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System Selection and Performance Evaluation for Manufacturing Company's ERP Adoption

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Abstract: Enterprise Resource Planning (ERP) system is an important investment for manufacturing companies that can affect their competitive advantages and operational performance. However, the implementation of ERP can be a complicated process, where many strategic decisions have to be made. We focus on two critical decisions in ERP implementation: (1) ERP system selection, and (2) ERP operational performance evaluation. For the former, we use Analytic Hierarchy Process (AHP) to design the key performance indicator (KPI) system. For the later, we combine AHP and Fuzzy Integrated Evaluation (FIE) methods to effectively evaluate the implementation of ERP. We use a typical industrial example and data analysis to illustrate our framework.
Keywords: ERP system selection, ERP performance evaluation, analytic hierarchy process, fuzzy integrated evaluation, manufacturing companies.

1 Introduction

Nowadays, severe market competition has dramatically transformed the business environment. For manufacturing companies, whose competitive advantages are mainly low cost operations and quick-response management, the implementation of information systems becomes critical. It is widely accepted that Enterprise Resource Planning (ERP) has the ability to integrate the flow of material, finance, and information and to support organizational strategies [10]. However, the implementation of ERP system can be a highly complicated process, especially for those contract manufacturing companies who have multiple businesses such as self-branded business, manufacturing business, and design business [4]. According to an independent research report [3], in 2014, 42% of the surveyed companies consider their ERP projects as a "neutral", or "not clear" , or "failed" project.

An important reason for the failure of ERP system implementation is that the ERP systems on the market do not fit the company's operations properties. For the successful implementation of ERP system, the adjustment of business process, the selection of suitable ERP system and IT tools, and the effective performance evaluation are the most critical decisions [15], [8], although all of them are hard to make. Being aware of these, managers in the manufacturing industry turn to consulting companies (e.g., IBM and Accenture) to find ERP solutions.

Meanwhile, many IT service companies identify this demand and build online service platform to help manufacturing companies to implement ERP systems. For example, TECTEC (http://www.technologyevaluation.com) proposes a ERP selection and assessment approach for its customers, and this approach is proven to be effective in their application cases for manufacturing companies that produce pharmaceutical and botanical products, industrial machinery products, and electronics and high-tech products [9], [10].

Recently, we have consulting interactions with a multinational manufacturing company which is Austria-headquartered. They turned to us for suggestions to implement ERP system to manage their supply chain. We conducted surveys and found that the standard approach proposed by TECTEC need be detailed. Thus we develop a framework to help the company to select the ERP system based on analytic hierarchy process (AHP) and use fuzzy integrated evaluation (FIE) method to measure the performance of their ERP implementation. Our work is summarized in this paper. All the data that is used to illustrate our framework comes from this consulting project. We combine the objectives of choosing the most appropriate ERP system and vendor with different criteria. We also compare the alternatives based on evaluators' opinions and identify the most appropriate ERP system.

2 Literature

Selecting the suitable ERP system for enterprise can help avoid the failure of ERP system implementation, so it is important to select the appropriate ERP system. There are several common methods to choose appropriate ERP system or the other management information system ([10], [15], [8]). The scoring method is one of the most popular methods, which is simple and intuitive, but does not guarantee the feasibility of resources. For example, [12] uses 10 criteria to evaluate the ERP system and develop a framework based on nominal group technique (NGT) and analytic hierarchy process (AHP) to select the ERP system. Some other methods are developed to improve the efficiency of ERP system implementation procedures, for example, [13], [14], and [4]. In practice, many companies use some financial indicators to select ERP systems. Since financial indicators are reported by professional institutions, they can be viewed as a trustable data resource, and can be used to index the implementers of ERP system [7]. Useful information includes the market size, the vendors and the overall system performance, etc.

Industry and academia also pay attention to the evaluation of ERP system. Companies want to use timely, accurate and objective performance evaluation to continuously adjust and improve the ERP project. Academia also try to identify the factors affecting the performance of ERP system through empirical study, and then construct the evaluation system to evaluate the performance of ERP system implementation ([5], [15]). [13] points out that it takes companies a long time to see the effect of ERP system on the performance. As a result, in the study on the comparison of performance between companies adopting ERP system and companies without ERP system, researchers couldn't find a significant difference [5]. When the time window is large enough that can eliminate this effect, there is a significant difference on the performance between companies using ERP system and companies without it [15].

3 Selection of ERP system

3.1 The criteria for selection

Before we discuss the criteria for selection of ERP system, determining the strategic objectives of ERP project is very necessary. Strategic objectives guide the team and indirectly coordinate

the interests of different departments inside the company.

The implementation of the ERP system including software and vendors. The quality of the system itself decides the influence of ERP system to the company. ERP vendors are responsible for ERP system development, implementation and maintenance services. Without vendors, the companies is unable to successfully implement ERP project. These two aspects are essential to the success of an ERP project. Therefore, we defined two objectives: Selecting the most appropriate ERP system and selecting the most appropriate ERP system vendor.

After determining the strategic objectives, we need to find the specific attributes of criteria according to two objectives. The following will discuss the attributes of criteria for ERP system selection and ERP system vendor selection.

ERP system

Most of the enterprisers have gradually understood the benefits from ERP system. According to the report of Panorama in 2014 [11], the most popular reason enterprisers implement ERP project is to improve the business (15%). The reason followed by is to better integrate the cross-regional and cross-department system (14%), and to get better service to customers (12%).

