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A step-by-step performance assessment and improvement method for ERP implementation: Action case studies in Chinese companies

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ABSTRACT

The implementation of enterprise resource planning (ERP) is a complex process, and the failure rate remains very high. The literature has reported over 80 critical success factors for ERP implementation, but companies typically do not know to exploit them. In this article, a step-by-step assessment and improvement method for ERP implementation is proposed and applied in three companies. First, a five-stage ERP implementation model is proposed. Second, about 80 critical success factors (CSFs) from the literature are elaborated into key performance indices (KPIs), which are associated with each stage of ERP implementation by ten local ERP experts. Third, the weights of the KPIs are calculated using the Dumpster–Shafer method and the evaluation of ten experts. During the implementation process, performance is measured at each stage and remedial actions are identified if the performance is below expectation. An implementation flowchart is developed based on a five-stage model and the philosophy of continuous improvement. Three action cases in Chinese manufacturing companies are conducted to illustrate the effects of the assessment model, which is also currently being used by a consulting company specialising in ERP implementation. With further evaluation by local experts, the model has the potential to serve as a guideline for ERP implementation in other countries.

1. Introduction

An enterprise resource planning (ERP) system can be a powerful weapon for enhancing companies' competition, but its implementation can be very risky if not planned and managed properly. ERP failure due to either cancellation or cost/time overrun remains a significant problem for enterprises [1]. A survey in 2013 shows that 54% of ERP projects are reported to be cost overrun, 72% are time overrun and 66% of the enterprises implementing ERP software initiatives receive less than 50% of the anticipated measurable benefits [2]. How to successfully implement ERP systems and achieve the related business outcomes is a thorny problem that deserves further exploration.

A significant process for overcoming ERP failure is the administration of *critical success factors* (CSFs) that relate to ERP success. Defined as '... the few key areas where things must go right for the business to flourish ...' [3], CSFs are believed to be the most influential forces in ERP success and thus must be monitored and controlled during ERP projects. There are many CSFs for ERP implementation [4–6], with as many as 80 CSFs identified in the literature [7]. Thus, a better understanding and administration of CSFs during ERP implementation could help enterprises sense otherwise unseen risks and take the corresponding actions necessary to reduce possible failure.

Hence, a practical and effective approach to CSFs administration is needed to convincingly demonstrate its validity in ERP implementation. Managers would benefit from answers to the following questions: Which CSFs are significant at a moment of concern? How can CSFs' performance be accurately measured and monitored? How should a departure from desired performance be handled? What is a practical means of assessing the performance of relevant CSFs during ERP implementation and improving the performance of each CSF if undesired deviation is identified?

The current understanding of CSF management is fragmented and static. One salient deficiency is the lack of a practical approach for monitoring and controlling CSFs' performance during ERP implementation. In most cases, a list of CSFs is presented based on limited case studies or an overview of the published literature [8]. Some studies do propose a menu of CSFs,

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but leaving the practical aspects of monitoring and managing CSFs an untouched field. As an ERP project can last for months or even years, and goes through various project stages, companies need a means of effectively managing CSFs by figuring out when and how to handle which CSF during ERP implementation [9]. This is even more important when considering the variation in CSFs' numbers and dimensions across different studies, which further confuses the salience of one CSF for a specific occasion and hampers CSFs' functionality.

Some researchers have tried to deal with the aforementioned problems. For example, Motwani [10] notes the importance of being able to identify which CSFs to consider during each stage of the implementation process. Bhatti [11] tries to develop items to measure seven CSFs in Australian organisations. However, neither of them provide a systematic association of CSFs with implementation stages, nor do they develop *key performance indicators* (KPIs) for all of the CSFs. Esteves' [12] study may be the only one that systematically associates CSFs with implementation stages, but KPIs for all of the CSFs are not provided. Thus far, CSFs' performance assessment and improvement remain unsolved issues.

The objective of this study is to develop and validate a practical approach for assessing and improving CSFs' performance during ERP implementation in Chinese companies. We divide the 80 CSFs based on the five stages of the ERP implementation process and elaborate KPIs for each CSF. The KPIs' weights are calculated using the *Dumpster–Shafer* (D–S) method and the assessment of ten local experts. The model is then applied in three companies. If there is a detected gap, an improvement process is applied to improve the performance of the stage until it is satisfied. As such, the CSFs can be managed if an unfavourable gap is detected. The proposed approach is new in that it (1) systematically associates CSFs with each implementation stage, (2) dynamically assesses the performance of each stage and (3) incorporates a continuous improvement philosophy to improve the performance of each stage.

2. Literature review

2.1. ERP implementation stages and CSFs

Lifecycle stages and static CSFs are two research streams in ERP implementation. ERP implementation stages reflect the various phases through which an ERP project passes in an organisation [13]. An ERP project usually comprises several stages, including adoption decision, acquisition, implementation, use and maintenance, evolution and retirement [14]. The number of stages varies from three to five across the literature [15,16]. CSFs in the ERP context are the factors needed to ensure a successful ERP project [17]. The literature is replete with a large variety of ERP CSFs. For instance, based on their review of the CSFs for successful ERP implementation across 10 countries/regions, Ngai et al. [7] identify 18 challenges and factors leading to underperformance, with more than 80 sub-factors.

A significant development in ERP implementation research has been the attempt to associate CSFs with implementation stages. For example, Parr and Shanks [16] try to combine CSFs with their project phase model, which includes planning, project and enhancement phases. Although the practical value of their model is limited in that it only includes nine CSFs, the notion that CSFs should associate with implementation stages is a noticeable advance in ERP implementation. The question of when and where a CSF should be applied during the ERP lifecycle must be answered, as a given CSF can function at a specific occasion during the ERP project lifecycle [18]. Markus and Tanis [15] also echo this sentiment in their four-phase ERP lifecycle model. They imply that different things can go wrong in each phase of the ERP lifecycle, and thus different actors are involved in different phases. Esteves [12] provides a more systematic association of CSFs with ERP implementation stages. Twenty-three CSFs are associated with five ERP implementation stages based on their relevance, which enables enterprises to monitor and control critical issues during ERP projects and take corresponding action against performance gaps.

However, none of the abovementioned studies attempts to develop performance assessment and improvement methods for ERP implementation. Esteves [12] proposes the most systematic association of CSFs with five ERP implementation stages, but performance measurement and improvement are not covered. The related framework develops KPIs for a limited number of CSFs, but how to measure their performance and cope with underperformance is not addressed. Our study contributes to efforts to fill this gap by proposing a performance assessment and improvement method.

