. Enhancing system module capability and reducing system cost
2. Adjustment of internal project organization	10. Providing system flexibility and expansibility
3. Establishment of ERP implementation strategies	11. Increasing compatibility between application structures and databases
4. Organizational flow reengineering	12. Promoting cross-departmental and cross-regional applications
5. Increasing the quality of educational training	13. Inspecting service quality of suppliers
6. Examining the rationality of organizational implementation	14. Examining professional expertise of consulting companies
7. Management by objectives (MBO)	15. Communication between consulting companies and enterprises
8. Enhancing personnel cooperation	16. Inspecting service quality of consulting companies

Table 8
Key response strategies for introducing ERP systems

Key strategy for introducing ERP systems	
1. Dominance and promotion of high-level management	5. Examining the rationality of organizational implementation
2. Adjustment of internal project organization	6. Management by objectives (MBO)
3. Establishment of ERP implementation strategies	7. Enhancing personnel cooperation
4. Organizational flow reengineering	8. Enhancing system module capability & reducing system cost

4.2. Recommendations

For future researches, introduction of different systems, including knowledge management, supply chain management and collaborative product commerce (CPC) may be evaluated effectively to assess the enterprises impacts from introducing information and electronic software.

This paper indicates that the best way for introducing ERP systems. By doing so, the company will achieve the success of ERP management and make more profits.

References

[1] W.C. Hauck, B.P.E. Anil and A.J. Hauck, Simultaneous engineering correlates of success, *International Journal of Production Economics* **52** (15 October) (1997), 83–90.

[2] Z.Y. Ge, W.H. Fan, G.L. Xiong, L.S. Zhou, Y.P. Li and X.H. Su, Application of ERP base on concurrent engineering, intelligent control and automation, in: *Proceedings of the 4th World Congress*, Vol. 4, 2002, 2604–2607.

[3] C. Kay and D. Madden, Critical success factors in implementing product data management, *International Journal of Micrographics & Optical Technology* **13** (1995), 191–194.

[4] Standish Group, CHAOS, 2000.

[5] Davenport, *Harvard Business Review* (July–August) (1998), 122–124.

[6] F.R. Jacobs and E. Bendoly, Enterprise resource planning: Developments and directions for operations management research, *European Journal of Operational Research* **146** (2003), 233–240.

[7] Y.T. Sun, A. Yazdani and J.D. Overend, Achievement assessment for enterprise resource planning (ERP) system implementations based on critical success factors (CSFs), *Int. J. Production Economics* **98** (2005), 189–203.

[8] C.B. Wang, T.Y. Chen, Y.M. Chen and H.C. Chu, Design of a Meta Model for integrating enterprise systems, *Computer in Industry* **56** (2005), 305–322.

[9] S. Carmona, Vogues in management accounting research, *Scandinavian Journal of Management* **19**(2) (2003), 213–231.

[10] A. Caglio, Enterprise resource Planning systems and accountants: towards hybridization? *European Accounting Review* **12**(1) (2003), 123–154.

[11] R.W. Scapens and M. Jazayeri, ERP Systems and Management Accounting Change: Opportunities or Impacts? *European Accounting Review* **12**(2) (2003), 201–233.

[12] S.F. Huin, L.H.S. Luong and K. Abhary, Internal supply chain planning determinants in small & medium sized manufactures, *Int. J. Phys. Distribution Logistics Manage* **32**(9) (2002).

[13] S.F. Huin, L.H.S. Luong and K. Abhary, Knowledge-based tool for Enterprise Resource Planning in small and medium sized enterprises (SMEs), *J. Robot Computer Integrated Manu* **19**(5) (2003).

[14] S.F. Huin, Managing deployment of ERP systems in SMEs using multi-agents, *International Journal of Project Management* **22** (2004), 511–517.

[15] S.F. King and T.F. Burgess, Beyond critical success factors: A dynamic model of enterprise system innovation, *International Journal of Information Management* **26** (2006), 59–69.

[16] J. Motwani, D. Mirchandani, M. Madan and A. Gunasekaran, Successful implementation of ERP projects: Evidence from two case studies, *International Journal of Production Economics* **75** (2002), 83–96.

[17] E.J. Umble, R.R. Haft and M.M. Umble, Enterprise resource planning: Implementation procedures and critical success factors, *European Journal of Operational Research* **146** (2003), 241–257.

[18] H.A. Akkermans, P. Bogerd, E. Yucesan and L.N. Vanwassenhove, The impact of ERP on supply chain management: Exploratory findings from a European Delphi study, *European Journal of Operational Research* **146**(2) (2003), 284–301.

[19] M. Al-Mashari, Enterprise resource Planning (ERP) systems: A research agenda, *Industrial Management and Data Systems* **102**(3) (2002), 165–170.

[20] M. Umble, E. Umble and L. Vondeylen, Integrating enterprise resource planning and theory of constraints: A case study, *Production and Inventory Management Journal* **42**(2) (2001), 43–48.