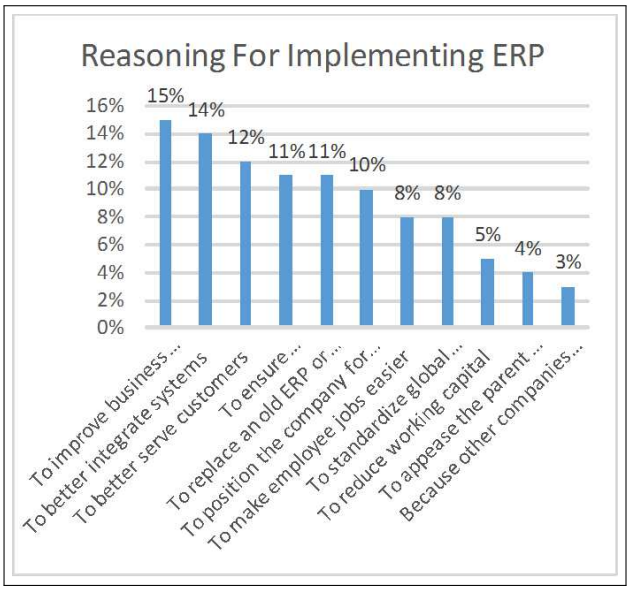

Figure 1: Reasoning for implementing ERP

We can analyze the attributes of criteria to select ERP system from the reasons for implementing ERP system:

Corresponding to the reason to improve business performance, ERP system should have complete functionality and help improve the company's performance by integrate business process through the complete module and fit function. Meanwhile, user-friendly interface and operations can help the internal and external personnel operate and understand the system, which can also help improve the operation efficiency and improve business performance.

Corresponding to the reason to better integrate the cross-regional and cross-department system, ERP system should have excellent system flexibility, providing the ease of in-house development and the ease of integration. The compatibility is particularly important to integrating the cross-regional and cross-department system.

Corresponding to better customer service, ERP system should have high system reliability, high system stability. Recovery ability can help avoid the loss of customers in the face of mistakes.

At the same time, long-term maintenance can also improve customers' satisfaction.

In addition, the total cost of the ERP system implementation is a factor that company must take into consideration. The total cost including system purchase price, consultant cost expenses, system maintenance cost and infrastructure cost. According to the report of Panorama in 2014, it shows that more than 54% of project will exceed the budget for unexpected technical or organizational issues. Considering a long-time implementation of ERP system, the implementation time is also an important attributes. According to the report of Panorama, 63% of the ERP system implementation will take more time than expected.

ERP vendor

According to the report of Panorama in 2014 [11], among the global famous vendors of ERP system, Oracle (34%) is the most popular, followed by Microsoft Dynamics (20%) and SAP (16%). Companies will pay great attention on the reputation of ERP system vendors. The financial condition, scale of vendor and market share will be taken into consideration.

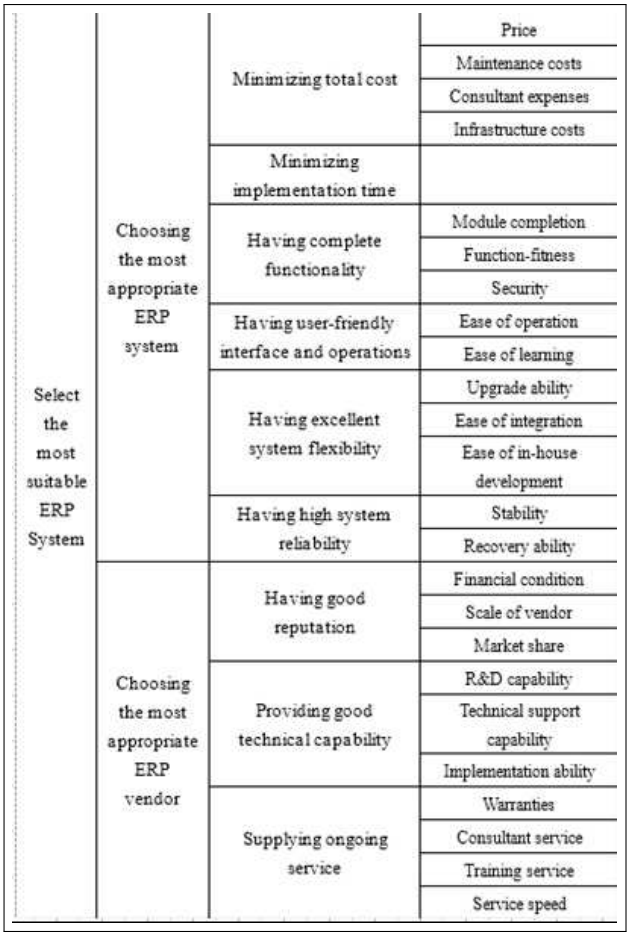

Figure 2: Factors to help select ERP systems

In addition, the service that vendors provide matters a lot to the companies. In the service that vendors provide, the implementation of ERP is the most common (21%), followed by related training (19%), organizational change management (14%), software selection (11%).The service is very important because the vendors have professional knowledge and the development and maintenance of system largely depends on the vendors. With the service of vendors, the

companies can integrate internal resources and external knowledge and play an important role on the development, implementation and maintenance of ERP system project. Therefore, in order to choose suitable system vendors, companies need to consider the vendors' technical capability, including R&D capability, technical support capability and implementation ability; Also, ongoing service needs considering, which includes warranties, consultant service, training service and service speed.

Based on the attributes of criteria above for the objective of ERP system and ERP system vendor, we sums up the attributes affecting the selection of ERP system:

Choosing the most appropriate ERP system: minimizing total cost (price, maintenance costs, consultant expenses, infrastructure costs), minimizing implementation time, having complete functionality (module completion, function-fitness, security), having user-friendly interface and operations (ease of operation, ease of learning), having excellent system flexibility (upgrade ability, ease of integration, ease of in-house development), having high system reliability(stability, recovery ability).

Choosing the most appropriate ERP vendor: having good reputation (financial condition, scale of vendor, market share), providing good technical capability (R&D capability, technical support capability, implementation ability), and supplying ongoing service (warranties, consultant service, and training service, service speed).

