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Int. J. Production Economics 96 (2005) 47–62
international journal of production economics
www.elsevier.com/locate/dsw

An AHP-based approach to ERP system selection

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Received 28 March 2003; accepted 5 March 2004

Abstract

An Enterprise Resource Planning (ERP) system is a critical investment that can significantly affect future competitiveness and performance of a company. This study presents a comprehensive framework for selecting a suitable ERP system. The framework can systematically construct the objectives of ERP selection to support the business goals and strategies of an enterprise, identify the appropriate attributes, and set up a consistent evaluation standard for facilitating a group decision process. A real-world example demonstrates the feasibility of the proposed framework.

Keywords: ERP system; Decision analysis; Analytic hierarchy process (AHP); Information system

1. Introduction

Severe market competition has dramatically transformed the business environment with the result that companies need to reduce total costs, maximize return on investment, shorten lead times, and be more responsive to customer demands. Highly dynamic markets call for effective enterprise information systems to enhance competitive advantage. Enterprise Resource Planning (ERP) is increasingly important in modern business because of its ability to integrate the flow of material, finance, and information and to support organizational strategies (Yusuf et al., 2004, Yao and He, 2000). A successful ERP project involves managing business process change, selecting an ERP software system and a co-operative vendor, implementing this system, and examining the practicality of the new system. Owing to the complexity of the business environment, the limitations in available resources, and the diversity of ERP alternatives, ERP system selection is tedious and time consuming. However, given the considerable financial investment and potential risks and benefits, the importance of a pertinent ERP system selection cannot be overemphasized (Teltumbde, 2000).

Existing ERP commercial packages cannot provide a once-for-all business model for every process of all industry. Thus, no single ERP packaged software can meet all company functionalities or all special business requirements (Sarkis and Sundarraj, 2000; Teltumbde, 2000; Hong and Kim, 2002). Therefore, companies must choose a flexible ERP system and a co-operative vendor that is responsive to customer needs. All too often there is no systematic evaluation framework in place when most companies evaluate ERP

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0925-5273/$ - see front matter
doi:10.1016/j.ijpe.2004.03.004

systems. In addition, "ERP vendor hype" further complicates the selection process. Decision makers frequently adopt the common ERP evaluation criteria as the measures without developing tailor-made objectives and clear requirements that echo the company characteristics, its position in its competitive environment, and its corporate strategy. The result is an inevitable delay of ERP implementation and under-performance of the system. Hence, an ERP system selection framework is extremely critical in assisting executives to evaluate from the perspective of company strategies.

Since the business environment is characterized by high uncertainty, the process of ERP system assessment involves numerous problems. Kumar et al. (2002) emphasized that installing an ERP system is much more than having another information technology tool; it is a decision on how to shape the organizational business. Motwani et al. (2002) emphasized that ERP adoption involves initiating appropriate business process changes as well as information technology changes to significantly enhance performance, quality, costs, flexibility, and responsiveness. However, many companies install their ERP systems hurriedly without fully understanding the implications for their business or the need for compatibility with overall organizational goals and strategies (Hicks and Stecke, 1995). The result of this hasty approach is failed projects or weak systems whose logic conflicts with organizational goals.

This study proposes a comprehensive ERP system selection framework in which the objective hierarchy is constructed and the appropriate attributes are specified to provide detailed guidance for ERP system evaluation. The proposed methodology also ensures that the evaluation process is aligned with the competitive strategies and goals of the enterprise. The analytic hierarchy process (AHP) method (Saaty, 1980) is applied for dealing with the ambiguities involved in the assessment of ERP alternatives and relative importance weightings of attributes. An empirical case in Taiwan is described to demonstrate the practical viability of the proposed method.

2. Selection method review

A number of methods have been applied to ERP or other information system (IS) selection including scoring, ranking, mathematical optimization, and multi-criteria decision analysis. The scoring (Lucas and Moore, 1976) method is intuitive, but too simple to truly reflect opinions of the decision makers. Buss (1983) proposed a ranking approach to compare computer projects. This method also has the same limitation with scoring method. Mathematical optimization such as goal programming, 0–1 programming, and nonlinear programming have been applied to resource optimization for IS selection. Santhanam and Kyparisis (1995, 1996) proposed a nonlinear programming model to optimize resource allocation allowing for the interaction of factors; their model considered interdependencies between projects in the IS selection process. Lee and Kim (2000) claimed that Santhanam and Kyparisis' model dealt with IS selection problems with limited criteria. They combined the analytic network process (ANP) and a 0–1 goal-programming model to select an IS project. Badri et al. (2001) presented a 0–1 goal programming model to select an IS project considering multiple criteria including benefits, hardware, software and other costs, risk factors, preferences of decision makers and users, completion time, and training time constraints. However, the applicability of these methods is often weakened by sophisticated mathematic models or limited attributes to carry out in a real-world ERP system selection decision, especially when some attributes are not readily quantifiable, as well as not too easy for managers to understand. Moreover, these methodologies focus too much on quantifiable calculations and look down upon the comprehensive selection framework of ERP system and the strategic considerations of a company.

