An Application of Data Envelopment Analysis (DEA) for ERP System Selection: Case of a Petrochemical Company

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AN APPLICATION OF DATA ENVELOPMENT ANALYSIS (DEA) FOR ERP SYSTEM SELECTION: CASE OF A PETROCHEMICAL COMPANY

Une application la méthode de Data Envelopment Analysis (DEA) pour la sélection des systèmes ERP : Cas d'une société pétrochimique

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Abstract

As a comprehensive software solution, ERP seeks to integrate all departments and functions of a company into a single computer system that can satisfy all departments' information needs. Nowadays, many companies have invested in the implementation of enterprise resource planning (ERP) systems. But, a large number of them have wasted millions of dollars as a consequence of failed ERP implementation and adoption. Some of the failures come back to the selection of inappropriate ERP systems. This paper seeks to propose a method for selecting appropriate ERP systems, to enable firms' decision-makers to achieve an overall consensus by using a multi-criteria decision making model.

Keywords: *Data Envelopment Analysis, Enterprise Resource Planning (ERP), IS evaluation*

Résumé

Actuellement, de nombreuses sociétés ont perdu des millions dollars à cause de difficultés de mise en œuvre de leur ERP. Certains échecs sont attribuables à la sélection de systèmes ERP inopportuns. Cet article vise à proposer un modèle de prise de décisions multicritères pour la sélection de systèmes ERP.

Introduction

In today's dynamic and unpredictable business environment, companies face the increasingly challenge of expanding markets and rising customer expectations. As one of the results of this trend, companies have invested considerable resources in the implementation of enterprise resource planning (ERP) systems. Companies employ ERP systems to focus primarily on improving transaction handling through the standardization of business processes and integration of operations and data (Cooke and Peterson, 1998; Davenport, 2000).

Owing to the complexity of the business environment, the limitations in available resources, and the diversity of ERP alternatives, ERP system selection is a problematic task for CIOs. Also, there is an increasing consensus among

ERP experts that selecting inappropriate software is a major reason for the failure of ERP implementation (Lall and Teyarachakul, 2006). There is a considerable literature related to the selection of ERP; most of these studies address the application of well known mathematical approaches for ERP selection, and some of them carry out contributions on the new initiative and heuristic methods for selecting ERP packages. Also, some consulting companies in business environment have developed suitable practical methods for ERP selection in the real world. The paper research question is:

RQ- How can data envelopment analysis (DEA) be applied in the process of ERP system selection in this particular context (the petrochemical company)?

In this paper, we apply DEA as an approach to evaluate the ERP packages performance. DEA is a mathematical programming technique that uses multiple inputs and outputs to calculate the relative efficiencies of multiple decision making units (DMUs). Through the conversion of multiple evaluating criteria into a single measurement of relative efficiency for each ERP solution, DEA can help firms' managers in order to evaluate usefulness of each ERP system with respect to all other systems under study.

Several papers addressed the fact that DEA evaluation can be used to discover which ERPs can be classified as efficient or inefficient. For instance, Fisher et al. (2004) used DEA analysis to compare the performance of ERP solutions. However, their assessments were based on information provided by ERP providers, this may not reflect organization's requirements. Moreover, Lall and Teyarachakul (2006) conducted a case study in a trading company, but, they simply applied two inputs and two outputs criteria for the evaluation of alternatives while employing more criteria could empower the decision making process and make it more comprehensive. Also, they interviewed only one manager for providing required data. However, in this paper 3 input and 6 output criteria are proposed. Furthermore, we highlight the research by Bernroider and Stix (2006) due to the similar approach, but with notable differences in the characteristics of DEA we have applied.

Given the complexity of ERP systems, selecting a good package involves different implementation issues in different types of ERP under different settings. Thus, this paper suggests that, first of all, ERP selection decisions are more likely to be efficient if they are taken according to the context and by ERP experienced experts in that particular field. Secondly, the proposed DEA based model is not recommended for large enterprises since at that level, the problem becomes more complex and other factors are needed to be taken into account in the decision model. Also, it is worth mentioning that DEA analysis for ERP selection can be done based on performance analysis of either individual modules such as core financials, manufacturing process, and purchasing (Jones, 2002) or overall ERP package (Lall and Teyarachakul, 2006). However, this paper takes the second approach.