[21] M. Al-Mashari, A. Al-Mudimigh and M. Zairi, Enterprise resource Planning: A taxonomy of critical factors, *European Journal of Operational Research* **146**(2) (2003), 352–364.

[22] T.H. Willis and A.H. Willis-Brown, Extending the value of ERP, *Industrial Management and Data Systems* **102**(1) (2002), 35–38.

[23] R. Poston and S. Grabski, Financial impacts of enterprise resource planning implementations, *International Journal of Accounting Systems* **2**(4) (2001), 271–294.

[24] V.A. Mabert, A. Soni and M.A. Venkataramanan, The impact of organization size on enterprise resource planning (ERP) implementations in the US manufacturing sector, *Omega* **31**(3) (2003), 235–246.

[25] J. Olhager and E. Seldin, Enterprise resource planning survey of Swedish manufacturing firms, *European Journal of Operational Research* **146**(2) (2003), 365–373.

[26] M. Bergstrom and L. Stehn, Matching industrialized timber frame housing needs and enterprise resource planning: A change process, *Int. J. Production Economics* **97** (2005), 172–184.

[27] M. Kennerley and Neely, Enterprise resource planning: Analyzing the impact, *Integrated Manufacturing Systems* **12**(2) (2001), 103–113.

[28] C.S. Chapman and W.F. Chua, Technology-driven integration, automation and standardization of business process: Implications for accounting, in: *Management accounting in the digital economy*, A. Bhimani, ed., 2003, pp. 74–94.

[29] C.S. Chapman, Not because they are new: Developing the contribution of enterprise resource planning systems to management control research, *Accounting Organizations and Society* **30** (2005), 685–689.

[30] M. Al-Mashari, Process-rotation through, Enterprise Resource Planning (ERP): A review of critical issues, *Knowledge and Process Management* (2001), 175–185.

[31] P. Soffer, B. Golany and D. Dori, Aligning an ERP system with enterprise requirements: An object-process based approach, *Computers in Industry* **56** (2005), 639–662.

[32] M. Sokovic, D. Pavletic and S. Fakin, Application of Six Sigma methodology for process design, *Journal of Materials Processing Technology* (2005), 162–163.

[33] G. Smith, Benchmarking success at Motorola, Copyright Society of Management Accountants of Canada, 1993.

[34] Michael, *Lean Six Sigma*, McGraw-Hill, New York, 2002, pp. 170–177.

[35] Sephen P. Robbins and David A. Decezo, *Fundamentals of Management*, 3rd edn, Prentice-Hall, Inc., 2001, pp. 415–417.

[36] E.W. Larson and D.H. Gobeli, Matrix management: Contradictions and insights, *California Management Review* **29**(4) (1987), 126–138.

[37] J.A. Kuprenas, Implementation and performance of a matrix organization structure, *International Journal of Project Management* **21** (2003), 51–62.

[38] S.S. Ariss and Q. Zhang, The impact of flexible process capability on the product-process matrix: an empirical examination, *Int. J. Production Economics* **76** (2002), 135–145.

[39] D.M. Lambert and A. Sharma, A Customer-Based Competitive Analysis for Logistics Decisions, *International Journal of Physical Distribution and Logistics Management* **20** (1990), 23–24.

[40] W.T. Lin, S.C. Chen and K.S. Chen, Evaluation of performance in introducing CE marking on the European market to the machinery industry in Taiwan, *International Journal of Quality Reliability Management* **33**(5) (2005), 503–517.

[41] R. Koch, This edition of the 80/20 principle: The secret of achieving more with less, Nicholas Brealey Publishing Limited, London, 1997.

[42] T.L. Satty, *The Analytic Hierarchy Process*, McGraw Hill, New York, 1980.

[43] K.-T. Cho and C.-S. Kwon, Decision Aiding Hierarchies with dependence of technological alternatives: A cross-impact hierarchy process, *European Journal of Operational Research* **156** (2004), 420–432.

[44] F.-H. Liu and H.L. Hai, The voting analytic hierarchy process method for selecting supplier, *Int. J. Production Economics* **97** (2005), 308–317.

[45] T.L. Satty and M. Takizaws, Dependence/Independence: From Linear Hierarchies to Nonlinear Networks, *European Journal of Operational Research* **26** (1986), 229–237.

[46] R.V. Rao, Evaluation of metal stamping layouts using an analytic hierarchy process method, *Journal of Materials Processing Technology* **152** (2004), 71–76.

[47] L. Meade, Strategic analysis of logistics and supply chain management systems using the analytic network process, *Transp Rev.-E (Logistic and Transp Rev.)* **34**(3) (1998), 201–215.

[48] Doctor Wen, Research of mailed questionnaire sampling design, Tamkang University Management Science Research doctoral thesis, 1984.

[49] J. Nunnally, *Psychometric Theory*, 2nd edn, McGraw-Hill, New York, 1978.