The AHP method, introduced by Saaty (1980), directs how to determine the priority of a set of alternatives and the relative importance of attributes in a multiple criteria decision-making problem, and has been widely discussed in various aspects. For example, Schniederjans and Wilson (1991) utilized the AHP method to determine the

relative weights of attributes and applied these weights to a goal programming model for IS selection. Lai et al. (1999) conducted a case study to select a multimedia authoring system using the AHP method. Teltumbde (2000) proposed a framework based on the Nominal Group Technique and AHP to select an ERP system. His study focused on the elaboration of some common criteria for ERP evaluation. However, it did not explain how to construct a specific objective structure relating to the company's strategies and how to extract the proper criteria for evaluating the fulfillment of the company's requirements. Little research has addressed the issue of objective structures for evaluating ERP systems. In this study, a systematic procedure is proposed to construct the objective structure taking into account company strategies and thus extract the associated attributes for evaluating ERP systems. This study uses the analytical framework of AHP to synthesize decision makers' tangible and intangible measures with respect to numerous competing objectives inherent in ERP system selection and facilitates the group decision-making process.

3. Procedure for selecting a suitable ERP system

To clearly present the proposed ERP system selection framework, a stepwise procedure is first described:

Step 1. Form a project team and collect all possible information about ERP vendors and systems.
Step 2. Identify the ERP system characteristics.
Step 3. Construct a structure of objectives to develop the fundamental-objective hierarchy and means-objective network.
Step 4. Extract the attributes for evaluating ERP systems from the structure of objectives.
Step 5. Filter out unqualified vendors by asking specific questions, which are formulated according to the system requirements.
Step 6. Evaluate the ERP systems using the AHP method.
Step 7. Discuss the results and make the final decision.

Fig. 1 shows a flowchart for the ERP selection process. The details of each step are presented below.

3.1. Form a project team and collect information on ERP systems

The first step is to form a project team that consists of decision makers, functional experts and senior representatives of user departments. The participation and support of top managers significantly influences the success of ERP adoption (Ptak, 2000). A wide range of information concerning ERP vendors and systems should be obtained from professional magazines, exhibitions, yearbooks, the Internet, and other sources to ensure that feasible systems are not overlooked.

3.2. Identify the ERP system characteristics

Different companies may adopt an ERP system for completely different reasons, including technical and business reasons. The initial rationale for adopting an ERP system influences problem definition, methods of achieving goals, and other subsequent activities. To ensure the process progresses smoothly from the start, the project team has to analyze the ERP selection problem by identifying decision elements, including the stakeholders, number of alternatives, project objectives, project risks, and other concerns. The project team can clarify the complex situation, sketch the problem and develop an initial plan. The phase also highlights in advance some difficulties in finding solutions and supports owing to organizational limitations and resource constraints.

3.3. Construct the structure of objectives

Structuring the objectives involves organizing them so that the project team can describe in detail what a company wants to achieve, and then incorporate these objectives appropriately into the decision model. In the first place, the project team should define the ERP system scope by company policy, business attribute, industry environment, and the goals of the project.

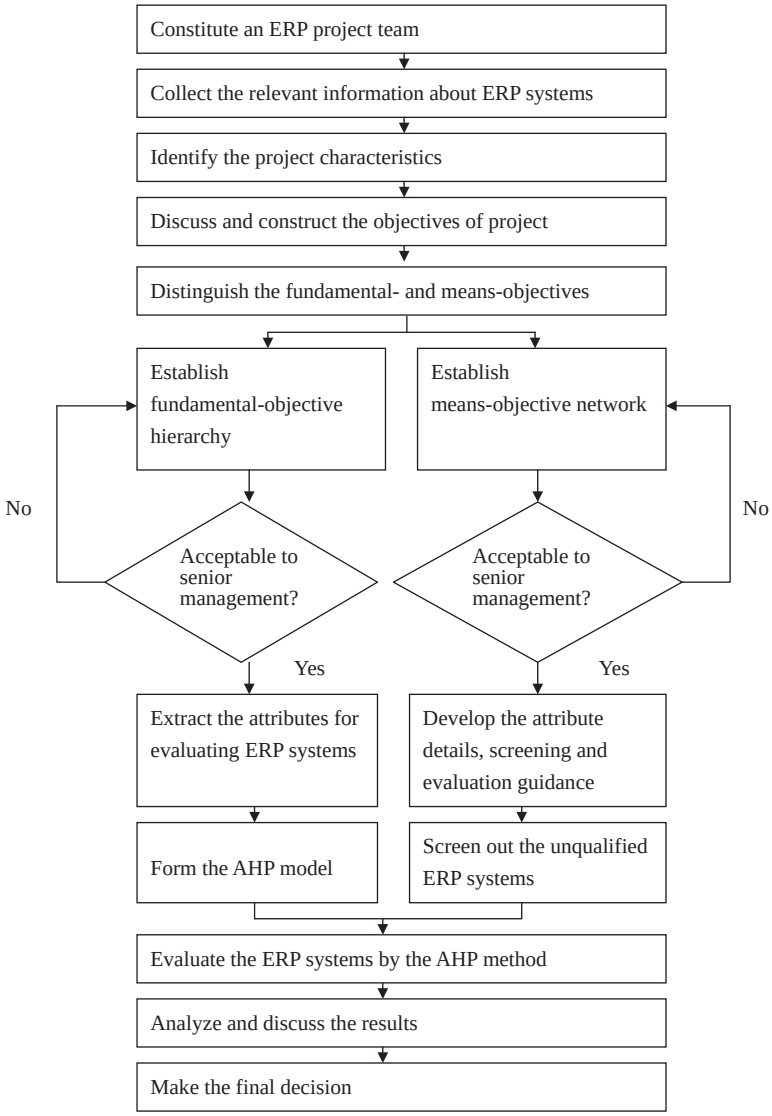

Fig. 1. Comprehensive ERP system selection framework.

Before constructing a detailed objective framework, it is necessary to ensure that the strategic objective scope is appropriate for the project characteristics. The strategic objectives offer a solid basis for decision-making and a stable reference point for ill-structured decision situations. The strategic objectives guide the ultimate goals that the project team should strive to achieve; thus they also serve as the mechanism to harmonize the opinions of different individuals within the project team.

