The Effect of Project Complexity, Team Members' Structure, and Process Index on Efficiency of System Integration Projects

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***Abstract*—**Data Envelopment Analysis (DEA) is a theoretically sound framework for performance analysis that offers many advantages over traditional methods such as performance ratios and regression analysis. Largely the result of multidisciplinary research during the last three decades in economics, engineering and management, DEA is best described as an effective new way of visualizing and analyzing performance data. Besides, overseas information technology companies have aggressively tried to enter the domestic market. In the age of globalization and high competition, it is imperative that the system integration (SI) companies need to introduce the performance evaluation models of SI projects, including Capability Maturity Model and Software Process Improvement and Capability Determination, to gain a competitive advantage. Therefore, it makes our research regarding evaluation of SI projects very opportune.

The purpose of the study is not only to evaluate efficiency of each project by DEA but also to gain insight into various factors such as project complexity, team members' man-months structure, and process index (project management index) that link to the projects performance.

Index Terms; Data Envelopment Analysis (DEA), System integration, Tier analysis

I. INTRODUCTION

Efficiency or productivity analyses are vital managerial tools for assessing the degree to which inputs are utilized in the process of obtaining desired outputs. DEA has become an accepted approach for assessing efficiency in a wide range of cases. The paper presents how DEA can be applied to evaluate the efficiency of the system integration projects. We also aim to obtain the meaningful managerial knowledge about the influential factors on the efficiency of the projects.

SI means by all the activities that are necessary to build and maintain various kinds of information systems in response to the customer needs. SI includes design, development and maintenance of software, hardware and communication networks. SI companies mainly carry their works by projects-basis. Upon receiving the project request from a customer, the SI Company organizes a team for the project. Precise evaluation of the project is an important issue for SI companies. Hence the quality of the company is determined by the efficiency and the customer satisfaction of the projects. The evaluation results of the proposed projects are considered critical in developing the competitive strategy of SI Company. The project evaluation results also influence the level of incentives for the employees who carried out the projects.

In this study, we use DEA to evaluate the efficiency of the 50 SI projects carried by an SI company. The purpose of the study is not only to evaluate efficiency of each project but also to gain insight into various factors such as project complexity, team members' career structure, and process index that link to the projects performance. To gain insights from the evaluation results, one has to develop a meaningful clustering analysis, that is, to develop specific characteristics distinct between two or more groups of projects, for example, failed or non-failed projects. For clustering analysis, we developed the tier analysis based on the DEA model.

II. Literature Review

2.1 DEA

DEA was developed by Charnes et al. as a generalization of the framework of Farrell [1957] on the measurement of productive efficiency. DEA, as a non-parametric approach, evaluates relative efficiency of inputs and outputs and determines a set of Pareto-efficient DMUs with an objective of calculating a discrete piecewise frontier. Details of the methodology as well as description of DEA can be found in Charnes et al. [1978] (see appendix).

Several characteristics that make DEA powerful are as follows: First, it can handle simultaneously multiple inputs and multiple outputs of a decision making units(DMU) Second, it does not require an assumption of a functional form relating inputs to outputs. Third, DMUs are directly compared against a peer or combination of peers and it provides managers with a procedure to differentiate between efficient and inefficient DMUs. Fourth, it pinpoints the sources and the amount of deficiency for each of the inefficient DMUs. Fifth, it can be used to detect specific inefficiencies that may not be detectable through other techniques such as linear regression or ratio analyses. Finally, inputs and outputs can have different units of

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measurement (John, 2006).

In our model, project complexity, team members' structure, and process management index are controllable variables which are determined in the progress of the project. Experienced managers knew that these variables are important to manage a system integration project, yet they are not sure how these characteristics should determine the overall quality of projects.

2.2 Efficiency evaluation of SI projects

Within an efficiency measurement framework, one is more interested in assessing how well a DMU uses its resources to obtain a desired outcome; alternatively, one may want to assess how good an outcome is producing with the given resources. Thus, one is intuitively interested in defining the main resources (inputs) and the relevant products (outputs) of the process, and in finding appropriate measures for these attributes. But, measuring the SI projects has not been easy, primarily because most researchers and practitioners have difficulty in agreeing on what to measure and how to measure it (Banker and Kemerer, 1992).

Christopher et al. [1996] used Customer Satisfaction Index (CSI) and meeting targets, which include schedules and budgets, and rework after delivery as output variables of Software development projects. Hong et al. [1999] gathered data on 50 projects carried by an SI company and proposed a SI project management model with four inputs and four outputs. The inputs used by each DMU are material and equipment resources such as software and hardware tools, and total labor hours. Total labor hours are the amount of total person-month considering career. The outputs are CSI, schedule performance, budget performance, and rework hours after delivery. These variables are summarized in Table 1.