The remainder of this paper is structured as follows. Section 2 reviews the prior literature of ERP selection and its criteria. The research methodology is presented in section 3. In section 4, the way in which the research has been conducted and the case application in an Iranian petrochemical company has been discussed, followed by concluding remarks.

ERP system selection methods and criteria

How to successfully implement an ERP system in an organization is always a hot research topic for researchers as well as a pending problem for an organization that wants to implement it (Yang et al. 2007). The evaluation and selection of enterprise software has become increasingly difficult for decision makers due to the large number of software products available for many applications. Therefore, systematic and repeatable methodologies and techniques are becoming significant in order to the product selection that best meets customer's requirements (Gungor Sen and Baracli, 2006). These techniques for ERP systems selection are documented in the literature. Table 1 presents some important ones of these papers. Apart from them, some practical methodologies for ERP selection have been developed and registered in real world. These methodologies have been usually introduced by expert consulting companies in the field of enterprise systems selection.

Table 1. Review of previous ERP selection research	
Author	A brief explanation

Teltumbde (2000)	Proposed a framework based on the Nominal Group Technique and AHP to select an ERP system
Wei and Wang (2004)	Proposed an integration model that uses the fuzzy average method and fuzzy integral value ranking for ERP system selection
Fisher et al.(2004)	Used DEA to analyze and compare the performance of ERP packages, based on information provided by ERP vendors
Wei, Chien, and Wang (2005)	Proposed an AHP based framework to 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
Soffer et al. (2005)	Employed an automated matching algorithm between the enterprise requirements and the ERP system capabilities based an a modeling technique called OPM
Lall and Teyarachakul (2006)	Used DEA for ERP performance evaluation based on the real corporate data reflecting the organization's needs and requirements
Bernroider and Stix (2006)	Combined the utility ranking method and the DEA for software selection
Liao, et al., (2006)	Presented a linguistic information processing model, which used a similarity degree based algorithm to aggregate the objective information about ERP systems and then a linear programming model is established for selecting the most suitable ERP
Bueno and Salmeron (2007)	Applied a Fuzzy Cognitive Map (FCM) based approach capable of offering a definitively organized and structural outline in the acquisition of an ERP tool
Karsak and Ozogul (2007)	Developed a novel decision framework for ERP selection based on quality function deployment (QFD), fuzzy linear regression and zero-one goal programming
Yang, Wu, and Tsai (2007)	Expressed a case study on selection of an ERP system for a local construction company in Taiwan

ERP software selection is a complicated task and numerous factors should be considered during the process. The complexity of the decisions that must be adopted in ERP projects is derived from their problematic nature (Fui-Hoon et al., 2001). However, an ERP tool carries relevant advantages and benefits for an organization (Hamilton, 2003), for example, offers a faster access to information and an improvement in the supply chain through e-commerce integration (Bueno and Salmeron, 2007).

Previous research addressed a large variety of influential factors for ERP system selection. Also, a reasonable consensus among the researchers for ERP selection factors can be observed. In Table 2, some of the main common factors for ERP selection in the literature are listed.

Table 2. ERP selection common factors							
Facrots	Wei and Wang (2004)	Wei et al (2005)	Karsak and Ozogul (2007)	Botta-Genoulaz and Millet (2005)	Mabert et al (2003)	Olhager and Selldin (2003)	Kumar et al (2003)
Total costs	✓	✓	✓		✓		✓
Implementation time	✓	✓					
Risks of failure	✓						
Goal and vision fit	✓						
Local environmental requirements	✓						
Reliability and quality	✓	✓					
User friendliness	✓	✓	✓				
Expansion and upgrades	✓	✓					
Functional Fit	✓	✓	✓				

System Flexibility		✓	✓				
Security		✓					
R&D technology	✓	✓					
Implementation and service Ability	✓	✓					
Consulting service	✓	✓					
Training support	✓	✓					✓
Financial condition	✓	✓					
Credentials and reputation	✓	✓	✓				✓
Service speed		✓		✓			
Availability of information				✓	✓	✓	
Quickened information response				✓	✓	✓	
Increased interaction across the				✓	✓	✓	✓
Integration of business operations				✓	✓	✓	
Improved inventory levels and				✓	✓	✓	
Improved interaction with customers				✓	✓	✓	
Improved interaction with suppliers				✓	✓	✓	