All objectives derived from the strategic objective scope will be structured systematically. It is critical to distinguish fundamental-objectives from means-objectives in the objective development process. Fundamental-objectives are those that are important because they reflect what the decision makers really want to accomplish. Meanwhile, means-objectives are those which help the fulfillment of other objectives (Clemen, 1996).

The fundamental-objectives are organized into a hierarchy and indicate directions in which the

project team should strive to perform better. Two methods can be used to establish the hierarchy of ERP system fundamental-objectives, namely top-down decomposition and bottom-up synthesis. In the top-down decomposition procedure, the project team discusses "What do you mean by that upper-level objective?" The answers reveal the lower-level fundamental-objectives, which explain the meanings of the upper-level objective. Alternatively, managers can start from a lower-level objective by asking, "Of what more general objective is this aspect?" to find a more general objective and move upwards via the bottom-up synthesis procedure. The upper levels in the hierarchy refer to more general objectives and the lower levels contain important elaborations of the upper objectives. When organizing the hierarchy of fundamental-objectives, the project team must keep in mind to pay attention to the limitations of decision elements and the alternation of business environment at any time.

Means-objectives are organized into networks (Clemen, 1996). The project team can create a means-objective apart from the fundamental-objectives by asking, "How could you achieve this?" The answers to this question identify the corresponding means-objectives and describe the linkages among them. Alternatively, the project team links a means-objective toward the corresponding fundamental-objective by asking the question "Why is that important?" Having formulated these means-objectives, the project team can ensure specific ways of accomplishing the fundamental-objectives. Additionally, the team can narrow the set of ERP candidates by examining these means-objectives and also develop detailed attribute specifications to assess the ERP systems.

3.4. Extract the attributes used for evaluation

After creating the structure of objectives, the project team can derive the attributes pertinent to evaluating each ERP system. Both quantitative and qualitative attributes that satisfy the strategies and goals of the company should be involved. Ideally, the team should develop its own structure of critical objectives and select appropriate measurable attributes to indicate the degree to which the corresponding objective is achieved, based on the business environment and requirements. Therefore, the selected attributes will be consistent with the objective framework, guided by the company strategy.

The project team should iteratively examine and modify the set of selected attributes so that they are complete, decomposable, nonredundant, measurable, and minimal (Keeney and Raiffa, 1993). Then, these attributes will be used as the basis of the AHP model.

3.5. Screen the unqualified ERP systems

Numerous alternatives are collected initially, and hence a filtering mechanism is required to shorten the list of ERP candidates. The detailed characteristics desired by the company for the ERP system are developed over many meetings. Next, suitable characteristics are transferred to specific requirements to form a questionnaire or checklist of system specifications. Simultaneously, examining the network of means-objectives can help to scrutinize system specifications and ensure that these requirements are consistent with corporate objectives. The listed vendors are requested to provide information in response to the specific questions included in the questionnaire. The project team then assesses this information to eliminate the obviously unqualified vendors.

3.6. Evaluate the ERP systems by using the AHP method

The AHP is a multi-attribute evaluation method that involves three phases: decomposition, comparative judgments, and synthesis of priorities (Saaty, 1980). In the decomposition phase, the project team can explicitly develop the AHP hierarchy model from the fundamental-objective hierarchy as mentioned above. In the second phase, each decision maker utilizes paired comparisons for the attributes and alternatives to extract judgment matrices with a nine-point scale at each level. In the third phase, the paired comparison process is repeated for each attribute in the alternative prioritization problem based on the largest eigen-value method. Finally, the relative

importance of attributes and the global priority of alternatives can be obtained by aggregating the weights over the hierarchy. Hence, AHP can accelerate the development of a consensus amongst multiple decision makers in ERP system selection process.

4. Practical example

The proposed framework was applied to ERP system selection at an electronics company in Hsinchu science park, Taiwan. This company designs and manufactures modular microwave communication systems and exports them to the USA, Europe, and Mainland China. On the one hand, the fragmented modules of the existing ERP system limited the company's operating efficiency, caused much duplication of effort, and confused the business processes. On the other hand, the sales cycle of export and the need to maintain good customer service in the highly dynamic business environment put increasingly heavy pressure on the company. In order to maintain its competitiveness, the top management announced the launch of a series of projects including the adoption of an ERP system and the re-engineering of the complex business process to enhance the effectiveness of its global logistics and provide quick responses to customer demands.

4.1. Identify the ERP system characteristics

A steering committee of three senior managers was formed, including the General Manager and senior MIS and Purchasing managers, with the responsibility to formulate the project plan, integrate project resources, and select a suitable ERP system. Representatives of different user departments, with at least 5 years experience in the company and expertise in their particular fields, were also chosen to participate in the project team. To encourage employee engagement and support, the project team held several promotional workshops. These meetings produced numerous valuable recommendations, to which the project team responded during the project implementation to reduce resistance to the project.

To obtain a clear understanding of the crucial elements involved in the decision, we suggested that the project team should discuss the goals of ERP implementation, the project scope, organizational strengths and weaknesses, potential alternatives, and other major concerns at the first regular project team meeting. This process was reviewed iteratively in later meetings to ensure that the flexibility to changes in the business environment was preserved.

The project team widely collected the information on ERP systems and vendors and actively delivered the invitations to various vendors. Top international ERP systems were not considered owing to a budget cap and the need to support local legal and tax systems. Initially, 20 ERP systems were proposed by various vendors.

