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(Technical Note)

Two DEA Models Employment in IS Project Selection for Iran Ministry of Commerce

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ABSTRACT

Selection of an appropriate set of Information System (IS) projects is a critical business activity which is very helpful to all organizations. In this paper, after describing real IS project selection problem of Iran Ministry of Commerce (MOC), we introduce two Data Envelopment Analysis (DEA) models. Then, we show applicability of introduced models for identifying most efficient IS project from 8 competing projects. Then, in order to provide further insight, results of two introduced models are compared. It is notable that using basic DEA models -CCR and BCC- decision maker is not able to find most efficient Decision Making Unit (DMU) since these models identify some of DMUs as efficient which their efficiency scores equal to 1. As an advantage, the applied models can identify most efficient IS (in constant and variable return to scale situations) by solving only one linear programming (LP). So these models are computationally efficient. It is while using the basic DEA models requires decision maker to solve a LP for each IS.

1. Introduction

A critical aspect of IT management is the decision whereby the best set of IS projects is selected from many competing proposals [2]. Selecting the right IS project is a critical business activity that has been recognized and repeatedly emphasized by many researchers. The optimal selection process is a significant strategic resource allocation decision that can engage an organization in substantial long-term commitments [9].

Data envelopment analysis (DEA) is a non-parametric linear programming based technique for measuring the relative efficiency of a set of similar units, usually referred to as decision making units (DMUs). It was introduced by Charnes, Cooper and Rhodes (1978) based on Farrell's pioneering work. They generalized the single-output to single-input ratio definition of efficiency to multiple inputs and outputs. In their original DEA model, Charnes, Cooper and Rhodes (CCR model) proposed that the efficiency of a DMU can be obtained as the maximum of a ratio of weighted outputs to weighted inputs, subject to the condition that the same ratio for all DMUs must be less than or equal to one. The DEA model must be run n times, once for each unit, to get the relative efficiency of all DMUs [5].

DEA has gained too much attention by researchers because of its successful applications and case studies. Evaluation of data warehouse operations [16], selection of flexible manufacturing system [15], ranking data mining association rules [7,20], assessment of bank branch performance [4], examining bank efficiency [8], analyzing firm’s financial statements [9], measuring the efficiency of higher education institutions [12], solving facility layout design (FLD) problem [11] and

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measuring the efficiency of organizational investments in information technology [17] are examples of using DEA in various areas. In this paper, we introduce two DEA models for finding most efficient DMU and then, using real case data from Iran ministry of commerce, we show an application of model for finding most efficient IS project from 8 competing proposals.

2. Literature Review

Numerous methodologies have been developed and reported for IS project selection or development during the last decades. Shafer & Byrd (2000), using DEA, developed a framework for measuring efficiency of organization investment in information technology. Using data compiled for over 200 large organizations, they illustrated application of their framework [17]. Lee & Kim (2001) considering interdependencies among criteria and candidate projects, suggested an integrated approach for interdependent IS project selection problems using Delphi, Analytic Network Process (ANP) concept and zero-one goal programming [14]. Badri et al., (2001) developed a mixed 0-1 goal programming model for IS project selection in health service institutions, considering multiple factors [2]. Wen et al., (2003) using DEA, proposed a model for evaluating e-commerce efficiency [22]. Sowlati et al., (2005) proposed a DEA model for prioritizing IS projects. Using the proposed model, each real project is compared to the set of defined projects and receives a score [18]. Kengpol & Touminen (2006) using ANP, Delphi and Maximize Agreement Heuristic (MAH), developed a framework for information technology evaluation [13]. Wang & Yang (2007) proposed use of AHP and PROMETHEE as aids in making IS outsourcing decisions. They mentioned that weights determined by the AHP, are considered as complete subjective weights. They proposed using DEA as an objective method [21]. Eilat et al. (2008) presented a multi-criteria approach for evaluating R&D projects in different stages of their life cycle. Their approach integrated the balanced scorecard (BSC) and DEA and developed an extended DEA model. Their proposed method could be applied for IS project selection [10]. Chen & Cheng (2009) presented a multiple-criteria decision-making method (MCDM) for selecting an information system project based on the fuzzy measure and the fuzzy integral [6]. In this paper, we introduce an integrated model for finding most efficient IS project.

3. The Problem and Research Method

The manager of IS department at Iran Ministry of Commerce (MOC) used to perform personally the task of selecting IS projects. The manager had to depend on experience and intuition. From an operational aspect, selecting the best project among large number of projects was difficult to do in order to the lack of a formal process and a clearly defined and transparent way for decision making. It was necessary to choose a model that could be used as an objective method for selecting right IS project.

DEA was suggested as the best solution which could model the complexity of choosing projects and show that the decisions so made are fair and equitable. Obviously, suitable research method for this article is case study. To choose the best IS project from a set of projects that are in competition for limited resources, different criteria, which may be qualitative in nature, must be included in the evaluation.