2.2. Performance assessment and improvement in ERP implementation

ERP performance has varied definitions [19]. For instance, people tasked with implementing an ERP system, such as project managers and consultants, often care most whether the project is completed within the planned time and budget. People who adopt an ERP system to achieve improved business outcomes tend to emphasise whether the system helps them to achieve their intended goals, such as cost or inventory reduction, or better delivery reliability and speed. A comprehensive approach encapsulating both ERP project and run performance is adopted in this research.

As the performance of the preceding stage is input for that of the succeeding stage, it is important to measure performance at each stage during ERP implementation to ensure success. Doing so makes continuous improvement possible at each stage of ERP implementation when underperformance is detected. However, most theoretical models only measure the performance at the end of an ERP project or live-run stage. For example, Lin et al. [20] develop a balanced scorecard to estimate the enterprise's effectiveness on ERP systems in the live-run phase and Wei et al. [21] set up performance indicators based on ERP implementation objectives and measure the business contribution of the ERP system after live-run. For these studies, improvement action is impossible due to the lack of step-by-step performance assessment, which places ERP success at risk.

A step-by-step performance assessment is made viable by managing the performance of CSFs to monitor and control performance in each ERP stage. Although this approach has been proposed by some authors, practical means are still lacking. For example, Bhatti [11] proposes an approach for managing CSFs by developing items to measure their performance during ERP implementation. Twelve CSFs are identified based on four stages of ERP implementation and are measured by multi-item measurement scales. Esteves [12] provides a framework for developing KPIs for ERP CSFs and applies it to four CSFs (sustained management support, business process reengineering, training and user involvement and participation). Developing KPIs for CSFs allows the performance of CSFs to be analysed and managed in different organisational contexts. However, Bhatti's [11] research ceases after the development of measurement scales and Esteves [12] only develops tentative KPIs for four CSFs. Neither of them attempts to develop an ERP performance assessment and improvement approach.

3. Identification of ERP implementation stages

The five-stage ERP implementation model identified is widely accepted in the literature, especially by models comprising five stages [13,22]. What should be highlighted here is the inclusion of

the organisational readiness assessment and final preparation stages. Organisational readiness is a hot topic in ERP research, but there has been no coverage of organisation readiness assessment in ERP implementation models [23,24]. The final preparation stage is strongly recommended to ensure that the infrastructure set up, system testing and user training have been successfully completed before the ERP live run [22,25].

3.1. Stage 1: ERP organisational readiness

This stage involves the readiness assessment of the focal enterprise in resources and management before selecting a candidate ERP solution. A steering committee first defines the CSFs and KPIs of organisational readiness, and then conducts a gap analysis by assessing the KPIs. This allows the organisation to address any performance gaps detected to accommodate the requirements for ERP implementation.

3.2. Stage 2: ERP selection

At this stage, a company starts the well-rounded process of selecting an appropriate ERP package and implementation partner. A working committee is set up to identify all of the business requirements across focal enterprise, customers and partners. Information about system functionality, reference sites, product roadmaps, ERP vendors, implementation partners and partners' local support capabilities are identified and screened. A short list of potential ERP packages and implementation partners is compiled. An in-depth evaluation process is conducted for the potential packages and partners, followed by a negotiation process, in which contractual terms are worked out, and a final recommendation is made and confirmed by the board of directors.

3.3. Stage 3: ERP implementation

This stage covers the determination of the project scope to the system installation and cut-over. In this stage, members of the project team are selected and the project's standards and procedures are established. Customers' requirements are incorporated into the definitions of the business blueprint and the business process is redesigned to meet requirements. Furthermore, system configuration, testing, user training and installation are conducted and completed.

3.4. Stage 4: ERP final preparation

The final preparation stage is important to ensure that the system, process, management and users are prepared for the ERP live-run. Gulledge and Simon [25] state that the final preparation stage should cover the following major tasks: integration and stress tests to confirm hardware capabilities, a disaster recovery test to determine system availability and recoverability during and after unexpected incidents, user acceptance evaluation to confirm user acceptance of system functionalities, complete user training and a cutover plan to move to the production environment and live-run.

3.5. Stage 5: ERP live-run

At this stage, system performance is assessed through performance monitoring and customer feedback. Performance should be measured every six months during the ERP live-run. To improve system performance, this stage includes system repair issues and extension and transformation that encapsulate the continuous improvement concept [26]. This stage also involves two other possible activities when conducting periodic reviews: a system upgrade that allows additional capabilities to be built into the system to obtain preferable benefits, and system retirement, in which the old ERP is replaced by a more suitable one to meet the organisational needs of the moment.

4. Research methods

4.1. Delphi method

The Delphi method was applied in the processes of associating CSFs with ERP implementation stages, developing related KPIs for CSFs and assigning the magnitude of KPIs' weights. The following basic principles that characterise the Delphi method [27] were applied: (1) it was a repetitive process. The same experts were asked the same questions at least twice. Feedback on the previous round was provided to enable the experts to change their estimations. (2) It was a structured process. The information flow was co-ordinated by the researchers. There was no direct information flow between the experts. (3) The anonymity of the experts was maintained throughout the process.

The criteria of expert selection were as follows. There were at least ten ERP experts on the panel [28]. An expert required at least 10 years of ERP-related experience. Experts came from different areas of the ERP value chain to ensure global views on ERP implementation. Table 1 lists the profiles of the ten experts invited to attend the current research.

4.2. Dumpster–Shafer combination method

Ten ERP experts provided scores for determining the magnitude of individual KPIs' influence. The results were then normalised by the D–S combination method to get the weight of each KPI.

The D–S method allows for the combining of several opinions on sets of decision alternatives, and there are no bounds on the number of individuals allowed on the decision inputs panel. The number of comparisons and opinions are at the decision makers' discretion [29]. In addition, there is no need for consistency checks at the decision alternative level [30], which perfectly matches the requirement of action research, as the ten ERP experts were providing independent and discrete professional inputs about scores of the KPIs' influence.

4.3. Action case study

The main purpose of action research is to solve practical problems while expanding scientific knowledge [31]. It involves both researchers and practitioners in an iterative process to solve problems and learn new knowledge reflectively. Action research has been a very popular way of conducting qualitative information

Table 1
Experts' profiles.