4.2. Organize the structure of objectives

The process of constructing the objective structure of ERP system selection was both dialectic and analytic, and thus captured the mental structure of decision makers. We recommended to first scope out the important strategic objectives. After discussing with the project team, we gathered the following results:

(1) To satisfy business strategy: to satisfy the industrial characteristics and the business goals and adapt to dynamic business environment.
(2) To enhance business process performance: to integrate business systems and procedures and enhance information transparency.
(3) To improve operations quality and efficiency: to standardize and simplify operations flow, improve quality and reduce lead times.
(4) To shorten turn-around time to the customer: to efficiently analyze customer information from various markets and quickly respond to various customer demands.
(5) To support globalization development: to support business operations worldwide.

Structured interviews and discussions were used to elicit the structure of objectives from the members of the project team during several meetings. Fig. 2 displays the fundamental-objective

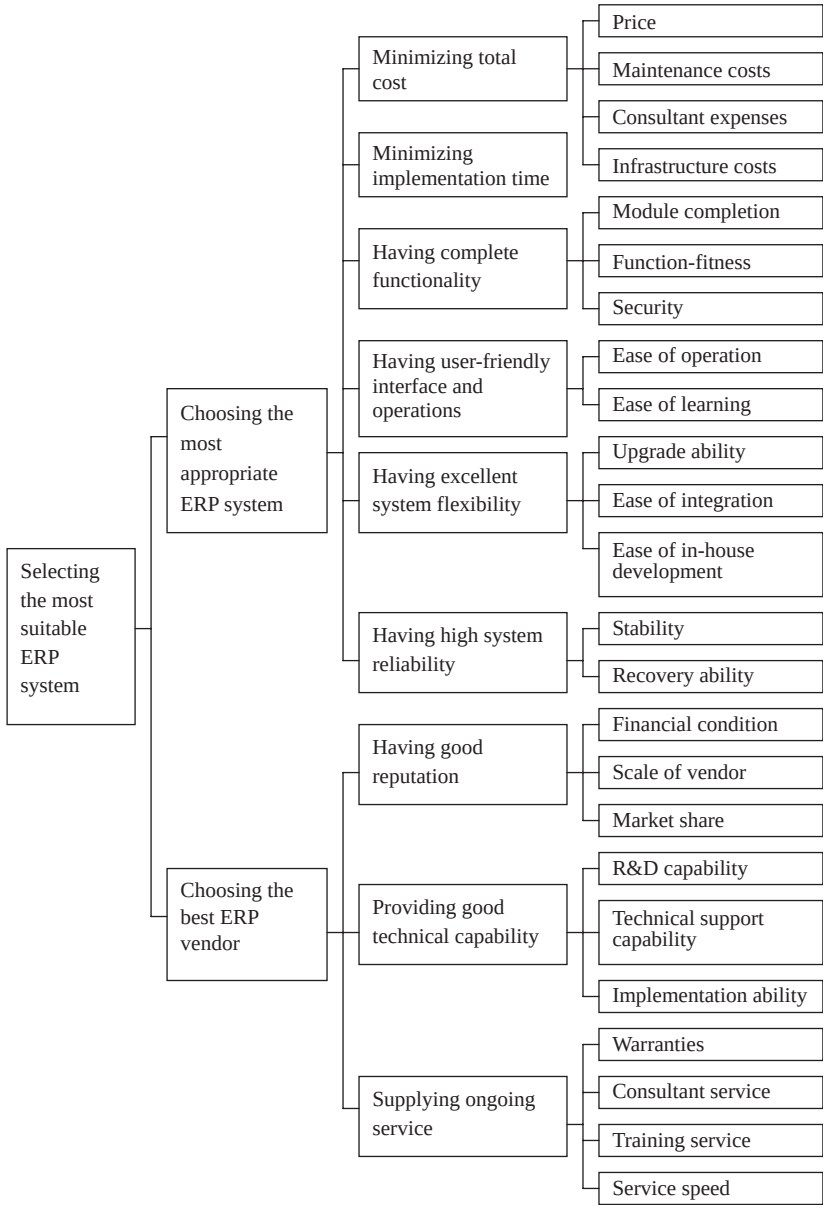

Fig. 2. Fundamental-objective hierarchy.

hierarchy. The ultimate goal is to ''select the most suitable ERP system''. This is divided into two lower-level objective sets, namely ''choosing the most appropriate ERP system'' and ''choosing the best ERP vendor''.

We led the team members to discuss ''What does choosing the most appropriate ERP system mean?'' ''Choosing the most appropriate ERP system,'' meant selecting an ERP system that can minimize total costs and implementation time, has complete functionality, user-friendly interface and operations, and satisfies system flexibility and reliability. On the other hand, the objectives of ''selecting the best ERP vendor'' were those related

to vendor features, including excellent reputation, technical capability, and ongoing service. Fig. 2 shows the two objective sets that constitute the third level of the fundamental-objective hierarchy. For example, we further asked "What does 'minimizing total costs' mean?" to drill down in the objective of total cost minimization and found that the answer lay in minimizing system price, maintenance expenses, consultant expenses, and infrastructure costs. Similarly, the top-down decomposition method found that the other objectives in level 3 must also be decomposed to establish their practical meanings. Level 4 reveals the details that can be used to compare the performance of alternatives.

To verify the consistency of the fundamental-objective hierarchy, we can simultaneously ask the project team to synthesize the lower-level objectives into more general objectives and thus refine the hierarchical structure previously derived from the top-down decomposition method. Indeed, this process was iterative and the structure was not unique.