Methodology

DEA model

Data envelopment analysis (DEA) is a mathematical programming technique that measures the relative efficiency of multiple decision-making units (DMUs) based on multiple inputs and outputs (Eilat et al., 2006). The number of DMUs is represented by n, each DMU uses m inputs and produces s outputs. In this paper, we regard these DMUs as ERP systems. Also, x_{ij} is the observed inputs (i = 1, . . . ,m) and y_{ij} the observed outputs (r = 1, . . . , s) of project j (j = 1, . . . , n). The relative value of each DMU (here ERP system) is defined as the ratio between the weighted sum of outputs to the weighted sum of inputs. The weights u and v are the variables of the model. They are defined in a way that allows each DMU in turn present itself in the most desired way. Formulation (1) presents the CCR model (basic DEA model proposed by Charnes et al., 1978) in its ratio form. The constant ε is an infinitesimal positive number that functions as a lower bound for the weights.

$$Max \quad \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}}$$

$$s.t. \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \, \forall \, j$$

$$u_r \geq \varepsilon,$$

$$v_i \geq \varepsilon, \qquad \qquad \textbf{(1)}$$

By solving this model n times (each time evaluating a different DMU), we earn relative efficiency scores for all the DMUs. These measures divides the DMUs into two categories: those with score of 1.0 (efficient), and those with scores smaller than 1.0 (inefficient).

The proposed methodology

The proposed methodology is composed of two steps. It begins with establishment of input and output indices as well as a set of ERP candidate systems (modeled as DMUs). Subsequently, the attractiveness scores of the individual ERP solutions are estimated using expert opinion and documented data from ERP providers (step 1). Ultimately, to evaluate the alternatives, the DEA model is used, and ERP systems for the current context are listed in terms of their efficiency score. In what follows we describe the methodology in details.

Step 1: Modeling the problem

Input factors in DEA analysis for this paper's purpose are those that a company spends for ERP implementation (like cost, time, and risk). In other words, the input factors are the resources of company which are consumed as a result of ERP implementation in the company. On the other hand, output factors are the gains that organization obtains from ERP implementation. Reviewing Table 2, one can realize that only few of them are consistent with nature of input and output factors in DEA. Companies spend money and time on ERP projects and also tolerate risks during the project. Thus, total cost, implementation time and risk of failure are considered as the input factors of DEA analysis.

On the other hand, there are some factors which could be considered as outputs of ERP implementation. Given factors listed in Table 2, one can realize that only some of them are consistent with the nature of output factors in DEA. They are generally the major benefits that company can take from ERP implementation. However, improved accessibility to information, integrity among business operations/processes, improved inventory levels, improved interaction with customers and supplier, and reduced direct operating costs are the major benefits of ERP implementation that we took into account of output factors. Having found those 3 input factors and these 6 output ones as our proposed DEA model factors, we interviewed few experts in the case study (See next section), as a result, we came in the conclusion that the model could be good enough to be used. Consequently, we found a 3-input 6-output DEA model for ERP selection which is presented in Table 3.

Step 2: Prioritizing alternatives using DEA

Having assigned the data, each project was evaluated using DEA model discussed earlier, and, the efficiency score of each alternative was calculated. Finally, the result was presented on a diagram in order to enable managers to select the most appropriate ERP system.

Case study

This paper case study is a medium-sized Iranian petrochemical company established as one of the important petrochemical companies in the country and in the Middle East to serve domestic as well as international market. This company has been deciding on selecting an ERP system.

In this research a group of 28 experts were asked to contribute to the research. They were all, high prestigious information technology (IT) experts who had had at least 5 years experience in ERP implementation in petrochemical industry. Eventually, 12 individuals agreed to contribute. First of all, having reviewed the literature, we interviewed few of them and found 5 ERP solution candidates to be tested using the model. Subsequently, a semi structured questionnaire was designed; in the first part, the set of factors affecting ERP system selection were presented and the experts were asked to weigh them in a 7 point Likert scale (Extremely low, Very low, Low, Medium, High, Very high, Extremely high) for each proposed ERP solution. In the remainder, they were asked to propose other influential factors and potential ERP systems which were not mentioned in the questionnaire, but, in the expert's point of view were important.