Experts	Company nature	Job nature	ERP experience (in years)
1	System integrator	Solution architect	11
2	ERP consulting	Consulting director	16
3	HK productivity council	Principle consultant	15
4	ERP customer	CIO	16
5	ERP customer	CIO	12
6	Hardware vendor	Solution architect	19
7	ERP vendor	Consulting director	15
8	ERP vendor	Consulting director	18
9	ERP consulting	Consulting director	13
10	ERP customer	SAP project manager	17

Notes: HK: Hong Kong; CIO: Chief information officer; SAP: an ERP provider.

system research, in which it has often been combined with practice studies, interventions and experiments for evaluating different types of guidelines, standards, methods, techniques or tools [32]. Thus, the methodology of action research was entirely appropriate for developing and testing our model, and was conducive to confirming the practicability of the new model.

5. Development of the performance assessment method

5.1. Associating CSFs and KPIs with stages

The initial lists of CSFs and KPIs were drawn from the literature and then assessed by experts using the Delphi method regarding their relevance to the ERP stages and their influence on ERP success. Through a literature review, we obtained a comprehensive understanding of CSFs and KPIs, and their influences on ERP success were then systematically assessed using the Delphi method. Thus far, no influential factors were omitted and no trivial factor was included.

First, we conducted a literature review to gain a comprehensive understanding of ERP implementation problems, which resulted in a list of 80 such problems. Second, the 80 problems were consolidated into an ERP problem identification worksheet[1], which was sent to the ten ERP experts. Each expert was asked to independently classify in which stage of ERP implementation the ERP problem occurred, using a 1–5 scale method where 1 signified 'strongly disagree' and 5 'strongly agree'. After two rounds of the Delphi survey, the experts identified 43 problems with a mean score equal to or above 4 as critical. They also classified each problem in one of the five stages of the ERP project. Third, following the same problem-matching process, the experts defined the CSFs needed to overcome the ERP implementation problems and matched them with each ERP stage. As the same CSF could overcome more than one implementation problem, this step generated 34 CSFs. Finally, a comprehensive literature review revealed the KPIs relative to measuring each of the 34 CSFs. The KPI list and previously defined CSFs were then sent to the ten experts. Through two iterative screening exercises, the ten ERP experts selected the relevant KPIs with mean scores equal to or greater than 4 to measure each CSF. Table 2 shows the association of CSFs with ERP stages. A complete list is in Appendix A.

Table 2
Classification of CSFs into the ERP implementation stages.

ERP stages	CSFs (No. of KPIs)	Literature
1. Organisational readiness assessment	Top management support (4)	[33–35]
	Effective communication (4)	[33,34]
	Right employee quality (3)	[24,33]
	Change management (3)	[7,23,33]
2. ERP selection	Sufficient financial budget (1)	[8]
	Contract management (2)	[7,23,33]
	Right quality compliance (1)	[8,34]
	Identification of customer needs (2)	[8,34,35]
	Balanced evaluation team (3)	[36,37]
	ERP and implementation partner's capability (10)	[8,36,38]
	Vendor management (3)	[33]
	Sufficient evaluation resources (2)	[8,34]
3. ERP implementation	Implementation cost (2)	[37,39]
	Project management with sufficient resources (2)	[37,40]
	Identification of customer needs (1)	[35,39]
	Balanced implementation team and top management support (4)	[7,8,23]
	Effective implementation skill set (6)	[33,35,37]
	Sufficient training resources and change mgt. (2)	[8,23,36]
	Effective communication (3)	[33,34]
4. ERP final preparation	Sufficient maintenance budget (2)	[33,34]
	Financial cut-off plan (1)	[7,23]
	System quality assurance (2)	[7,8,23]
	System administration and recovery plan (3)	[8,33]
	Well system protection (2)	[8,33]
	IT and data management (2)	[36,39]
	ERP support and training (3)	[33,34]
	Performance monitoring (3)	[7,23,34]
5. ERP live run	ERP cost and benefits control (3)	[22,41]
	Traceable operation cost (2)	[39,42]
	Periodic system performance review (2)	[33,34]
	Positive customer satisfaction (5)	[39,43]
	System operations efficiency (3)	[37]
	Employee productivity and satisfaction (3)	[22,37]
	Effective learning environment (3)	[37,39]

Notes: The full list of CSFs, KPIs and weights are listed in Appendix A.

5.2. Determining KPI weight using the D–S combination method

The D–S combination method was used to determine the weight of each CSF on its own stage and the weight of each KPI on its own CSF. The weight of KPI on its own stage was calculated by multiplying the above two weights.

The ten experts were invited to provide their opinions on the magnitude of influence of the individual CSFs and KPIs. The scoring was designed in a 1 to 5 range, with 1 signifying 'strongly disagree' and 5 signifying 'strongly agree'. Each CSF and KPI had a single score. The scores were integrated using the D–S method—a mature technique for analysing and synthesising experts' views.

First, a normalised weight $m_i(X)$ was calculated using the following formula:

$$m_i(X) = \frac{m_{iX}}{Sum_i}$$

where m_{ix} is the score of CSF (or KPI) X by expert i and Sum_i is the sum of the CSFs' score of one stage by expert i, or the sum of the KPIs' score of one CSF by expert i.

[1] This sheet is not presented in this paper. Interested readers can obtain it from the authors, together with the 80 ERP implementation problems.

The combination rule of the D–S method was operationalises as follows. Normalised scores from the first two experts were combined first, and the result was combined with the normalised score assigned by the third expert. Then, the result was combined with the normalised score from the fourth expert. The process continued until inputs from all ten experts were combined.

For example, if we get two experts' normalised scores on CSFs A, B and C as follows:expert 1: $\{m_1(A), m_1(B), m_1(C)\}$, expert 2: $\{m_2(A), m_2(B), m_2(C)\}$, then the D–S combination would be:

$$DS_2(A) = \frac{m_1(A) \times m_2(A)}{1 - \left\{ \begin{array}{c} (1 - m_1(A)) \times m_2(A) + (1 - m_1(B)) \\ \times m_2(B) + (1 - m_1(C)) \times m_2(C) \end{array} \right\}}$$

$$DS_2(B) = \frac{m_1(B) \times m_2(B)}{1 - \left\{ \begin{array}{c} (1 - m_1(A)) \times m_2(A) + (1 - m_1(B)) \\ \times m_2(B) + (1 - m_1(C)) \times m_2(C) \end{array} \right\}}$$

$$DS_2(C) = \frac{m_1(C) \times m_2(C)}{1 - \left\{ \begin{array}{c} (1 - m_1(A)) \times m_2(A) + (1 - m_1(B)) \\ \times m_2(B) + (1 - m_1(C)) \times m_2(C) \end{array} \right\}}$$

The weights of the KPIs were first calculated by the above methods on their own CSFs. Given that there were more than one KPI for the same CSF, the final weight of each KPI on its own stage was the result of the multiplication of the CSF weight and the KPI weight on its CSF. If there was only one KPI suggested for a CSF, then the weight of that KPI was the weight of the corresponding CSF. The weights of all of the KPIs are presented in Appendix A.