The means-objective networks for system and vendor factors were formulated simultaneously as shown in Figs. 3 and 4, respectively. The project team started from the bottom objectives of the fundamental-objective hierarchy (Fig. 2) by asking the question, "How can this objective be achieved?" to help the project team to identify the means-objectives and establish links among them. For example, in Fig. 3, the answers to the question, "How can a lower price for the ERP system be achieved?" were "minimizing the degree of customization" and "reducing the price of vendor's quotation". That is, if the team could provide clear requirements and specifications to the vendor, then customization could be controlled and the price thus lowered. Furthermore, in order to have clear requirements, business process re-engineering ought to be done first. In additional, as illustrated in Fig. 4, the project team concerned the situation in which an ERP vendor may be too large to give sufficient supports to a mid-range customer or an ERP vendor may be too small to survive and provide consistent service. Thus the project team needed to collect and analyze "the ERP market data" and "the vendor provided data" to ensure that the size of the vendor matches well with the size of the company. Following a similar approach, we systematically elaborated the cause–effect relationships among all the means-objectives into a complete network. Similarly, the project team incorporated other means-objectives into the network in a logical way.

Also, we encouraged the team to repeatedly examine all means-objective linkages in order to confirm every relationship was reasonable. The process was iterative and diagnostic. For instance, the answer to the question "Why are clear requirements important?" was that providing clear requirements would enable the project team to reduce the degree of customization, produce precise specifications, and confirm all required modules by redefining and repositioning the business processes. Furthermore, clear requirements would also help to identify the system functions and clarify the gap between the ERP system and the existing operations procedure. By this means, the company would be able to reduce project cost, assess system suitability, and propose complete functional requirements.

4.3. Extract the attributes for evaluating ERP systems

It may be impractical to make paired comparisons among the ERP systems with respect to every detailed dimension in level 4 of the fundamental-objective hierarchy in Fig. 2. The difficulty arises because too many attributes lead to numerous paired comparisons in AHP and cause an inefficient process. Representatives from different user departments in the project team were divided into research groups to gather and evaluate the ERP system data based on their specialities and job responsibility. For example, the Finance Department and Purchase Department members joined a "cost" research group to provide financial data, and the MIS Department members studied the functionality, flexibility, and reliability of each ERP system as well as the technical ability of each vendor. The evaluations from the research groups were discussed in a full assembly of the project team. The three major decision makers then combined the suggestions of each research group

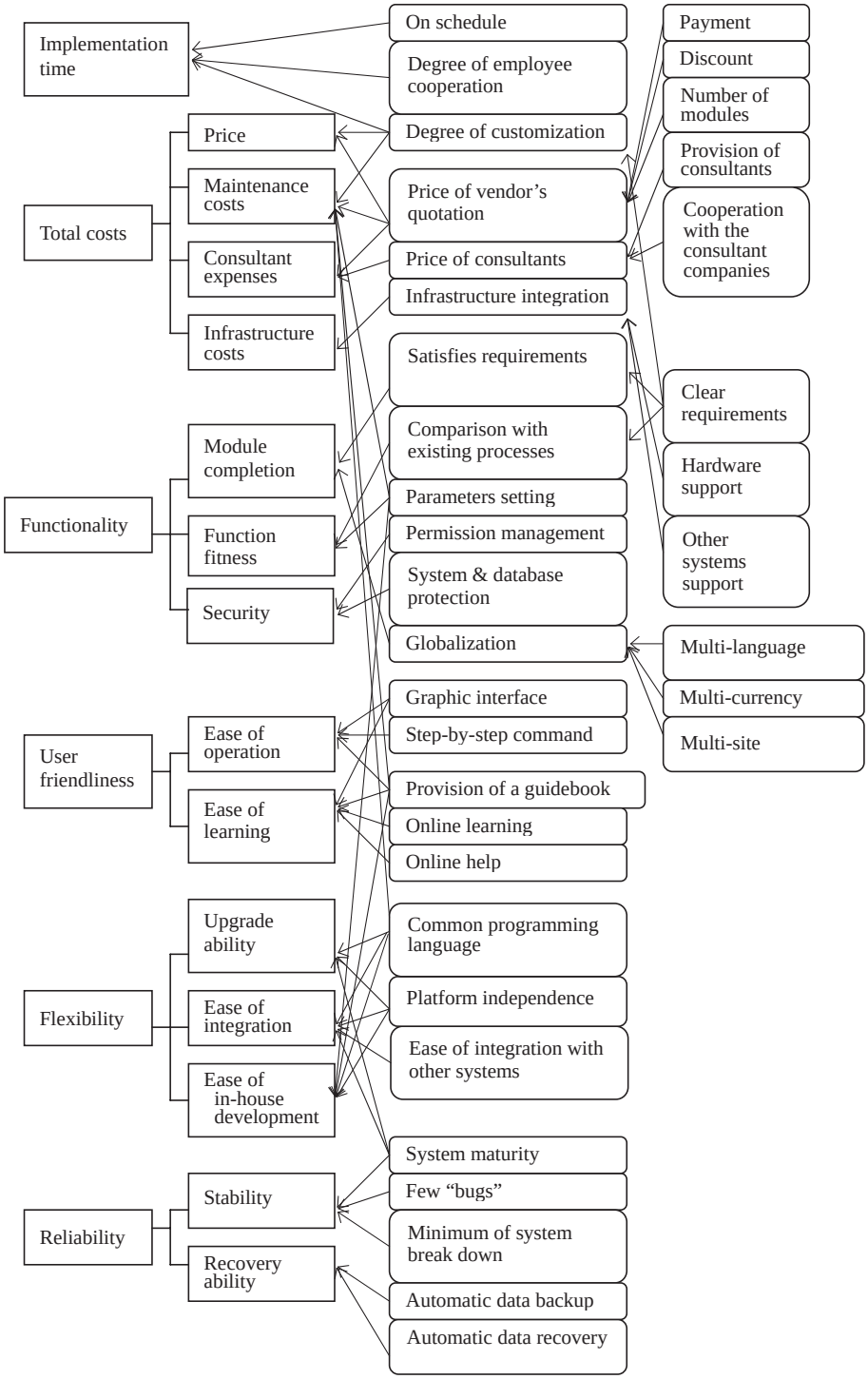

Fig. 3. Means-objective network (system factors).