First, IS department of Iran ministry of commerce employed a team include several specialists on the field of IS and software engineering. These specialists were asked to develop a set of criteria which capture all aspects of IS projects and to estimate them for each project. It is notable that data of software cost, training cost and support cost values were obtained from proposals and potential risk, time reduction, system accuracy and improvement management capabilities were subjectively scored by specialist. Table (1) shows estimations of inputs and outputs obtained by specialist.

Tab. 1. Estimation of criteria values for IS projects

DMU	Inputs				Outputs		
	oftware Cost	Training Cost	Support Cost	Potential Risk	Time Reduction	System Accuracy	Improvement management capabilities
1	3500	12	24	7	5	5	1
2	455	45	0.83	9	23	5	9
3	695	69	1.5	5	14	5	3
4	513	14	122	5	16	5	3
5	3510	351	16.8	1	23	5	7
6	3725	30	100	1	14	5	5
7	4000	40	50	3	10	5	1
8	2500	250	30	7	13	5	7

4. DEA Models

DEA is commonly used to evaluate the relative efficiency of a number of DMUs. The basic DEA model in Charnes et al. (1978), called the CCR model, has lead to several extensions, most notably the BCC [3]. Assume that there are n DMUs , ($\mathrm{DMU_j} : j = 1,2,...,n$) which consume m inputs ($\mathbf{x}_i : i = 1,2,\ldots,m$) to produce s outputs ($\mathbf{y}_r : r = 1,2,\ldots,s$). The BCC input oriented (BCC-I) model evaluates the efficiency of $\mathrm{DMU_o}$, DMU under consideration, by solving the following linear program:

$$
\begin{aligned}
&\max \sum_{r=1}^{s} u_r y_{rj} - u_0 \\
&s.t. \\
&\sum_{i=1}^{m} w_i x_{io} = 1 \\
&\sum_{r=1}^{s} u_r y_{rj} - u_0 - \sum_{i=1}^{m} w_i x_{ij} \le 0 \qquad j = 1,2,...,n \\
&u_0 \quad free \\
&w_i \ge \varepsilon \qquad i = 1,2,...,m \\
&u_r \ge \varepsilon \qquad r = 1,2,...,s
\end{aligned} \tag{1}
$$

where x_{ij} and y_{rj} (all nonnegative) are the inputs and outputs of the $\mathrm{j^{th}}$ DMU, w_i and u_r are the input and output weights (also referred to as multipliers). x_{io} and y_{ro} are the inputs and outputs of $\mathrm{DMU_o}$. Also, ε is non-Archimedean infinitesimal value for forestalling weights to be equal to zero. On account of the fact that basic DEA models identify more than one DMU as efficient units, finding the most efficient DMU is an issue. Amin & Toloo (2007) proposed an integrated model for finding most efficient DMU. The proposed model finds most efficient DMU without solving the model n times (one LP for each DMU). Using Model (2), decision makers could identify most efficient DMU from a set of several competing alternatives [1].

$$
\begin{aligned}
&M^* = \min M \\
&s.t. \\
&M - d_j \ge 0 \qquad j = 1,2,...,n \\
&\sum_{i=1}^{m} w_i x_{ij} \le 1 \qquad j = 1,2,...,n \\
&\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} w_i x_{ij} + d_j - \beta_j = 0 \qquad j = 1,2,...,n \\
&\sum_{j=1}^{n} d_j = n - 1 \\
&0 \le \beta_j \le 1, d_j \in \{0,1\} \quad j = 1,2,...,n \\
&w_i \ge \varepsilon^* \qquad i = 1,2,...,m \\
&u_r \ge \varepsilon^* \qquad r = 1,2,...,s
\end{aligned} \tag{2}
$$

In following subsections, we explore components of Model (2).

4.1 Decision Variables

In Model (2) d_j represents the deviation variable of $\mathrm{DMU_j}$. When applying Model (1), $\mathrm{DMU_j}$ is efficient if and only if $d_j = 0$, thus d_j can be interpreted as a measure of inefficiency.

β_j is considered in the Model (1) because of discrete nature of d_j and M represents maximum inefficiency. Furthermore Amin & Toloo (2007) proposed Model (2) for finding ε^* which is maximum non-Archimedean epsilon [1].

$$
\begin{aligned}
&\varepsilon^* = \max \varepsilon \\
&s.t. \\
&\sum_{i=1}^{m} w_i x_{ij} \le 1 \qquad j = 1,2,...,n \\
&\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} w_i x_{ij} \le 0 \qquad j = 1,2,...,n \\
&w_i - \varepsilon \ge 0 \qquad i = 1,2,...,m \\
&u_r - \varepsilon \ge 0 \qquad r = 1,2,...,s
\end{aligned} \tag{3}
$$

4.2 Constraints

First constraint implies that M is equal to maximum inefficiency. Second constraint shows input-oriented nature of the Model (1). Considering d_j as a measure of inefficiency, third constraint cause efficiency of all units is less that 1. Forth constraint ($\sum_{j=1}^{n} d_j = n-1$, with the binary variables d_j, $j = 1,2,...,n$) implies among all the DMUs for only most efficient unit, say $\mathrm{DMU_p}$, which has $d_p^* = 0$ in any optimal solution [1].