5.3. Performance calculation and assessment

To calculate the performance of each ERP stage, a template for a *performance assessment worksheet* (PAW) (Table 3) was developed. The assessment scores obtained from users were input into the column 'user feedback' in the PAW. The performance assessment scale and recommended action (shown in Table 4) were used as a reference in the ERP performance assessment.

In the following example (Table 3), the organisation was ready for ERP implementation because the score was 4.0140. In addition, the performance of each CSF was either equal to or larger than 4, which was satisfactory as defined by the performance assessment scale in Table 4.

5.4. Design of step-by-step performance assessment and improvement flow

Fig. 1 presents the planned operational flow that guides step-by-step performance assessment and improvement. It is a plan–do–check–act cycle that ensures that the performance of each stage meets the satisfactory level.

At the organisational readiness assessment stage, an ERP steering committee comprising members from top management and external or internal ERP consultants develops the strategic directions for acquiring an ERP system. The committee reviews CSFs and KPIs for organisation readiness assessment and a performance assessment is then conducted. If the performance of organisation readiness is rated under the acceptance level, then an improvement plan must be performed immediately. The progress of remedial actions is tracked weekly to ensure that it remains on track and delivers the desired results so that the project can move to the next stage of ERP selection.

Table 3
An example of a performance assessment worksheet (PAW).

CSF ID	Stage1 KPI	KPI weight	User assessment	Weighted KPI score	CSF weight	CSF performance
1	11a	0.1082	4	0.4328	0.5359	4.0000
	11b	0.2113	4	0.8452		
	11c	0.1082	4	0.4328		
	11d	0.1082	4	0.4328		
2	12a	0.0351	5	0.1755	0.1054	4.1328
	12b	0.0281	4	0.1124		
	12c	0.0211	4	0.0844		
	12d	0.0211	3	0.0633		
3	13a	0.0980	3	0.2940	0.2744	4.0000
	13b	0.0784	4	0.3136		
	13c	0.0980	5	0.4900		
4	14a	0.0281	4	0.1124	0.0843	4.0000
	14b	0.0281	4	0.1124		
	14c	0.0281	4	0.1124		
Sum of weights		1.0000	–	–	1.0000	–
Stage performance				4.0140	–	–

Notes: Weighted KPI score = KPI weight × user assessment; stage performance = sum of weighted KPI scores; CSF performance = sum of weighted KPI score of a CSF/CSF weight.
If a score is equal to or above 4, then the performance of a stage (CSF) is assessed as satisfactory; otherwise, remedial actions must be defined and taken until the score exceeds 4 on re-assessment.

Table 4
Performance assessment scale and recommended action.

Stage performance	Assessment result	Colour grade	Recommended action
≥4	Satisfactory	Green	The project can move to the next stage
3.0–3.9	Below satisfactory	Yellow	Do not advance to the next stage until remedial action has been taken and the performance has entered the Green zone
<3	Failed the test	Red	Undertake a basic review and take the necessary remedial actions in respect to all KPIs at that stage. Do not proceed to the next stage unless the process can get a Green pass on re-assessment

At stages 2–4, the steering committee defines its goals and objectives and reviews the CSFs and related KPIs. An ERP working committee identifies the required tasks accordingly, and each individual task has its task owner, task schedule and resources budget. All of the task owners report progress weekly to the ERP working committee. Any requests from the task teams are then communicated to the ERP working committee. This weekly feedback mechanism is performed until all of the tasks have been successfully completed. Then, a performance assessment is hosted by the ERP steering committee. If performance is above the satisfactory level, the project proceeds to the next stage. Otherwise, based on any identified gaps, remedial actions are planned and executed. The committee does not allow the project to proceed to the next stage until the result of performance assessment is acceptable.

After the ERP system has been running for at least six months, the steering committee measures system performance in terms of business outcomes. It begins by defining the goals and objectives of the ERP live-run, and then the CSFs and KPIs are derived accordingly. Next, the committee conducts a performance assessment with external customers and business partners. If the performance of business outcomes is satisfactory, then the ERP performance is classified as successful. Otherwise, remedial actions are identified and implemented accordingly, to be taken iteratively until the KPIs are all satisfactory. Furthermore, the business system performance review is conducted periodically to ensure that the ERP system is continuously improving the company performance.

6. Action case studies

The objectives of the action case studies were: (1) to test the viability of performance assessment and improvement in live situations, (2) to test the applicability of CSFs and KPIs for each stage, (3) to fine-tune and enhance the operational flow, (4) to test the applicability of data collection and project progress reporting and (5) to test the acceptance of the new ERP implementation method by companies and consultants.

6.1. Selection of case companies

Three action case studies were performed to test our method across different ERP implementation situations, ERP systems,