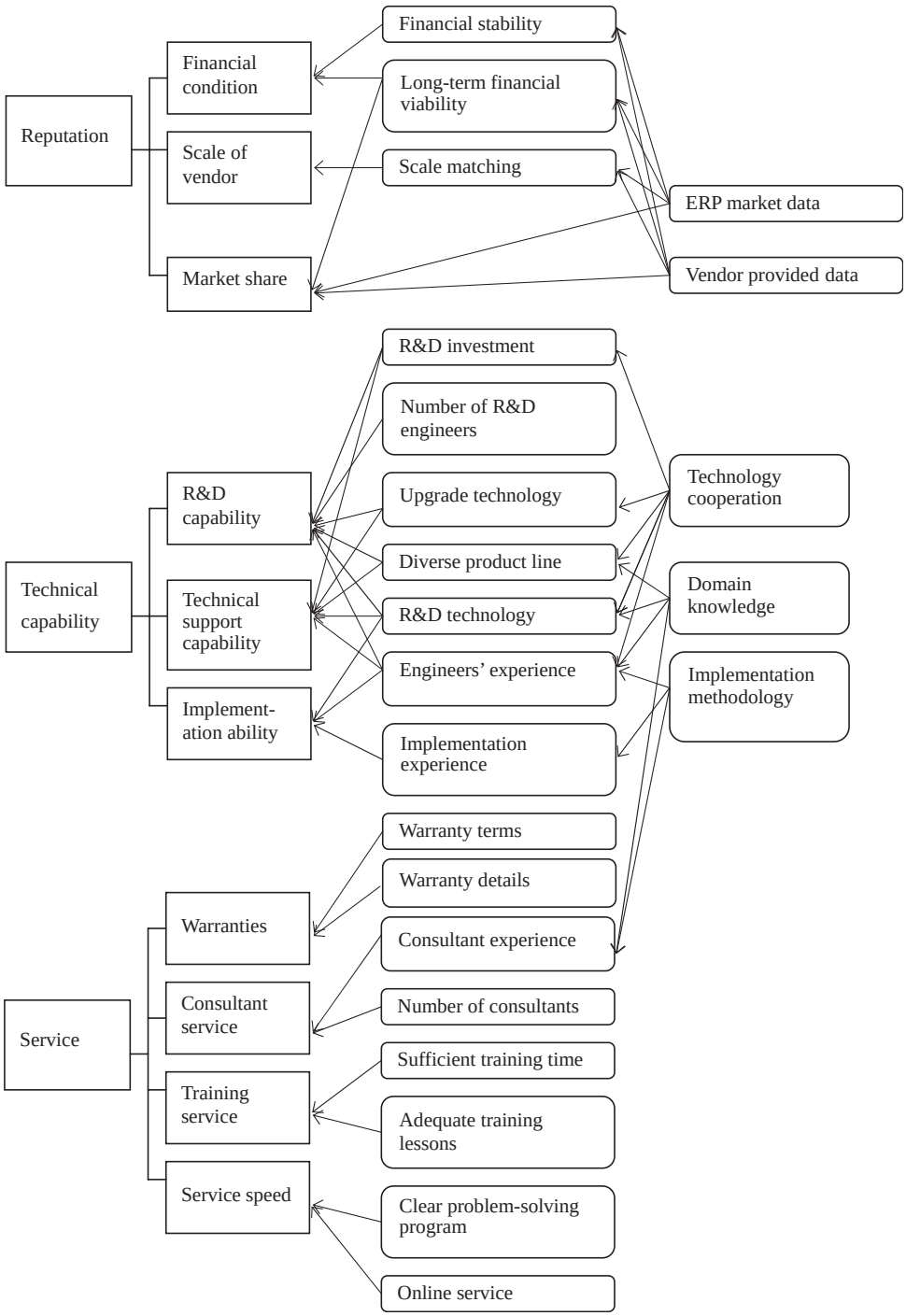

Fig. 4. Means-objective network (vendor factors).

with their subjective opinions to evaluate the alternatives.

The fundamental-objective hierarchy was modified to generate an AHP hierarchy. This AHP hierarchy is composed of four levels, as illustrated in Fig. 5. Level 1 reveals the strategic objective for selecting the most suitable ERP system. Level 2 consists of two main objectives, namely choosing the most appropriate ERP system and selecting the best vendor. Level 3 contains the associated attributes that are used to measure various ERP systems and vendor, respectively. The bottom level consists of the alternative ERP systems.

Using the means-objective network (Figs. 3 and 4), we assisted the project team to establish the evaluation criteria and specific requirements. This process can ensure that everyone follows the same criteria in the evaluation process consistently. Table 1 presents the detailed description of the attributes in the AHP model (Fig. 5) with the associated means extracted from the means-objective network.

4.4. Screen the ERP alternatives

Unfavorable alternatives were eliminated by thorough examination of system specifications and requirements derived from the means-objective network. Table 2 lists some of the questions. After preliminary screening, three systems A, B, and C, were selected and requested to provide detailed proposals for further consideration. Meanwhile, intensive interviews and working meetings were scheduled with each vendor. Further, core business workflows and special requirements of the company were assessed by running demo scenarios and examining the capacity of each system to fulfill these key demands. Finally, user representatives conducted unit tests related to system feasibility.