4.3 Objective Function

The objective function attempts to minimize the maximum inefficiency of DMUs [1].

It should be noted that Model (2) is based on CCR model and identify most CCR-efficient DMU. Indeed, Model (2) is not applicable for situations in which DMUs operating in variable return to scale. To overcome this drawback, Toloo & Nalchigar (2009) proposed an integrated model which is able to find most BCC-efficient DMU [19]. Their model is as follows:

$$
\begin{aligned}
& M^* = \min M \\
& s.t. \\
& M - d_j \geq 0 \qquad j = 1,2,...,n \\
& \sum_{i=1}^{m} w_i x_{ij} \leq 1 \qquad j = 1,2,...,n \\
& \sum_{r=1}^{s} u_r y_{rj} - u_0 - \sum_{i=1}^{m} w_i x_{ij} + d_j - \beta_j = 0 \qquad j = 1,2,...,n \\
& \sum_{j=1}^{n} d_j = n - 1 \qquad (4) \\
& 0 \leq \beta_j \leq 1, d_j \in \{0,1\} \quad j = 1,2,...,n \\
& M, u_0 \quad free \\
& w_i \geq \varepsilon^* \quad i = 1,2,...,m \\
& u_r \geq \varepsilon^* \quad r = 1,2,...,s
\end{aligned}
$$

In brief, Model (4) has wider range of application than Model (2) since it is applicable for situations in which DMUs operates in variable return to scale. In order to find ε^* in Model (4), Toloo & Nalchigar (2009) proposed a model which has similar structure to Model (3). Interested readers could refer to [19] for further discussion. In the next section, applicability of these models is illustrated and their results are compared.

5. Selection of Most Efficient IS Project

In this section, the applicability of introduced models is shown in the filed of IS project selection. Using DEA-Solver, we applied basic DEA models (BCC and CCR) on data of IS projects in Iran Ministry of Commerce. Efficiency scores obtained from these models are presented in Table (2).

Tab. 2. Efficiency scores of IS projects obtained from basic DEA models

DMUs (IS projects)	CCR Efficiency Score	BCC Efficiency Score
1	1.00	1.00
2	1.00	1.00
3	1.00	1.00
4	1.00	1.00
5	1.00	1.00
6	1.00	1.00
7	1.00	1.00
8	0.69	0.69

Results presented in Table (2) indicate that using basic DEA models, manager of IS department at Iran Ministry of Commerce is not able to select best IS project. In situations like this, finding the most efficient DMU is desirable.

Identifying most efficient IS project, requires Model (3) to be solved prior than Model (2). Using WinQSB, we solved Model (3) for data presented in Table (1) which resulted in $\varepsilon^* = 0.0002$. Using this value, we solved Model (2) for IS projects. The results indicate that DMU_4 is most CCR-efficient IS project ($d_4^* = 0,\ d_{j\neq 4}^* = 1$). Moreover, considering suitable value for epsilon (equal to 0.0002), Model (4) were solved for data presented in Table (1). The results indicate that DMU_3 is most BCC-efficient IS project. To provide further insight, Table (3) present detailed answer of models in comparison to each other.

Tab. 3. Results of models

Variable	Results of Model (2)	Results of Model (4)
d_j^*	$d_4^* = 0,\ d_{j\neq 4}^* = 1$	$d_3^* = 0,\ d_{j\neq 3}^* = 1$
w_1^*	0.0002	0.0002
w_2^*	0.0006	0.0006
w_3^*	0.0002	0.0020
w_4^*	0.0325	0.0173
u_1^*	0.0157	0.0002
u_2^*	0.0110	0.0548
u_3^*	0.0002	0.0002
u_0^*	-	0.3778

Using the proposed models, IS department at Iran Ministry of Commerce is able to identify most efficient IS objectively. In comparison with the conventional weighted score model and the AHP model some of the clear benefits of the proposed models are:

- Introduced models finds most efficient IS project (in variable and constant return to scale) objectively and there is no need for determining weights and pair-wise comparison for all criteria and projects.
- IT manager could find most efficient IS by solving only one LP, so it is computationally efficient.

6. Conclusion

The problem of IS project selection is an important issue for any business. In this paper, two DEA models for solving real problem of Iran Ministry of Commerce presented. To provide data of competing alternatives, Iran ministry of commerce employed a team include several specialists on the field of IS and software engineering and asked them to develop a set of criteria which capture various aspects of IS projects and to estimate them for each project. Considering different criteria as inputs and outputs of candidate IS project, two DEA models which are able to identify most CCR-efficient and BCC-efficient IS project by solving only one LP. In comparison with previous related works, proposed models have two main advantages. First these models find most efficient IS project objectively and there is no need for determining weights and pair-wise comparison for all criteria and projects. Second, IT managers could find most efficient IS project by solving only one LP, so it is computationally efficient. As suggestion for future research, scholars could apply proposed models for IS project selection in some other organizations. Moreover, comparison of results could be conducted. Finally, future researchers could use introduced models for other managerial decision making problems such as supplier selection, technology selection, etc.

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