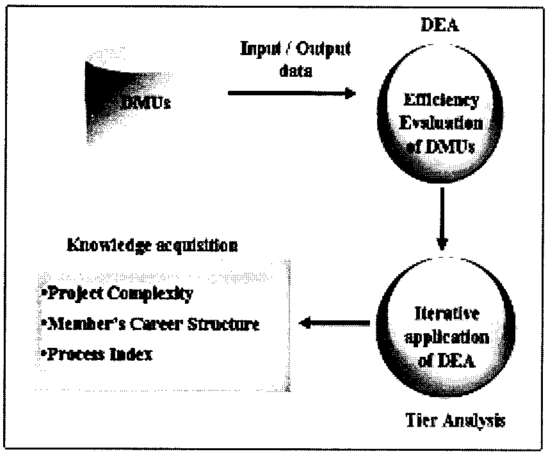

Fig. 1 Framework of our analysis

III. Methodology

In this chapter, we present our research model (see Fig 1). We evaluate the efficiencies of the DMUs via a DEA and cluster the DMUs together through the tier analysis, which recursively applies the DEA analysis to the remaining inefficient DMUs, and then find out knowledge about project complexity, team members' structure, and process index with the comparison of tier-efficiency value among DMUs.

Table 1 Summary of Input/Output Variables

Variable		Measurement
Input	Labor hours A (La) : senior	Amount of total man-months, who has a career over 10 years
	Labor hours B (Lb) : middle	Amount of total man-months , who has a career over 6-10 years
	Labor hours C (Lc) : junior	Amount of total man-months , who has a career below 5 years
	Material and Equipment Res.	Total Monetary Amount of H/W, S/W and other materials
Output	CSI	Customer Questionnaire
	Schedule performance (Sp)	Ratio of planned period to real period
	Budget performance (Bp)	Difference between real development cost and planned budget
	Rework after Delivery (Rew)	5 man-months –man- months of rework (additional service)

Project manager would like to know which project is more efficiency than any other project. And Managers also sought to determine the ideal staffing level, project management level, and required resource level for each project based on the volume and mix of services it intended to offer. Our study figured out situation variables such as project complexity, team members' man-months structure, and process index. The situation variables are summarized in Table 2.

Table 2 Summary of Situation variables

Variable		Measurement
Project complexity		H (high), M (Middle) L (Low)
Team members' man-months structure		Ratio of Team members' man-months (La : Lb : Lc)
Process index	Project Guide Follow-Up	# of Completed Items / # of Items in Project Guide
	Design Review Meetings	# of DR meeting held / # of initially planned DR meeting
	Test / Build Effort Ratio	Resources used for Test / Overall resource
	Members' Experience	Average career years Of the project members

In our model, situation variables are controllable variables which are determined in the progress of the project. Experienced managers knew that these variables are important to manage a system integration project, yet they are not sure how these characteristics should determine the overall quality of projects.

IV. The Results

We used the DEA linear programming model developed by Charnes et al. [1978], also followed the application procedure suggested by Golany and Roll [1989]. And we used the data in research of Hong et al. [1999].

We applied DEA technique to find out how this project complexity, team members' structure, and process index influences performance within the limited input resources. DEA could determine the most productive group of DMUs and the group of less-productive DMUs by the tier analysis. Tier analysis is a technique which can be used to classify DMUs according to their efficiency level.

In the first phase of the tier analysis, one selects the set of input and output variables and obtains the efficiency score for the entire set of DMUs. The result of the first phase should reveal the most efficient group of DMUs by indicating their score is equal to one. We call this group as Group I. In the second phase, one proceed DEA analysis again only with DMUs which are not part of Tier 1. DMUs of which efficiency score of the second phase is one are Tier 2. The analysis should be repeated until the number of remained DMUs gets small enough. We call this procedure the tier analysis because DMUs of the efficient group of each phase form the efficient production frontier in that phase. Once all the DMUs are clustered by their efficiency level, the project complexity, team members' man-months structure, and process index are traced further. Finally, we could obtain knowledge on the ideal characteristics of the efficient SI projects.

We could classify the fifty projects into four tiers via DEA and tier analysis (see Table 3 & 4). The efficiency score itself is not important because DEA evaluates the efficiency of the projects relatively. Only what matters is what tier the project belongs to. We could observe some tendency exists in the distribution of the process indices. Our findings on project complexity and team members' career structure are the followings.

First, team members' structure of project with high complexity and high efficiency (P8, P29, P47, P48) is senior, middle, and junior in order. Projects with high complexity show above average in CSI and Rework after delivery, but low in schedule and budget performance. It means that first and most importantly in order to improve efficiency of large-scale projects or projects at the first time is the experience of senior members.

Secondly, team members' structure of projects with low complexity and high efficiency (P7, P21, P32, P45) is junior, middle, and senior experience in order. These projects show below average in CSI and Rework after delivery, but high in schedule and budget performance. It means that the most important in order to improve efficiency of small-scale projects or projects with many experience is juniors' technical tasks.