4.5. Evaluate the alternatives using AHP and select a suitable ERP system

Following the AHP methodology, paired comparisons of the alternatives on each attribute and

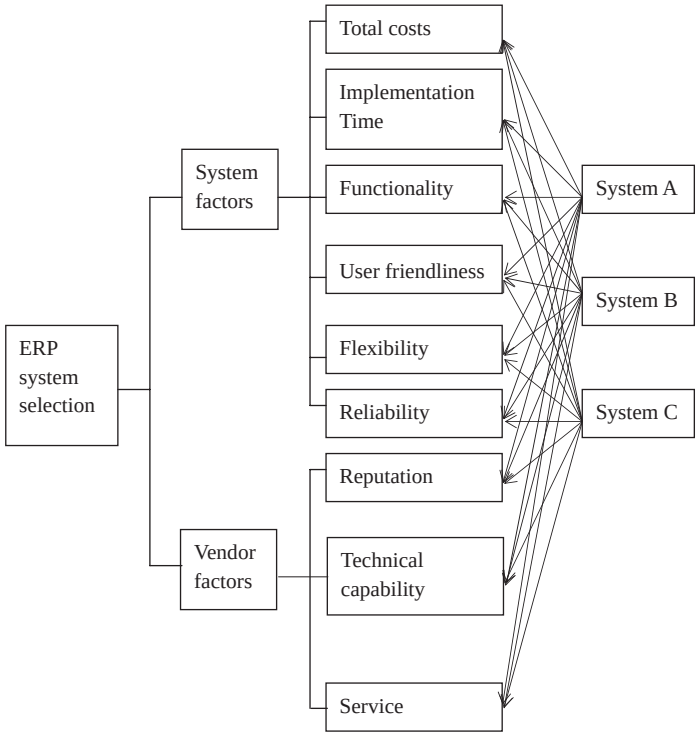

Fig. 5. AHP hierarchy.

Table 1
Attribute details

	Attributes	Evaluation items	Means
System software factors	Total costs	1. Price 2. Maintenance costs 3. Consultant expenses 4. Infrastructure costs	1. Limited project budget 2. Limited annual maintenance budget 3. Limited infrastructure budget
	Implementation time		1. 6–9 months 2. Project management ability
	Functionality	1. Module completion 2. Function fitness 3. Security	1. Availability of necessary modules 2. Parameter setting 3. High function-fitness 4. Multi-currency, multi-language, and multi-site 5. Permission management 6. Database protection
	User friendliness	1. Ease of operation 2. Ease of learning	1. Graphic interface 2. Step-by-step command 3. Provision of a guidebook 4. Online learning 5. Online help
	Flexibility	1. Upgrade ability 2. Ease of integration 3. Ease of in-house development	1. Common programming language 2. Platform independence 3. Ease of integration with other IS
	Reliability	1. Stability 2. Recovery ability	1. Automatic data recovery 2. Automatic data backup
Vendor factors	Reputation	1. Scale of vendor 2. Financial condition 3. Market share	1. Scale matching 2. Financial stability 3. Long-term financial viability 4. Provision of reference sites
	Technical capability	1. R&D ability 2. Technical support capability 3. Implementation ability	1. Good upgrade service 2. Diverse product line 3. Good implementation experience 4. Ease of implementation 5. Adequate number of engineers 6. Cooperation with other partners 7. Domain knowledge
	Service	1. Warranties 2. Consultant service 3. Training service 4. Service speed	1. Warranty details 2. Adequate number of experienced consultants 3. Complete training lessons 4. Good problem-solving program 5. Online service

the inter-attribute relative importance were made and converted to a numerical scale of 1–9. The software Expert Choice was then used to determine the normalized weights and synthesize the results. Table 3 lists the inter-attribute paired comparison matrices of decision maker 1 for system software and vendor attributes. The relative weights of each attribute for all decision

Table 2
Examples of screening questions

Items	Questions
Cost vs. budget	1. What are the total costs of the project? 2. If a discrepancy exists between cost and budget then is it acceptable?
Complexity	1. Is the ERP system too complex, too simple or just right? 2. Does it fit our requirements or is it overqualified?
Requirement coverage	1. Do the system and modules meet all our requirements?
Flexibility	1. Is the technology flexible and long lasting?
Fundamentals	1. What database and hardware can support the system?
Information technology	1. Does the vendor provide other information systems, such as, Supply Chain Management (SCM), Manufacturing Execution System (MES), Data Warehousing (DW), Customer Relationship Management (CRM), and Electronic Commerce (EC)? 2. Is the system integrated with those of other partners?
Vendor size	1. Does the size of the vendor match that of our company? 2. Is the vendor too big to pay attention to us? Or is the vendor too small to survive and provide consistent service?
Domain knowledge	1. What are the target domain and market of the provider? 2. Do they correspond with the company's needs of the purchasing company?
Implementation methodology	1. What is the implementation methodology? 2. Is it feasible and simple?
Maintain service	1. Who supports upgrades and maintenance? The software supplier or the reseller? 2. Does the vendor have any local service point or branch company?
Consultant service	1. Does the vendor provide consulting services? 2. Does the vendor co-operate with other consultant companies?
Financial considerations	1. What was the financial performance of the vendor in the past 2 years? 2. What are its current financial forecasts? 3. Does the vendor have any venture capital investors or show any signs of potential financial crisis? For example, is this vendor deep in debt? Is this vendor a candidate for takeover by another? Has its income substantially dropped in a short time?

makers are listed in Table 4. Table 5 presents the evaluation results of all decision makers, and the last column of this table indicates the overall priority of the three ERP systems using the geometric mean method. As shown in Table 5, system A was the best choice for the company.