3.2 AHP-based approach to select ERP system

Introduction of AHP

Analytic Hierarchy Process (AHP) was developed by Thomas Saaty in 1971, mainly used in decision-making problems with uncertain circumstances and many criteria [16]. The main property of AHP is that it can turn qualitative problem quantitative. It gives a quantitative importance of each level and uses mathematical method to determine the weights of all elements [5]. Basic steps are as follows:

(a) *Determine the objectives and criteria* P attributes $u = \{u_1, u_2, ...u_p\}$,

(b) *Pairwise comparison and judgment matrix* The pairwise comparison show the importance of one attributes to another. This subjective judgment can be convert to a numerical value using a scale of 1-9. We can draw the judgment matrix from pairwise comparison.

(c) *Weights calculation and aggregation* Calculate the greatest characteristic root and characteristic vector of the judgment matrix S. The characteristic vector is the importance of each evaluation attributes or alternatives and also is the distribution of weight coefficient.

(d) *Check the consistency.* We need to check the consistency of the judgment matrix with $CI = \frac{\lambda_{max}-n}{n-1}$. If the consistency index CI of judgment matrix is less than 0.10, we believe the results of the analytic hierarchy sort have satisfactory consistency and the weights is reasonable; Otherwise, the pairwise comparison matrix need to adjust and redistribute the weights.

An example of company A

Company A is a large multinational manufacturing corporation. Company A has its own production workshop and assembly workshop in mainland China. Its product is involved in seven industries and there are thousands of different types of products. After ten years of development, Company A has rapidly expanded business and grown fast. The staff team has

grown from dozens to more than 1500 and the annual sales expand to millions of dollars from only six hundred million.

With the growing of business, the difficulty of company's management is also appearing, which makes the implement of ERP system become necessary.

Within the company, the sales department is only responsible for the order fulfillment. The lack of a standard process makes the sales department low-efficient. Besides, there is contradiction between purchasing department and project department. Project department, as the service department of the purchasing groups, makes the final decision in the procurement process. The purchasing department can only give suggestions and fulfill the order. This mismatching between right and duty during the procurement process in two departments induces many conflicts. Besides, the financial department uses an independent financial system which only manages the cash flow in that department but not the whole company.

Outside the company, purchasing department does not collaborate well with the suppliers. Most of the suppliers are small and medium-sized companies and the information construction remains to be improved.

The company cannot timely access to the useful information and the low standardization level of business operation process brings lots of troubles to company A. ERP system may help company A to integrate the departments and manage the information within and outside the company.

The leaders of company A are thinking whether they should purchase the professional ERP system and form a project team. They have already selected three ERP systems from different vendors, denoted as system 1, system 2, system 3.

The required function for ERP system of different industries has a huge difference. Therefore, enterprisers need to know its industry characteristics and function requirements, when choosing the appropriate ERP system. In addition, the enterpriser need consider the scale of company.

We ask three leaders as evaluators for a questionnaire survey and propose ERP system selection framework as follows.

a) Identify the ERP system characteristics For the ERP system selection, we collect the opinions through the purchasing department, project department, finance department, human resources department and marketing department. It is decided that the system selection is considered from two aspects: One is the ERP system itself; the other is the ERP system vendor.

b) Organize the hierarchy structure of Objectives, Criteria, and Alternatives. Objectives are the target of the problem. Criteria is to extract the attributes for evaluating ERP systems. Alternatives are the feasible solutions of the problem. In the case of company A, there are two Objectives with different Criteria. The first objective is screening out the most appropriate ERP system. There are six attributes for evaluating the ERP system, including minimizing total cost (C1), minimizing implementation time (C2), having complete functionality (C3), having user-friendly interface and operations (C4), having excellent system flexibility (C5), having high system reliability(C6). There are three alternatives, called as system 1,system 2 and system 3.

The second objective is choosing the most appropriate ERP vendor. There are three attributes for evaluating the ERP vendor, including having good reputation (D1), providing good technical capability (D2), supplying ongoing service (D3). The alternatives are same, called as system 1, system 2 and system3.

c) The comparison of attributes among Criteria (for example)

C1:Minimizing total cost; C2:Minimizing implementation time.

If the ratio is 3:1, the evaluator think that minimizing total cost is more important than minimizing the implementation time. The importance degree of former is 3 compared to the later. If the ratio is 1:5, the evaluator think that minimizing the implementation time is more important. Its importance degree is 5 compared to minimizing total cost.