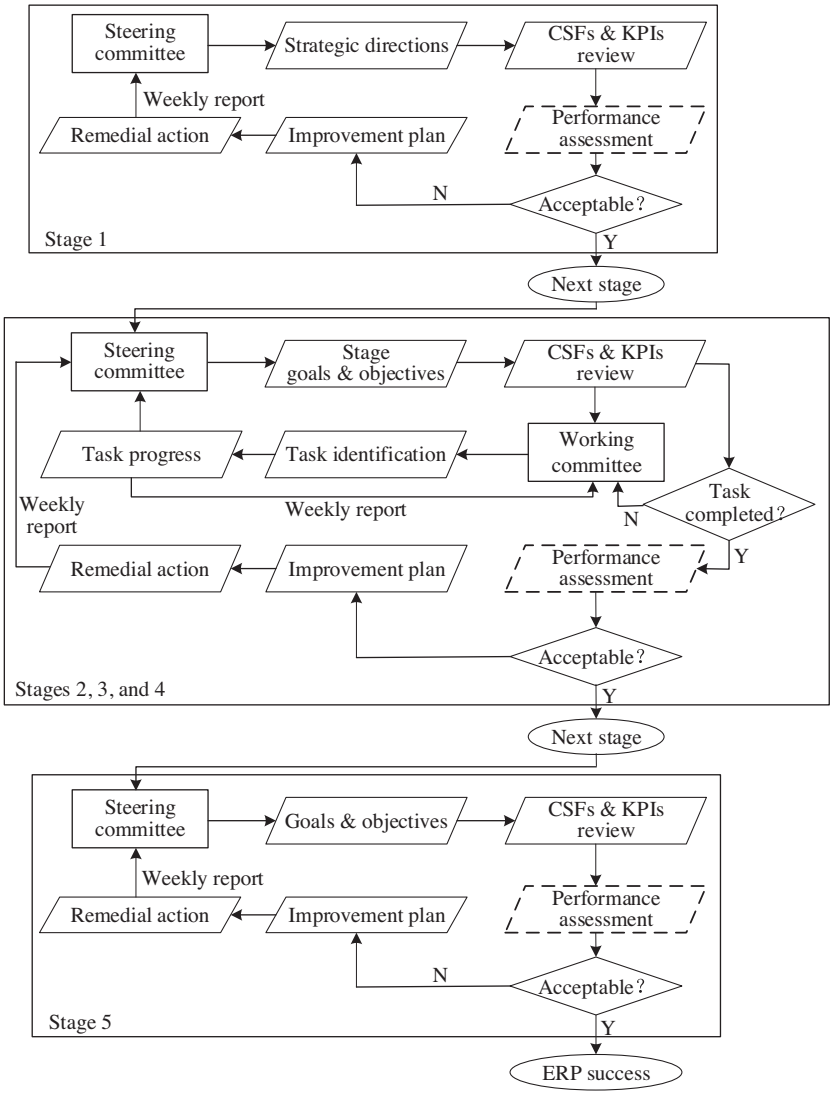

Fig. 1. The step-by-step performance assessment and improvement flow.

industries and company sizes. We applied a theoretical sampling method to select three case companies, simultaneously considering their willingness to participate in an action case study. The three companies and their ERP project information are presented in Table 5. Company-A represents an ERP implementation situation in which an already implemented system is rolled-out into a new subsidiary. Company-B represents a situation in which a new ERP system is being introduced. Company-C represents the enhancement of an existing ERP system. Companies A and C were implementing SAP systems, which are widely applied on a global level, whereas Company-B was introducing a local ERP system from the Hong Kong Productivity Council (HKPC). In addition, all three companies were different with respect to their industries and sizes.

Table 5
Basic information on the three action case ERP projects.

	Company-A	Company-B	Company-C
Size of the company (number of workers)	3000	2000	800
Business nature	Watch manufacturing	Leather manufacturing	Electronic manufacturing
ERP package	SAP	HKPC ERP	SAP
ERP project nature	Roll out	New	Enhancement
Project starting date	May-2008	Jun-2008	Jun-2008
Project end date	Feb-2009	Apr-2009	Apr-2009
Project time actual vs. scheduled (%, months)	91% (10)	92% (11)	100% (11)
Project cost actual vs. budget (%)	97%	98%	75%
ERP live run performance	Satisfactory	Satisfactory	Satisfactory
Reasons as a case company	A large-sized company to roll out an existing, widely used SAP system to a new subsidiary	A large-sized company to implement a new local ERP system	A medium-sized company to enhance an existing, widely used SAP system

However, given length limitations, we only report the case study for Company-A in detail, as it was the first action case and knowledge from it was applied to the other two cases. We summarise the results from the other two companies at the end of the case study to present the whole picture with an economy of words (Table 10).

Company-A, headquartered in Hong Kong, produces watches and related devices. In May 2008, it selected an SAP ERP system for its subsidiary in Southern China, as the package had already been implemented at the mother company for 3 years. Mr Chan, the corporate SAP project manager, was appointed to start implementation planning. First, the goals and objectives of the next year's business and manufacturing operations were defined by the management as follows:

- the margin should be improved by 10%;
- cost to be reduced by 5%;
- delivery to be shortened by 10%;
- inventory to be reduced by 10%; and
- revenue may grow 5% quarter to quarter.

Mr Chan agreed to explore the feasibility of the action research to see how it could help his forthcoming ERP roll out project.

6.2. Stage 1 in Company-A

In May 2008, the ERP steering committee was set up first, with the group chairman, plant director, CFO and CIO as the members. In addition, an ERP working committee comprising department heads, the CIO, the internal SAP project manager, the SAP principal consultant and the vendor's SAP project manager was also organised.

The organisation readiness was then checked. The steering committee reviewed the pre-defined PAW for ensuring that the goals, objectives and KPIs were applicable to the company. Then, the steering committee input their assessment to fill the PAW. The organisational readiness assessment showed that the company was not ready for ERP, given that it achieved a performance score of 2.94 and failed the test (Table 6).

The recommendation was to not implement the ERP immediately. The underperformance CSFs and related KPIs were used as a guide to identify remedial actions. The working committee was responsible for developing underperformance KPIs and CSFs into a detailed improvement plan. After several rounds of in-depth discussions with related departments and staff members, the following remedial actions were proposed and approved by the working committee:

(1) Hold communication sessions with staff members at every level to clearly explain the mission and the importance of the project.
(2) Include more managers with ERP experience in the project team.
(3) Review the information technology (IT) infrastructure requirements for the ERP system and then firm up the IT budget accordingly.

Table 6
Performance assessment of Stage 1.

CSFs	Sum of weighted KPIs score	CSF performance	Status
Top Mgt. support	1.72	3.2	Yellow
Effective communication	0.25	2.4	Red
Employee quality	0.74	2.7	Red
Change management	0.23	2.7	Red
Stage performance	2.94		Red

Notes: Sum of weighted KPIs score = Σ(weighted KPIs score of one CSF).

Table 7
Performance assessment of Stage 3.

CSFs	Sum of weighted KPIs score	CSF performance	Status
Implementation cost	1.09	4	Green
Project management with sufficient resources	0.76	3.5	Yellow
Identification of customer needs	0.42	3	Yellow
Balanced implementation team and Top Mgt. support	0.31	3.73	Yellow
Implementation skillset	0.49	3.3	Yellow
ERP training resources	0.10	2	Red
Effective communication	0.14	2.2	Red
Stage performance	3.31		Yellow

(4) Set up ERP quality circles in the work force across different departments. The plant production manager would be the leader and each production line would be supervised by a team member. They would contribute to improving SAP deployment in daily business operations.

The company completed the abovementioned tasks in about a month and conducted the performance assessment again. With a result of 4.01, the steering committee allowed the ERP project to proceed to the next stage of ERP selection.