Data for all output criteria and the third input (I3) were estimated by experts. As for I1 and I2 (total cost and implementation time), they were determined on the basis of ERP vendors' declaration. At the request of the project manager and in order to not promote any company, the names of the five actual ERP systems have been changed to A, B, C, D and E. ERP "A" and "C" are two famous ERPs with a good reputation. ERP "A" is very popular in oil and gas industry and the majority of top petrochemical companies are its customers. But, ERP "C" is more popular in other industries rather than petrochemical. ERP "B" is a domestic new product with less than 10 years of experience. The previous customers of this ERP are mostly small-sized companies. This ERP has been implemented in some chemical companies which work domestically. ERP "D" has been developed by a vendor in the Middle East aiming to serve middle-sized companies. The market share of this product has considerably increased during last decade especially in that area among SMEs. Finally, ERP "E" is a well known ERP too, with successful implementation experience in chemical and petrochemical companies especially in Asia pacific. But its market share is not as much as ERP "A" and "C".

After analyzing the data and calculating averages of respondents' estimations on the Likert scale 1-7, the problem was modeled as is depicted in Table 3. Also, most of the factors proposed by them in section 2 of the questionnaire were overlapped with current factors, and, no new ERP system was proposed by them as a potential one.

Table 3. Values of input/output factors for DEA analysis						
ERP Solutions / DEA Factors		ERP A	ERP B	ERP C	ERP D	ERP E
Input Factors	I1: Estimated total costs (million US$)	2,500,000	800,000	1,900,000	2,750,000	1,250,000
	I2: Estimated implementation time (Month)	36	18	24	36	18
	I3: Estimated risk (failure probability)	25	10.8	11	11.7	13.6
Output Factors	U1: Information accessibility	3.5	6.5	6.4	4.3	3.8
	U2: Improved integrity level among business operations/processes	5.1	6.7	6.8	6.7	3.5
	U3: Improved inventory levels and purchasing	3.5	4.7	3.6	2.2	1.7
	U4: Improved interaction with customers	5.0	5.0	5.0	3.5	0
	U5: Improved interaction with suppliers	3.5	5.6	5.6	2.5	0
	U6: Reduced direct operating costs	1.4	2.8	0.8	1.2	0.35

Assigning the data, each project was evaluated through the DEA model (Formulation 1) discussed earlier. The efficiency score of each alternative was calculated for all 5 different systems (The result is depicted in Table 4). The results obtained from this DEA analysis is something reasonable in our case. Regarding the characteristics which were given for our five ERP systems, one can find out that the attractiveness of each ERP is justifiable. ERP "A", which is the first offer of the analysis, is the leader of ERPs in oil and gas and petrochemical companies. The next offer is the ERP "D" which is serving middle-sized companies. ERP "B" is the third choice (it is the cheapest among the five) followed by ERP "E". ERP "C", the last offer, is not recommended because although this ERP is very famous, it doesn't have enough experience in petrochemical industry.

It is worth mentioning that one limitation of this research was the lack of experts in the country for this particular purpose, so we had to do our analysis based on 12 experts' opinion. More importantly, the result of this research cannot be generalized because it is customized for one specific company. However, the way that the paper pursued to elaborate the model and come up with the result can be effectively used by different middle-sized companies.

Table 4. ERP systems DEA score		
Rank	ERP system	DEA score
1	A	1
2	D	0.9959
3	B	0.9222
4	E	0.5844
5	C	0.4997

Conclusions

As selecting inappropriate software is a major reason for the failure of ERP implementation and can waste lots of money and time, this paper sought to provide IT managers with a decision making process in order to assess mid-level ERP packages to decrease risk of ERP implementation failure. The article tried to demonstrate how ERP

system selection can be done systematically using Data Envelopment Analysis. This methodology firstly modeled the problem in terms of input and output criteria and then assessed the relative efficiency of each ERP system given the set of input and output criteria. The approach discussed in the paper can be used for other enterprise systems such as Customer Relationship Management (CRM). For future research we propose a decision model for ERP system selection in large enterprises using expert opinion (e.g. Delphi method) in order to model the problem taking into account of their complexities.

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