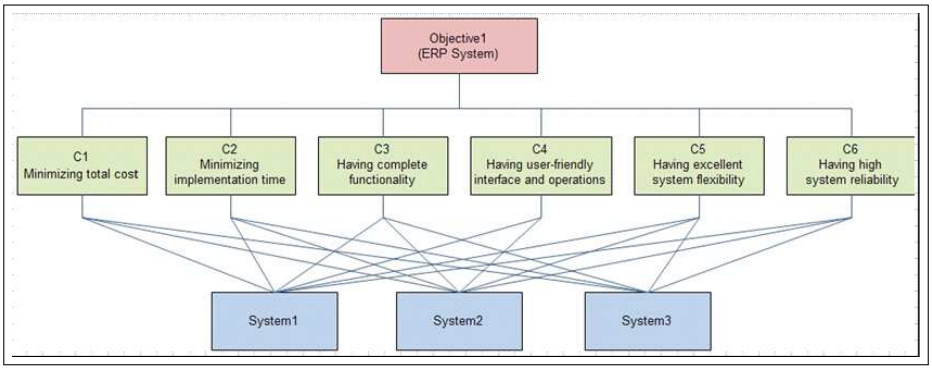

Figure 3: AHP-based ERP system selection framework

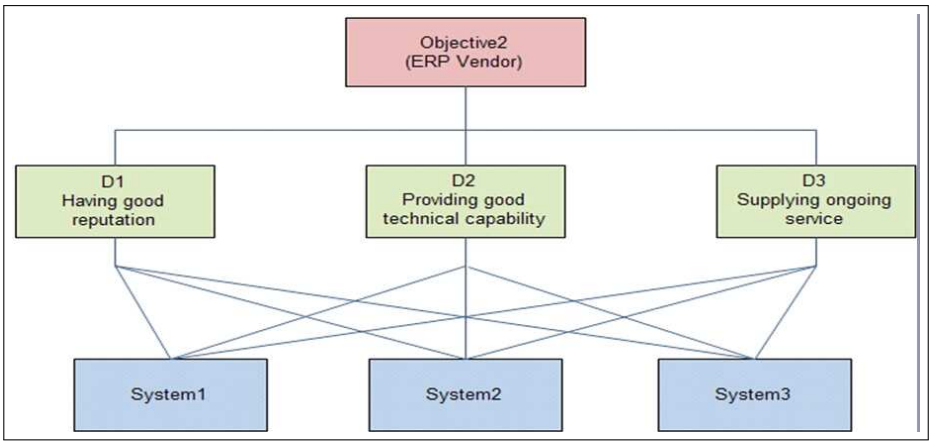

Figure 4: AHP-based ERP vendor selection framework

Table 1: Criteria questionnaire

	9:1	8:1	7:1	6:1	5:1	4:1	3:1	2:1	1:1	1:2	1:3	1:4	1:5	1:6	1:7	1:8	1:9	
C1																		C2

Table 2: Alternatives questionnaire

	9:1	8:1	7:1	6:1	5:1	4:1	3:1	2:1	1:1	1:2	1:3	1:4	1:5	1:6	1:7	1:8	1:9	
S1																		S2

Table 3: Judgment matrix of attributes for ERP system

Evaluator 1	C1	C2	C3	C4	C5	C6	Wi(weight)
C1 Minimizing total cost	1	1/3	1/3	1	1/3	3	0.0766
C2 Minimizing implementation time	3	1	1/4	3	1/3	5	0.1500
C3 Having complete functionality	3	4	1	5	3	7	0.3954
C4 Having user-friendly interface and operations	1	1/3	1/5	1	1/5	5	0.0766
C5 Having excellent system flexibility	3	3	1/3	5	1	5	0.2690
C6 Having high system reliability	1/3	1/3	1/7	1/5	1/5	1	0.3240
λ_{max}: 65.222; Consistency: 0.0829							

The comparison of alternatives: Known from the AHP selection framework, each attributes correspond three alternatives which need to take account of the project, so decision-makers need to compare the alternatives for each attributes.

d) Select ERP system We can obtain the corresponding judgment matrix through the pairwise comparison after we collect the questionnaire of the evaluators. We need to check the consistency of the judgment matrix with $CI = \frac{\lambda_{max}-n}{n-1}$. We find that the consistency index CI of judgment matrix is all less than 0.10.The following only show the judgment matrix for ERP system and each alternative of evaluator 1.

Comparing the importance of attributes to each evaluator, we can find that three evaluators tend to share the same opinion:

For the attributes of ERP system, “having complete functionality " is considered as a very important attributes for three evaluators, of which the relative weight comes to be the 1st for evaluator 1 and evaluator 2, 2nd for evaluator 3. “having excellent system flexibility " is also of great importance, respectively to be the 2nd,2nd and 1st for evaluator1, 2 and 3. While, “having high system reliability "is considered as the least important attribute for all three evaluators.

It is necessary to analyze the result with the situation of company. Company A, a large manufacturing enterpriser, is an integrated supplier providing complete sets of production lines, equipment and services. It has its own production workshop and assembly workshop with complete functional departments. More specifically, the number of project team is large and the organizational structure is loose. There are too many types of equipment and spare parts to procure. There is too much communication between project teams and different functional departments, so are the purchasing department and suppliers of company A. Moreover, the difficulty of purchasing has worsen the information distortion and then deepen the contradictions between project teams and functional departments. Thus, an information system covered multi-department is particularly important, which can reduce the conflicts between different de-

Table 4: Judgment matrix of alternatives for C_1 and importance of attributes

The pairwise comparison of alternatives for C1				
	System 1	System 2	System 3	Wi(weight)
System 1	1	3	5	0.6370
System 2	1/3	1	3	0.2583
System 3	1/5	1/3	1	0.1047
λ_{max}: 3.0385; Consistency: 0.0370				

Table 5: Judgment matrix of alternatives for C_2 and importance of attributes

The pairwise comparison of alternatives for C2				
	System 1	System 2	System 3	Wi(weight)
System 1	1	5	1/3	0.2790
System 2	1/5	1	1/7	0.0719
System 3	3	7	1	0.6491
λ_{max}: 3.0649; Consistency: 0.0624				

Table 6: Judgment matrix of alternatives for C_3 and importance of attributes

The pairwise comparison of alternatives for C3				
	System 1	System 2	System 3	Wi(weight)
System 1	1	7	3	0.6694
System 2	1/7	1	1/3	0.0879
System 3	1/3	3	1	0.2426
λ_{max}: 3.0070; Consistency: 0.0068				

Table 7: Judgment matrix of alternatives for C_4 and importance of attributes

The pairwise comparison of alternatives for C4				
	System 1	System 2	System 3	Wi(weight)
System 1	1	1/3	1/7	0.0879
System 2	3	1	1/3	0.2426
System 3	7	3	1	0.6694
λ_{max}: 3.0070; Consistency: 0.0068				

Table 8: Judgment matrix of alternatives for C_5 and importance of attributes

The pairwise comparison of alternatives for C5				
	System 1	System 2	System 3	Wi(weight)
System 1	1	5	1	0.4806
System 2	1/5	1	1/3	0.1400
System 3	1	3	1	0.4054
λ_{max}: 3.0291; Consistency: 0.0279				