6.3. Stage 2 in Company-A

The stage 2 began in June 2008. The goals, objectives and KPIs were reviewed by the steering committee. The SAP Consulting Group was chosen as the implementation partner. Before final approval of the partner, the assessment process was conducted and the result was satisfactory. The SAP Consulting Group achieved a score of 4.30, which was above the satisfactory level. The project moved to the next stage.

6.4. Stage 3 in Company-A

The ERP working committee started to define implementation processes and process owners at Stage 3, in July 2008. During the implementation, the process owners were required to report the progress weekly to the working committee, with all activities logged on a worksheet.

After four months, all of the processes involved in the implementation stage were completed and the assessment process was conducted. However, the assessment returned a score of 3.31, which indicated that some areas required fine tuning before going on to the next stage (Table 7).

By analysing the failed CSFs and KPIs, the following remedial action was identified by the ERP working committee. The remedial processes were then closely monitored on a weekly basis.

(1) Conduct the system recovery test in the event of one of the computer servers failing.
(2) Enhance the ERP training and support manuals based on the feedback obtained from users during integration testing and training sessions.
(3) Conduct the integration test simulating month- and year-end scenarios.
(4) Conduct periodic functionality updates not only on end users, but also on green regulations such as WEEE, RoHS and REACH.
(5) SAP consultant should configure the system for product design, production planning and quality control to ensure compliance with green rules.

Table 8
Performance assessment of Stage 4.

CSFs	Sum of weighted KPIs score	CSF performance	Status
Maintenance budget	0.19	4.6	Green
Financial cut-off plan	0.70	5	Green
System quality assurance	1.10	4	Green
System administration a nd recovery plan	0.43	4	Green
System protection	0.78	4.4	Green
IT and data Mgt.	0.60	3.5	Yellow
ERP support and training	0.15	4	Green
Performance monitoring	0.42	4.6	Green
Stage performance	4.37		Green

Table 9
Performance assessment of Stage 5.

CSFs	Sum of weighted KPIs score	CSF performance	Status
ERP cost and benefits control	1.30	4.6	Green
Traceable operation cost	1.12	5	Green
Periodic system review	0.15	3.5	Yellow
Customer satisfaction	0.98	4.4	Green
Operational efficiency	0.30	4.4	Green
Employee productivity and satisfaction	0.46	5	Green
Knowledge and learning	0.30	4.3	Green
Stage performance	4.61		Green

(6) Provide more resources and incentives to employees joining quality circles for understanding how SAP can help them achieve better results.

After over one month, in December 2008, load and recovery tests were conducted and the training and user manuals were revised. The IT system had been reviewed, confirming that there was no single point of failure that could incapacitate the entire IT system. The assessment process now returned a score of 4.17. It was decided to proceed to the next stage, final preparation.

6.5. Stage 4 in Company-A

According to the assessment worksheet, the ERP steering committee first derived the tasks to fulfil the goals and objectives of this stage, and reviewed the CSFs and KPIs in the PAW based on the goals and objectives. All of the tasks were linked with the holistic vision of the ERP project. Furthermore, the weekly feedback mechanism ensured that the management of individual tasks in terms of time, cost and quality was under control. After completing all of the related tasks, the assessment process was conducted and returned a result of 4.37, which was in the green zone. Thus, the IT infrastructure was ready for an SAP live run (Table 8).

However, the performance of 'IT and data management' was still not acceptable. The data migration plan, which affected data integrity in the new system, had not yet been finalised. Remedial actions were planned and taken. It was confirmed that the implementation partner would be responsible for data migration one week before the system cut-off date. The KPIs were then re-assessed and the score was 4.47. The SAP system was put to live run on 8 Feb 2009.

6.6. Stage 5 in Company-A

Once the ERP system had been running for over 6 months, the post implementation review was conducted. In the performance assessment process, the result was 4.61, which was in the green zone, proving that ERP had been successfully deployed to achieve the business goals. Please refer to Table 9.

Most of the CSFs at Stage 5 had matched expectations, except that of the periodic system review. It was decided that the performance should be reviewed every six months.

6.7. Knowledge from action case studies

The results of the action research in the three companies are summarised in Table 10. The performance assessment and improvement method effectively controlled the quality, time and resources spent on the project through the step-by-step assessment and improvement mechanism, which emphasised companywide communication, strategic management of the project to meet business objectives and operational management of the project in resources, schedule and quality control. The validity of the performance assessment and improvement for ERP implementation was proven. Insightful knowledge from the action case studies is summarised as follows:

(1) The performance of the organisational readiness assessment was under the satisfactory level at all three companies, with two of them returning a performance score under 3. Most of the problems resided in ambiguous roles and responsibilities, insufficient communication about the ERP project across different departments and levels and insufficient IT infrastructure. Therefore, it is important to include the organisational readiness assessment stage in ERP implementation models.
(2) The CSFs and KPIs served as converters between the strategic objectives and operation tasks. By reviewing the pre-defined CSFs and KPIs, and defining stage CSFs and KPIs, the enterprises were able to define the specific initiatives or processes required to achieve strategic objectives in each stage. When a performance gap was detected, the underperformance of CSFs and KPIs provided the basis of improvement action identification. The CSFs and KPIs are clearly important management tools underlying companywide communication during ERP projects.
(3) The remedial actions were context dependent, both on the underperformance CSFs/KPIs and the process of communication and change management. Communication and change management were critical in identifying remedial actions and improving performance, although the CSFs and KPIs acted as an underlying basis. Remedial actions can be identified by developing the underperforming CSFs or KPIs into improvement actions. However, CSFs and KPIs only provide the reference point for defining improvement actions and cannot automatically develop into action programmes. Companywide communication and change management is important in identifying improvement areas, which was a top-down approach in our three action case studies. In this regard, the remedial actions listed in Table 10 only apply to the three case companies. They can serve as reference for other companies, but not as a remedial action menu.
(4) A comprehensive management approach to ERP projects emerged during the action case studies. The main components of this approach included implementation task identification, step-by-step ERP performance assessment, a weekly progress report system, performance gap analysis and improvement tasks identification. The critical issue at the core of this approach, nevertheless, hinges on the performance assessment and improvement by monitoring and managing CSFs and KPIs.

Table 10
ERP performance assessment and improvement in three case companies.