Our findings on the process indexes are the followings (see Table 4). First, project guide follow-up is very important for a project to success. The higher efficiency is (tier 1), the higher the value of project guide follow-up is. This means that the current internal project guide is effectively organized. Second, projects observed design review meeting well show high efficiency. Therefore, project managers should give more effort to design review activity. Third, the ratio of test / build effort is distributed around 0.25 throughout four groups. Finally, the average experience of team members is short in successful projects. This tendency seems to stem from the revolutionary development pace of information technology.

Table 4 Average of process index of each tier

Tier	# of DMUs	Project Guide Follow-Up	DR Meetings	Test/Build Ratio	Experience (year)
1	13	0.79	0.73	0.27	7.1
2	10	0.65	0.66	0.24	8.4
3	12	0.64	0.49	0.27	8.5
4	15	0.51	0.36	0.25	9.3

Table 3 The results of DEA and Tier analysis

Project (DMU)	Input Factors				Output Factors				Efficiency (%)	Tier	Project Complexity
	La	Lb	Lc	Mr	CSI	SP	BP	Rew			
P1	2	7	7	14.5	90.8	0.96	8.1	4.1	64	3	M
P2	1.1	3.3	2	4.6	89.4	1.2	4.1	4.8	100	1	M
:	:	:	:	:	:	:	:	:	:	:	:
P6	0.6	1.9	1.8	2.1	71	0.88	1.2	4.9	90	2	L
P7	2	6	5	4.8	87.9	1	7.7	4.5	100	1	**L**
P8	2.1	1.9	1	1.17	91	1.0	0.9	1.5	100	1	**H**
:	:	:	:	:	:	:	:	:	:	:	:
P21	0.5	1.5	2.6	1.4	75.8	1.7	4.2	4.7	100	1	**L**
:	:	:	:	:	:	:	:	:	:	:	:
P29	16.5	15.4	13	22	88.1	0.98	1.2	1.5	100	1	**H**
P30	1	4.9	3.2	4.54	79.8	0.75	0.4	3.9	38	3	M
P31	3	3.8	7.1	3.79	72.7	0.71	1	3.6	29	4	H
P32	1	4	3.8	2.69	89	1.15	4.6	4.8	100	1	**L**
:	:	:	:	:	:	:	:	:	:	:	:
P40	0.4	1	1	1.2	91	1	0.5	4.2	100	1	**L**
P41	0.7	2	2.8	2.74	70.0	1.25	4.2	4.0	100	1	**L**
:	:	:	:	:	:	:	:	:	:	:	:
P45	1.2	1.5	1.8	1.29	75.8	1.19	4.84	4.9	100	1	**L**
P46	2.5	2.1	0.2	1.85	94.4	1.01	0.83	2.1	100	1	**H**
:	:	:	:	:	:	:	:	:	:	:	:
P47	16.8	16.1	9	22.7	95.8	1.08	1.1	1.5	100	1	**H**
P50	2	3	3	2.71	74.0	0.77	0.95	4.3	44	3	M
Average	5.6	9.1	6.8	9.63	78.3	1.03	4.1	3.4	58		

V. Conclusion

Managers of SI projects seek to find best practice through precise evaluation of projects. The managers could have used the traditional methods of economic analysis. Due to the special features of the SI project, simple ratio analysis could not bring knowledge for managing SI projects. Using DEA, we develop tier analysis method for clustering DMUs and we could obtain useful knowledge on SI project management.

Findings in this study indicate that in order to deliver projects successfully, managers should consider project complexity, CSI, Schedule and Budget performance when building project team members. And also design review meeting and procedure manual are very vital and the average experience of employees is short in successful projects.

Our further study is to develop the tier analysis to suggest improvement path for specific projects based on the features of the projects.

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APPENDIX

The DEA Model : The CCR ratio model is proposed by Charnes, Cooper, and Rhodes in 1978. In this model, the efficiency measure of any DMU is obtained as the maximum of a ratio of weighted outputs to weighted inputs subject to the condition that the similar ratios for every DMU be less than or equal to unity. That is, the model is as follows:

$$\max \quad e_0 = \sum_{r \in R} u_r Y_{ro} \Big/ \sum_{i \in I} v_i X_{io}$$

$$\text{s.t.} \quad \sum_{r \in R} u_r Y_{rj} \Big/ \sum_{i \in I} v_i X_{ij} \leq 1 \; \forall j \in N$$

$$u_r \Big/ \sum_{i \in I} v_i X_{io} \geq \varepsilon \; \forall r \in R$$

$$v_i \Big/ \sum_{i \in I} v_i X_{io} \geq \varepsilon \; \forall i \in I$$

i: index for input i, i∈Î/={1, 2, ..., I}

r: index for output r, r∈ÎR={1, 2, ..., R}

j: index for DMU j, j∈ÎN={1, 2, ..., n}

u_r : virtual multiplier(weight) of r-th Output

v_i : virtual multiplier(weight) of i-th Input

X_{ij}: the values $(\geq^{3}0)$ of input i for j-th DMU(for j=1, ..., n)

Y_{rj}: the values $(\geq^{3}0)$ of output r for j-th DMU(for j=1, ..., n)

ε: Non-Archimedean infinitesimal

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