Table 9: Judgment matrix of alternatives for C_6 and importance of attributes

The pairwise comparison of alternatives for C6				
	System 1	System 2	System 3	Wi(weight)
System 1	1	1	1/5	0.1336
System 2	1	1	1/7	0.1194
System 3	5	7	1	0.7471
λ_{max}: 3.0126; Consistency: 0.0121				

Table 10: Judgment of importance of attributes

	Attributes	Evaluator 1	Evaluator 2	Evaluator 3
ERP System	minimizing total cost	0.0766(4)	0.1500(3)	0.0378(5)
	minimizing implementation time	0.1500(3)	0.1500(3)	0.1790(3)
	having complete functionality	0.3954(1)	0.3910(1)	0.3356(2)
	having user-friendly interface and operations	0.0766(4)	0.0565(5)	0.0566(4)
	having excellent system flexibility	0.2690(2)	0.2085(2)	0.3710(1)
	having high system reliability	0.0324(6)	0.0420(6)	0.0200(6)
ERP Vendor	having good reputation	0.0719(3)	0.0554(3)	0.0995(3)
	providing good technical capability	0.2790(2)	0.5990(1)	0.3355(2)
	supplying ongoing service	0.6491(1)	0.3456(2)	0.5650(1)

partments and project teams by sharing the information effectively. To sum up, we can find the great importance of “having complete functionality".

At the same time, company A is a foreign multinational enterprisers. It has different branches in 44 countries around the world and five business areas. There are many different brands and products in each business area. While in the implementation of procurement, the boundaries between different departments is clear and they independently do different works in the business. There is no communication and no collaboration which generates a lot of repetitive work and additional costs such as assessment, repeated negotiation, travel cost, quality control cost and so on. It is necessary for company A share information and resources cross areas and departments, so the system flexibility is very valued.

For the attributes of ERP vendor, “providing good technical capability" and “supplying on-going service" are of great importance while “having good reputation" is not considered as an important attribute.

“Providing good technical capability" includes R&D capability, technical support capability and implementation ability. Besides the initial system development, maintenance and upgrade stage of ERP project also need excellent technical support. In the adjustment stage, ERP system need continuous operation maintenance, and even need a new version or new functions. The system’s maintenance and upgrade require a long-term technical support.

“Supplying on-going service" includes the most basic warranty service, consultant service and training services. The users’ feedback is an important criterion to see whether ERP system is running smoothly. It is necessary that users approve and understand the system. The implementation of ERP project requires users to master the complicated operation skills. If the employee do not understand how the system works, it will ultimately affect the entire ERP system. The success of ERP system must be based on reasonable operation.

In the ERP system implementation of company A, training objects include the suppliers of A company besides the employees. There are more than 500 suppliers and quite of them are small and medium-sized companies, which adopt the traditional manufacturing management mode and are lack advanced management philosophy. The information cannot be inputted and processed timely and the information management system is incomplete and imperfect. To help the suppliers to adapt the ERP system is necessary and challenging. Therefore, ongoing training service is valued.

After three evaluators give a weight to all attributes, we can get the evaluation score of three ERP systems through the two judgment matrix (including criteria judgment matrix and alternative judgment matrix). Considering that we develop two objectives (ERP system and ERP vendor), we give equal weights to them. Finally we get the evaluation score of three ERP systems. Following is the result of evaluator 1:

Table 11: Evaluation score of ERP systems (1)

Evaluator 1	ERP system	ERP vendor	final score
System 1	0.4957	0.3129	0.4043
System 2	0.1185	0.323	0.22075
System 3	0.3858	0.3641	0.37495
(1) Equal weights to ERP system and ERP vendor			

Table 12: Evaluation score of ERP systems (2)

	Evaluator 1	Evaluator 2	Evaluator 3	final score
System 1	0.40430(1)	0.37155(2)	0.27362(2)	0.34982(2)
System 2	0.22075(3)	0.18145(3)	0.23123(3)	0.21114(3)
System 3	0.37495(2)	0.44700(1)	0.49515(1)	0.43904(1)
(2) Equal weights to each evaluator				

e) Get the final result. Evaluator 2 and evaluator 3 prefer to choose system 3 while evaluator 1 prefers to choose system 1. We can find that the score of evaluator 1 to system 1 and system 3 is close. Moreover, system 3 gets the highest final score. The result show that system 3 is the most appropriate ERP system for company A.

4 Evaluation of ERP system

Company A started to promote the ERP project after selecting the appropriate ERP system. In order to implement ERP project successfully, company A set up a team to take charge of the entire implement. In the preparatory stage, company A focused on the training and helped employee understand the ERP system. Then, company A started to research and analyze, even the specific operation of each departments, in order to adapt the ERP system to match the company.

After this, company A formally set up ERP system. They built a complete system framework taking full consideration of opinions from each departments and vendors. Company A fully combined the original function with the business process. In addition, ERP project team also optimized the mismatch between ERP system and company's business. Next is to import massive data. Company A successfully imported the internal and external data before changing the system and checked the accuracy of data. In November 2013, company A officially started using ERP system. After cautious consideration and selection, the new system still bring impact to the company on business. With time goes by, employees have been familiar with ERP system and it has run methodically.

Reviewing the ERP project of company A, it went well during the implementation, but we need to see whether it brings significant benefits to company A. The evaluation of implementation of ERP system is of great importance, which involved the influence on company's strategy, the impact on performance of management and the business process. The following will show the evaluation for the performance of the ERP system implementation.

4.1 The framework of evaluation

The success of ERP project is far more than that system goes live. How to judge or define the success of ERP project is also different for different companies or different industries. According

to company A's business and structure, we listened the opinion of managers and sort out the following performance evaluation structure.