Stages	Company-A		Company-B		Company-C		Major remedy actions
	1st	2nd	1st	2nd	1st	2nd	
Stage 1	2.94	4.01	2.31	4.35	3.21	4.17	A: Conduct staff communication sessions for ERP rolling out. Include more managers with ERP experience in the project team. Review IT infrastructure requirements for the ERP system and firm up the IT budget. Set up ERP quality circles in the work force across different departments B: Conduct staff communication sessions for ERP rolling out. Apply enough IT budget; Recruit an IT administrator with ERP experience. Clearly define the roles and responsibilities of each key working position. Set up ERP quality circles in the work force across different departments C: Conduct staff communication sessions for ERP rolling out. Train IT staff in green data centre policy
Stage 2	4.30		3.12	4.00	3.12	4.01	B: The ERP partner should have local and mainland support, be long term and of stable size and have knowledge of Green Policy application C: Partner understands the business and culture of the company is important. Long term and prompt support is important for rolling out of new features of the ERP
Stage 3	3.31	4.17	4.54		4.67		A: Conduct system recovery test. Enhance ERP training manual and support manual. Conduct the integration test simulating month end and year end scenarios. Conduct periodic functionality updates also on green regulations. The system for product design, production planning and quality control should comply with green regulations. Provide more resources and incentives to quality circles
Stage 4	4.37	4.47	4.31		3.14	4.65	A: The implementation partner handles data migration one week before the cut-off date C: Set up the transaction document management system. Set up a standby data network by the existing telecom services provider
Stage 5	4.61		4.18		4.24		A, B, C: The performance should be reviewed every six months

Notes: Score of 1st is the result of first round performance assessment; score of 2nd is the result of performance assessment after performance improvement.

(5) Some new management tools were developed to smooth the continuous improvement process of each stage, including an implementation process identification worksheet, an improvement process identification worksheet and weekly process progress reports. These tools were important in transforming the goals and objectives into tasks and the performance gap into an improvement process, and they assisted management in allocating resources and monitoring the progress of each task and improvement project.

7. Conclusions and future research

As the literature strives to identify CSFs for ERP implementation, the amount of CSFs is currently over 80 [7]. However, research on the application and implementation of the CSFs in the ERP implementation process remains rather rare [44]. Additionally, the contribution of the 80 CSFs to ERP success has not been validated in practice. Whether one CSF is *critical* in achieving the success of an ERP implementation is still a question. Industry people are expecting to apply CSFs all along the ERP implementation process, and researchers have been calling for dynamic lifecycle research on ERP implementation [44,45].

Most academic research in this area has been based on static factors without considering the dynamic nature of the ERP implementation process. A few lifecycle models have been reported, but rarely validated or applied. More research on the process model for practical application should be encouraged in the ERP implementation field, and the performance of ERP projects should be measured continuously.

We believe that this study enriches the ERP implementation literature and practice. Its main contributions include (1) the dynamic lifecycle perspective, (2) the step-by-step assessment approach, (3) the allocation of over 80 CSFs into five stages, (4) the expert evaluation of CSFs' importance and (5) the continuous improvement approach during the implementation process. The action cases may also be another feature in ERP implementation literature. The model has been commercialised in a local consulting firm, but has the potential to be adopted in other countries.

However, this study does have a limitation in terms of the generalisation of its results to other countries. The action case research was conducted in Chinese manufacturing companies and CSFs in other countries could be different. The weights of KPIs may also vary. We do not recommend a ready list of CSFs and remedies; instead, we provide a model and a procedure for how to select and identify CFSs and KPIs and the remedies. We encourage company implementation teams to involve actively in the process of performance assessment at each stage. Researchers in other countries may apply the approach reported in this paper to conduct a CSF selection and evaluation by local experts so that a localised list of CSF, KPI and KPI weights can be generated.

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Appendix A. CSFs and KPIs of performance measurement for ERP implementation

Tables A.1–A.5.

Table A.1
Stage 1: organisational readiness assessment.

ERP CSFs	ID	Key performance Indicators (KPIs)	Weight*
Top management support	11a	Top management support exists in the strategic investment projects	0.1082
	11b	Cross-department cooperation is smooth and effective	0.2113
	11c	Clear roles and responsibilities	0.1082
	11d	Every staff member has a career development plan	0.1082
Effective communication	12a	The goals and objectives for implementing a new ERP system are clear among the top and middle management	0.0351
	12b	There are information-rich ecosystems inside the company	0.0281
	12c	There are accountability mechanisms that monitor performance and provide system members with useful, ongoing feedback	0.0211
	12d	Learning activities (such as adopting ISO or Six Sigma) are effective	0.0211
Right employee quality	13a	Management (CEO, COO, Directors) has ERP project knowledge or experience	0.0980
	13b	Learning and new skills development is encouraged by management	0.0784
	13c	The ERP project manager of the company has adequate ERP project experience	0.0980
Change management	14a	Change management has been well prepared in the organisation	0.0281
	14b	The organisation's structure and business processes are open to changes	0.0281
	14c	Sufficient IT resources for business requirement changes	0.0281

* The weights of the KPI are obtained by the D–S combination method.

Table A.2
Stage 2: ERP selection.

ERP CSFs	ID	Key performance Indicators (KPIs)	Weight
Contract management	21a	The vendor and implementation partner have a clear benefit proposal with an ROI plan	0.0980
	21b	Sound contract management caters to the ERP vendor and implementation partner	0.0980
Sufficient financial budget	22a	The cost of ERP implementation is under budget and includes the package license, maintenance, consulting, administration, hardware and network costs	0.1567
Right quality compliance	23a	The ERP system has green and safety compliance functions in the manufacturing modules	0.0803
Identification of customer needs	24a	The vendor, ERP package and implementation partner know how to response to all customers and partner requests	0.0871
	24b	The candidate ERP system can provide eBusiness capability	0.1088
Balanced evaluation team	25a	The evaluation team involves both management and user representatives	0.0386
	25b	Top management support with clear and unambiguous authority exists in the evaluation team	0.0386
	25c	An external ERP consultant is involved in the evaluation team	0.0482
ERP and implementation partner's capability	26a	There is a local reference of the same industry for both the vendor and implementation partner	0.0169
	26b	Global and local maintenance and 7 day/24 h support are provided	0.0135
	26c	The system runs on different operating systems and databases	0.0169
	26d	The hardware and infrastructure are low cost to increase system performance	0.0169
	26e	The ERP package and implementation partner bridge the gap between the existing business/operations flows with best practices of specific industries	0.0108
	26f	The Package has a detailed authorisation and security system	0.0135
	26g	The ERP implementation partner has a local ERP-certified consulting team with implementation, help desk and maintenance services offerings	0.0081
	26h	The system is easily self-maintained and customised	0.0065
	26i	The ERP vendor and implementation partner have strong financial structures	0.0135
	26j	The ERP package and implementation partners are capable of delivering local and international legislation and best practices of specific industries	0.0087
Vendor management	27a	The vendor and implementation partner understand the company culture and industrial norms	0.0211
	27b	The vendor and implementation partner will build a long-term partnership with the company	0.0180
	27c	The implementation partner has the change management capability for organisation readiness in the event of new operation flow deployment by the new ERP system	0.0211
Sufficient evaluation resources	28a	The vendor/partner provides training on using ERP systems to different levels of end-users with sufficient documentation	0.0301
	28b	There is internal provision of sufficient resources for ERP evaluation	0.0301

Table A.3
Stage 3: ERP implementation.