Throughout the evaluation process, the consistency index (CI) and consistency ratio (CR) of each decision maker's paired comparison matrix should be less than the threshold value 0.1 (Saaty, 1980) to ensure that the decision maker was consistent in assigning paired comparisons. Otherwise the decision maker may need to reconsider his evaluation.

According to Table 4, the decision makers were fairly consistent in ranking the attributes. The functionality of the ERP system was ranked first among system factors, followed by system flexibility, implementation time, total cost, user-friendliness, and system reliability. As for vendor

Table 3
Paired comparison judgment matrices (decision maker 1)

	Total costs	Implementation time	Functionality	User-friendliness	Flexibility	Reliability
Total costs	1	1/3	1/3	1	1/5	4
Implementation time	3	1	1/4	3	1/3	6
Functionality	3	4	1	7	3	9
User-friendliness	1	1/3	1/7	1	1/5	3
Flexibility	5	3	1/3	5	1	7
Reliability	1/4	1/6	1/9	1/3	1/7	1

	Reputation	Technical ability	Service
Reputation	1	1/7	1/5
Technical capability	7	1	3
Service	5	1/3	1

Table 4
Relative weights of attributes

	Attributes	DM 1	DM 2	DM 3
System factors	Total costs	0.063 (4)	0.170 (3)	0.119 (4)
	Implementation time	0.138 (3)	0.170 (3)	0.128 (3)
	Functionality	0.457 (1)	0.351 (1)	0.420 (1)
	User-friendliness	0.058 (5)	0.057 (5)	0.048 (5)
	Flexibility	0.257 (2)	0.208 (2)	0.247 (2)
	Reliability	0.028 (6)	0.042 (6)	0.039 (6)
Vendor factors	Reputation	0.072 (3)	0.094 (3)	0.072 (3)
	Technical capability	0.649 (1)	0.627 (1)	0.649 (1)
	Service	0.279 (2)	0.280 (2)	0.279 (2)

Table 5
Results of AHP analysis

Alternatives	DM 1	DM 2	DM 3	Geometric mean
System A	0.429 (1)	0.378 (2)	0.449 (1)	0.410 (1)
System B	0.349 (2)	0.381 (1)	0.360 (2)	0.356 (2)
System C	0.224 (3)	0.242 (3)	0.191 (3)	0.210 (3)

selection, all decision makers agreed that technical ability of the vendor was the most important factor. Vendor service ability and reputation followed as the second and third most important consideration.

As shown in Table 5, decision makers 1 and 3 preferred System A while decision maker 2 preferred System B. However, the difference in the preference of decision maker 2 for Systems A and B was minimal. The project team thus achieved sufficient agreement to choose System A for implementation.

5. Discussion

To avoid being constrained by the existing structure of objectives, the project team should ask the questions and discuss the answers in any order during constructing the fundamental-objective hierarchy and means-objective network (Clemen, 1996). It is important to refine the structure of objectives iteratively to ensure that the decision situation has been examined fully and different perspectives have been considered. As shown in Fig. 1, during each round of discussion, the team was given an opportunity to review and

revise the hierarchy of fundamental-objectives and the network of means-objectives to reach a consensus on ERP system selection.

The precision with which decision makers could provide a paired comparison was limited by their knowledge, experience, and even cognitive biases, as well as by the complexity of the ERP system selection problem (Chien et al., 2002). Thus, to avoid inconsistency among semantic descriptions and score assignments to the attributes, we trained the decision makers to understand the details, strengths, and limitations of the AHP method. During the development process, consistency checks were conducted and the decision makers in some cases were asked to provide reasons and detailed explications to justify and refine their assessments.

In practice, it seems to be time consuming to establish an objective framework in the first place. Very often, people rush into the stage of comparing available alternatives and conducting the system demonstrations and tests before they identify the right problem through needs assessment and objective construction. However, people involved in the project team agreed that the entire process enabled detailed review of this important project and facilitated the clarification of problems to reach consensus in group decision process. Therefore, the decision quality was increased while actually saving a lot of time in possibly revising the decisions and projects. In this case, it took about 2 weeks in total to construct and refine the objective structure.

6. Conclusion

This study presents a comprehensive framework for selecting a suitable ERP system based on an AHP-based decision analysis process. The proposed procedure allows a company to identify the elements of ERP system selection and formulate the fundamental-objective hierarchy and means-objective network. The pertinent attributes for evaluating a variety of ERP systems and vendors can be derived according to the structure of objectives.

The proposed comprehensive ERP system selection framework has the following advantages:

(1) It ensures that the structure of objectives is consistent with corporate goals and strategies. The project team can understand the relationships among different objectives and assess their influence by modeling them to the hierarchical and network structures.
(2) The project team can decompose the complex ERP selection problem into simpler and more logical judgments of the attributes. Particularly, knowledge of structure of objectives can help the project team to identify the company requirements and develop appropriate system specifications. These objectives also indicate how outcomes should be measured and what key points should be considered in the decision process.
(3) The approach is flexible enough to incorporate extra attributes or decision makers in the evaluation. Notably, the proposed framework can accelerate the reaching of consensus among multiple decision makers.
(4) The approach systematically assesses corporate attributes and guidance based on the company goals and strategic development. It can not only reduce costs during the selection phase, but also mitigate the resistance and invisible costs in the implementation stage.

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