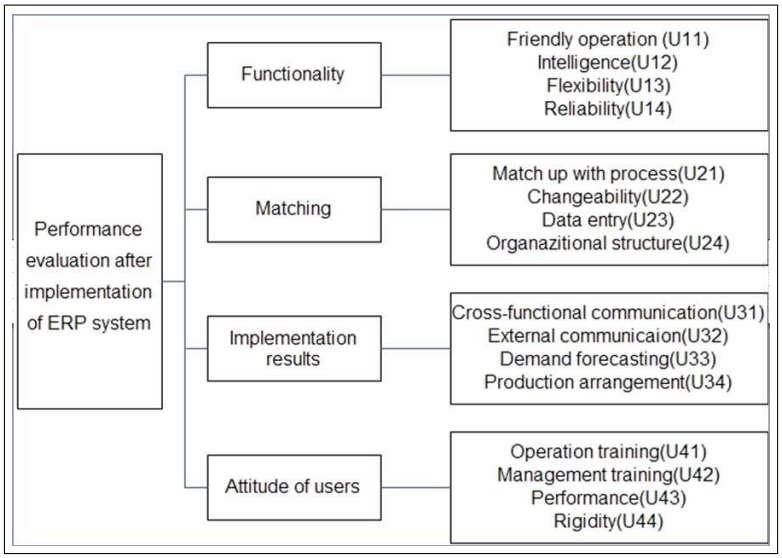

Figure 5: Structure of performance evaluation

The description of each factors in the structure of evaluation above is as follows. It's worth mentioning that "functionality" and "implementation result" are positive statements, "matching" and "attitude of users" is reverse. This is to reduce the respondents' deflection and is also helpful to remove those regardless of content. As a result, we need to adjust correspondingly when scoring. In the following results, "average score" is not adjusted and the "real score" is adjusted.

Functionality: ERP system has user-friendly interface and operations; ERP system has high intelligence; ERP system has excellent flexibility and compatibility; ERP system has high reliability.

Matching: ERP system does not match the company's operation process; ERP system does not adapt to the mismatch; The data entry and processing of ERP system does not match with the original model; ERP System does not match company's organizational structure and strategy.

Implementation results: ERP system helps improve the efficiency and communication cross-department; ERP system promotes the collaboration with suppliers; ERP system help the company with demand forecasting and capacity management; ERP system help the company improve the quality of the products and arrange the production reasonably.

Attitude of users: The users of ERP system do not get the corresponding training and do not understand ERP system; The management does not know the implementation of ERP system implementation and give no support to it; The users of ERP system think that it does not improve the performance. The performance get even worse than before; ERP system lacks flexibility and makes the company lose advantages.

4.2 The analysis based on FIE

30 questionnaires were distributed within the company, we recycled 30 questionnaires and the 23 of them were valid. The results are as follows:

From the data we can see that the mean of real average score is 3.3894 and the total real score is 54.2308, higher than the total real average score 48, under normal distribution assumption. If

Table 13: Evaluation score

		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Average score	Real score	Standard deviation
Functionality	1	0.0000	0.0769	0.2308	0.6923	0.0000	3.6154	3.6154	0.62
	2	0.0000	0.3846	0.3077	0.3077	0.0000	2.9231	2.9231	0.83
	3	0.0000	0.3077	0.4615	0.2308	0.0000	2.9231	2.9231	0.73
	4	0.0000	0.0769	0.3846	0.4615	0.0769	3.5385	3.5385	0.75
Matching	5	0.0000	0.3077	0.5385	0.1538	0.0000	2.8462	3.1538	0.73
	6	0.0000	0.5385	0.3846	0.0769	0.0000	2.5385	3.4615	1.12
	7	0.0000	0.3846	0.3077	0.3077	0.0000	2.9231	3.0769	0.84
	8	0.1538	0.3846	0.3077	0.1538	0.0000	2.4615	3.5385	1.42
Implementation result	9	0.0000	0.2308	0.3077	0.4615	0.0000	3.2308	3.2308	0.80
	10	0.0000	0.0000	0.3077	0.6154	0.0769	3.7692	3.7692	0.58
	11	0.0000	0.1538	0.3846	0.4615	0.0000	3.3077	3.3077	0.72
	12	0.0000	0.0769	0.0769	0.7692	0.0769	3.8462	3.8462	0.66
Attitude of users	13	0.0769	0.4615	0.4615	0.0000	0.0000	2.3846	3.6154	1.38
	14	0.2308	0.3846	0.3846	0.1538	0.0000	2.7692	3.2308	1.26
	15	0.2308	0.5385	0.1538	0.0769	0.0000	2.0769	3.9231	2.02
	16	0.0000	0.3077	0.4615	0.2308	0.0000	2.9231	3.0769	0.75
							Total	54.2308	

only judging from this data, we can say that company A thinks the ERP project help improve the performance.

There are some shortcomings in the classical statistical analysis. It cannot show the overall attitude intuitively and cannot directly show the proportion of different order of evaluation. Given the order of evaluation in questionnaires is fuzzy, we analyze the data using the fuzzy integrated evaluation (FIE) method. When determining the weights of each sub-factor, we use the AHP method.

FIE

FIE is a method to evaluate after fuzzy transform according to the criteria and measured values. The process of FIE: Assume the evaluation target as a fuzzy set composed of a number of factors; Then set order of evaluation to these factors and make up a fuzzy set; Next calculate the membership degree of each factors to the order of evaluation; And then according to the weights of factors in the evaluation, calculate the quantitative value [18].