ERP CSFs	ID	Key performance indicators (KPIs)	Weight
Implementation cost	31a	A fixed implementation cost model is vital to the ERP project	0.1512
	31b	Financial funding is properly distributed during the different implementation phases	0.1210
Project management with sufficient resources	32a	A contingency budget for over-run ERP implementation is available	0.1089
	32b	Project management with sufficient resources and planning is well organised	0.1089
Identification of customer needs	33a	External customers' requirements and internal needs are well covered in the ERP implementation	0.1394
Balanced implementation team + top management support	34a	The functional department heads are involved in ERP team or fully support their subordinates during implementation	0.0167
	34b	The ERP implementation team is well balanced with business and ERP user	0.0223
	34c	There is top management support of the change management and resources	0.0223
	34d	The external consultant work harmonises with the internal staff in the implementation team	0.0223
Effective implementation skill set	35a	The implementation team can bridge the gap between the existing work flow and new ERP business practice by appropriate change management in the organisation	0.0230
	35b	Implementation is fully supported by the top management	0.0287
	35c	System integration and stress tests with real data have been conducted successfully	0.0383
	35d	The implementation team is responsible and supportive during the implementation period	0.0306
	35e	Customisation is limited to a certain extent (at most 30%)	0.0306
	35f	The scope and goals are clearly identified by implementation team	0.0230
Sufficient training resources + change Mgt.	36a	Key user training during implementation is effective	0.0251
	36b	The organisation is well trained to accept the changes for the best practices of specific industries from the new ERP system	0.0251
Effective communication	37a	An ERP quality circle is formed for promoting ERP capability and improving ERP quality in the company	0.0257
	37b	There are well-established, open and accessible communication infrastructures inside the company	0.0206
	37c	Most employees share the organisation's vision and mission	0.0164

Table A.4
Stage 4: ERP final preparation.

ERP CSFs	ID	Key Performance Indicators (KPIs)	Weight
Sufficient maintenance budget	41a	Sufficient system maintenance cost has been reserved	0.0174
	41b	The outsourcing of the IT data centre has been planned for the ERP on-going support to minimise the operational running cost	0.0232
Financial cut-off plan	42a	The financial cut-off plan has already been considered in the ERP cut-off plan, for example, the timing of peak season, so as not to affect the company's financial book record and business effects	0.1411
System quality assurance	43a	A user acceptance test has been signed for all system testing, including loaded, integration, and stress testing	0.1225
	43b	The external partner/customer has an eBusiness connection with the ERP system	0.1531
System administration & recovery plan	44a	The system administration procedure for supporting the ERP system is ready	0.0326
	44b	Both manual and automatic failover procedures have been developed for ERP system failure	0.0326
	44c	The ERP disaster recovery plan has been tested successfully to minimise the down time and business interruption, should the ERP system accidentally fail	0.0407
Well system protection	45a	Fast backup and recovery has been implemented in the infrastructure design	0.0784
	45b	No single point of failure exists in the system infrastructure	0.0980
IT and data management	46a	The cut-off plan, including the data migration plan, has been tested ready for the ERP go-live	0.0661
	46b	Sufficient resources have been invested in IT infrastructure, including networks, servers and storage with well-managed integrated software	0.0661
ERP support and training	47a	The ERP help desk has been well established for providing efficient end-user support	0.0139
	47b	The users are effectively trained in ERP knowledge using multiple channels (manual, formal training and personal help)	0.0104
	47c	Both management and workers clearly understand the benefits of ERP	0.0139
Performance monitoring	48a	Employees have ongoing/sustained ERP learning opportunities	0.0248
	48b	There are accountability mechanisms that monitor performance and provide system members with useful, ongoing feedback	0.0291
	48c	Change readiness is clear among employees (cross-trained on alternative tasks, ability to communicate, disperse workforce, trust level of management)	0.0364

Table A.5
Stage 5: ERP live run.

ERP CSFs	ID	Key performance indicators (KPIs)	Weight
ERP cost and benefits control	51a	The ROI of the ERP project is satisfied	0.0999
	51b	The ERP project is on-time, on-cost and of an acceptable quality	0.0999
	51c	The ERP operating cost has been kept in reduction continuously	0.0799
Traceable operation cost	52a	The decrease in manufacturing costs after the ERP project is acceptable	0.0873
	52b	All of the costs are traceable in the company	0.1364
Periodic system performance review	53a	Performance metrics are periodically defined for business objective changes	0.0237
	53b	The ERP system is periodically reviewed to ensure that all or most of the customer requirements are met	0.0202
Positive customer satisfaction	54a	Customer satisfaction after the ERP project improves	0.0426
	54b	Product pricing and quality after the ERP project is acceptable to the customer	0.0426
	54c	Product maintenance service after the ERP project is acceptable to the customer	0.0426
	54d	Product delivery lead time after the ERP project is acceptable to the customer	0.0533
	54e	Product time to market after the ERP project is shortened	0.0426
System operations efficiency	55a	The material inventory after the ERP project is low	0.0207
	55b	The production throughput after the ERP project is satisfied	0.0259
	55c	The ERP system performance and maintenance are acceptable	0.0221
Employee productivity and satisfaction	56a	The decision-making system improves after the ERP implementation	0.0295
	56b	Employee productivity improves after the ERP implementation	0.0276
	56c	Employees enjoy the new efficient operation flow generated by the ERP best practices in that industry	0.0345
Effective learning environment	57a	The ERP business objectives are well communicated in the organisation	0.0225
	57b	ERP adoption is encouraged with re-enforcement from the ERP help desk support	0.0282
	57c	ERP training and change management continues within the company	0.0180

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