The evaluation of ERP implementation of company A

a) The factors set U_t:

$U = \{U_1, U_2, U_3, U_4\}$= {functionality, matching, implementation results, attitude of users}

$U_1 = \{U_{11}, U_{12}, U_{13}, U_{14}\}$= {friendly operation, intelligence, flexibility, reliability}

$U_2 = \{U_{21}, U_{22}, U_{23}, U_{24}\}$= {match up, changeability, data entry, organizational structure}

$U_3 = \{U_{31}, U_{32}, U_{33}, U_{34}\}$= {cross-department communication, external communication, demand forecasting, production arrangement}

$U_4 = \{U_{41}, U_{42}, U_{43}, U_{44}\}$= {operational training, management training ,performance, rigidity}

b) The evaluation set for factors: Evaluation set is a collection of all results of the evaluation by evaluators. V= strongly disagree, disagree, neutral, agree, strongly agree

c) The fuzzy relationship matrix R: According to the questionnaire statistics, we can get the proportion of different order of evaluation .The statistical records are as follows:

Table 14: Factor set U_1

Factor set U_1					
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Friendly operation	0.00%	7.69%	23.08%	69.23%	0.00%
Intelligence	0.00%	38.46%	30.77%	30.77%	0.00%
Flexibility	0.00%	30.77%	46.15%	23.08%	0.00%
Reliability	0.00%	7.69%	38.46%	46.15%	7.69%

Table 15: Fuzzy relationship matrix

$$\mathbf{R_1} = \begin{pmatrix} 0.00\% & 7.69\% & 23.08\% & 69.23\% & 0.00\% \\ 0.00\% & 38.46\% & 30.77\% & 30.77\% & 0.00\% \\ 0.00\% & 30.77\% & 46.15\% & 23.08\% & 0.00\% \\ 0.00\% & 7.69\% & 38.46\% & 46.15\% & 7.69\% \end{pmatrix}$$

$$\mathbf{R_2} = \begin{pmatrix} 0.00\% & 15.38\% & 53.85\% & 30.77\% & 0.00\% \\ 0.00\% & 7.69\% & 38.46\% & 53.85\% & 0.00\% \\ 0.00\% & 30.77\% & 30.77\% & 38.46\% & 0.00\% \\ 0.00\% & 15.38\% & 30.77\% & 38.46\% & 15.38\% \end{pmatrix}$$

$$\mathbf{R_3} = \begin{pmatrix} 0.00\% & 23.08\% & 30.77\% & 46.15\% & 0.00\% \\ 0.00\% & 0.00\% & 30.77\% & 61.54\% & 7.69\% \\ 0.00\% & 15.38\% & 38.46\% & 46.15\% & 0.00\% \\ 0.00\% & 7.69\% & 7.69\% & 76.92\% & 7.69\% \end{pmatrix}$$

$$\mathbf{R_4} = \begin{pmatrix} 0.00\% & 0.00\% & 46.15\% & 46.15\% & 7.69\% \\ 0.00\% & 15.38\% & 38.46\% & 38.46\% & 23.08\% \\ 0.00\% & 7.69\% & 15.38\% & 53.85\% & 23.08\% \\ 0.00\% & 23.08\% & 46.15\% & 30.77\% & 0.00\% \end{pmatrix}$$

We can get the fuzzy relationship matrix R_1 from U_1. Similarly, we can get fuzzy relationship matrix R_2 from U_2. While this subset is disjunctive, we should reverse the arrangement.

d) The weight of each factor: In the evaluation system, the importance of each factor to realize the goal of system is different. The weight of each factor show the different importance. Set the weights reasonably and appropriately is important for evaluation. Here we use AHP to get the weights. The Supervisors of company score the four factors: functionality, matching, implementation results, and attitude of users. We get the following results:

Calculate the greatest characteristic root and characteristic vector of the judgment matrix. The characteristic vector is the importance of each evaluation factors and also is the distribution of weight coefficient. $U = [0.2477, 0.1259, 0.5538, 0.0727]$. Similarly, calculate the weight of each factor under the four dimensions according to the experts' scoring:

Each weight of factors passes the consistency check.

e) Get the evaluation results. $B = U * R$: $B_1 = U_1 * R_1$= (0.0000 0.2299 0.3975 0.3571 0.0154); $B_2 = U_2 * R_2$= (0.0000 0.1679 0.4360 0.3590 0.0370); $B_3 = U_3 * R_3$= (0.0000 0.0927 0.2966 0.5657 0.0451); $B_4 = U_4 * R_4$= (0.0000 0.0799 0.3147 0.4684 0.1618). $D = U * R$= (0

Table 16: Comparison matrix of factors

Comparison matrix of factors					
	U_1	U_2	U_3	U_4	Wi(weight)
U_1 functionality	1	3	1/3	3	0.2477
U_2 matching	1/3	1	1/5	1/3	0.1259
U_3 implementation result	3	3	1	5	0.5538
U_4 attitude of users	1/3	5	1/5	1	0.0727
λ_{max}: 4.1975; Consistency: 0.0740					

Table 17: Comparison matrix of sub-factors in U_1

Comparison matrix of sub-factors in U1					
	U_{11}	U_{12}	U_{13}	U_{14}	Wi(weight)
U_{11} functionality	1	3	1/3	1/2	0.1612
U_{12} matching	1/3	1	1/5	1/3	0.0740
U_{13} implementation result	3	5	1	5	0.5641
U_{14} attitude of users	2	3	1/5	1	0.2006
λ_{max}: 4.2219; Consistency: 0.0831					

Table 18: Comparison matrix of sub-factors in U_2

Comparison matrix of sub-factors in U2					
	U_{21}	U_{22}	U_{23}	U_{24}	Wi(weight)
U_{21} match up	1	5	3	3	0.5244
U_{22} change ability	1/5	1	1/2	1/2	0.0957
U_{23} data entry	1/3	2	1	1/3	0.1390
U_{24} organizational structure	1/3	2	3	1	0.2408
λ_{max}: 4.1575; Consistency: 0.0590					

Table 19: Comparison matrix of sub-factors in U_3

Comparison matrix of sub-factors in U3					
	U_{31}	U_{32}	U_{33}	U_{34}	Wi(weight)
U_{31} cross-department communication	1	1/3	4	3	0.2854
U_{32} external communication	3	1	3	4	0.4944
U_{33} demand forecasting	1/4	1/3	1	2	0.1290
U_{34} production arrangement	1/3	1/4	1/2	1	0.0912
λ_{max}: 4.2367; Consistency: 0.0886					

Table 20: Comparison matrix of sub-factors in U_4

Comparison matrix of sub-factors in U4					
	U_{41}	U_{42}	U_{43}	U_{44}	Wi(weight)
U_{41} operational training	1	3	1/2	3	0.3089
U_{42} management training	1/3	1	1/3	3	0.1612
U_{43} performance	2	3	1	3	0.4369
U_{44} rigidity	1/3	1/3	1/3	1	0.0930
λ_{max}: 4.2148; Consistency: 0.0805					

0.1352 0.3405 0.4810 0.0452).

f) Analyze the results. The results show 1.64% of evaluators strongly disagree that ERP project bring positive effect; 18.75% of them disagree; 34.05% remain neutral; 42.87% agree the positive effects of ERP project and 2.88% strongly agreed with it. According to the maximum membership degree principle, the conclusion is "agree". Multiply the raw score (1-5) in Likert scale by the number of sub-factors, 16. Then we get the level parameters in evaluation set and the column vector is: $p = DE = 016 + 0.135232 + 0.340548 + 0.481064 + 0.045280 = 55.0677$. The result is close to the statistical analysis result, 54.2308. It shows that the result based on FIE is consistent with the result based on classical statistical analysis. Company A recognizes ERP project as a beneficial project.

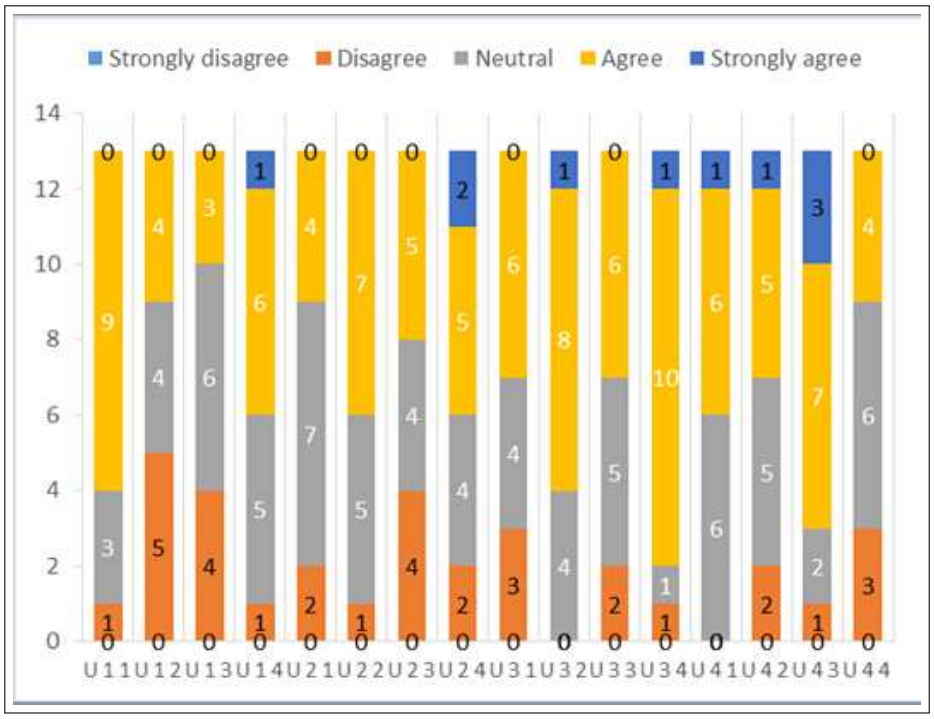

Figure 6: 6 S Assessment scale

We can see the factor “attitude of users" get the highest score (60.5846). Factor “implementation results" follows (57.0085). The other two factors “matching degree "(52.2384) and “functionality" (50.5253) is not ideal, which are lower than the average score (55.0677). This result is meaningful for company A’s management. They should focus on improving the matching degree and the system’s functionality in the future.

Regarding the factor “matching degree", we can see that in most cases, company’s organizational structure and process mismatch the ERP system’s functionality. When there exist mismatches between ERP system and company’s business process, what to do depends on different situations. On the one hand, if the operation of ERP system is inefficient, company can ask the vendors to adjust the system to adopt company. On the other hand, if the ERP system can improve more efficient performance, then company can make appropriate changes on the operation process to adapt to ERP system.

Regarding the factor “functionality", although company A pays much attention to system’s functionality during the selection, we still find that the respondents is not very satisfactory with the functionality. It reflects that there exists difference between the effects after t implementation and expectations. Company A should fully understand the ERP is a long-term project and it is

ongoing to look for problems and put forward the solution. The project team needs to stay close to the ERP vendors and solve the problems together.

5 Conclusions

It is necessary to use the proper process control method during the implementation of a successful ERP system project. This research focuses on the selection and performance evaluation of ERP system.

We study the criteria of the ERP system selection and develop a framework to select ERP system based on AHP method. We combine the objective and criteria, then compare the importance of attributes among criteria and alternatives, which represents the opinion of different evaluators from different departments. Finally, we select the most appropriate ERP system.

The selection based on AHP helps the ERP system match with the strategies of the company. With the help of AHP, we can divide the goal of company into simple ones. This help the goal be put into practice. The selection framework based on AHP could be adjusted according to the development of company and has a high degree of flexibility.

After the selection of ERP system, we study the evaluation of ERP implementation in company A. We combine the Likert scale, AHP and FIE methods, from four dimensions (the system's functionality, the matching degree, implementation results and attitude of users), to evaluate the implementation of ERP project. We find that objective and accurate evaluation of the ERP implementation can help company allocate resources.

We develop an evaluation framework based on FIE and also use AHP to determine the weights, which reducing the subjectivity of evaluation. Regarding the future work, creating a practical decision support software package could serve. This can be valuable for companies facing similar decision-making problems as company A, which we have extensively studied in this paper.

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