Expert Systems with Applications 37 (2010) 5931–5938

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Information technology project evaluation: An integrated data envelopment analysis and balanced scorecard approach

Abbas Asosheh [a], Soroosh Nalchigar [b,*], Mona Jamporazmey [b]

[a] Department of Information Technology Engineering, Tarbiat Modares University, Jalal Ale Ahmad Highway, P.O. Box 14115-111, Tehran, Iran
[b] Department of Information Technology Management, Faculty of Management, University of Tehran, Tehran, Iran

ARTICLE INFO

Keywords:
Data envelopment analysis (DEA)
Balanced scorecard (BSC)
Project selection
Imprecise data
Ranking

ABSTRACT

Information technology (IT) is a tool crucial for enterprises to achieve a competitive advantage and organizational innovation. A critical aspect of IT management is the decision whereby the best set of IT projects is selected from many competing proposals. The optimal selection process is a significant strategic resource allocation decision that can engage an organization in substantial long-term commitments. However, making such decisions is difficult because there are lots of quantitative and qualitative factors to be considered in evaluation process. This paper has two main contributions. Firstly, it combines two well-established managerial methodologies, balanced scorecard (BSC) and data envelopment analysis (DEA), and proposes a new approach for IT project selection. This approach uses BSC as a comprehensive framework for defining IT projects evaluation criteria and uses DEA as a nonparametric technique for ranking IT projects. Secondly, this paper introduces a new integrated DEA model which identifies most efficient IT project by considering cardinal and ordinal data. Applicability of proposed approach is illustrated by using real world data of Iran Ministry of Science, Research and Technology.

1. Introduction

In recent years, the rapid development of information technology (IT) has made it easier for employees, customers, suppliers, and partners to interact while carrying out each of their business functions; moreover, cross-function collaborations become feasible in product development, marketing, distribution, and customer service. That is, IT does not merely support efficient business operations, workgroup task and collaborations, and effective business decision making; but they also change the way businesses compete (Ruiz-Mercader, Merono-Cerdan, & Sabater-Sanchez, 2006). Therefore, it is obvious that IT is a tool crucial for enterprises to achieve a competitive advantage and organizational innovation (Tseng, 2008).

In these organizations, IT managers have many responsibilities (data centers, staff management, telecommunication, servers, workstations, web sites, information systems (ISs), user support, regulatory compliance, disaster recovery, etc.) and connect with almost all the departments (accounting, marketing, sales, distribution, etc.). In many organizations, they can have a direct influence on strategic direction of the company (Holtsnider & Jaffe, 2007). A critical aspect of IT management is the decision whereby the best set of IT projects is selected from many competing proposals (Badri, Davis, & Davis, 2001). Selecting the right projects 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 (Santhanam & Kyparisis, 1995). According to Chen and Cheng (2008), selecting the most suitable from a set of projects is a significant resource allocation decision that can enhance the operational competitive advantage of a business. However, IT project selection is difficult because there are lots of quantitative and qualitative factors to be considered in the candidate IT projects such as business goals, benefits, project risks and available resources. Investigation of previous related works indicates that various method such as goal programming (Badri et al., 2001), analytic hierarchy process (AHP) (Schniederjans & Wilson, 1991), analytic network process (ANP) (Lee & Kim, 2001), quality function deployment (QFD) (Han, Kim, Choi, & Kim, 1998), data envelopment analysis (DEA) (Sowlati, Paradi, & Suld, 2005) have been applied for IT project selection problem. This paper combines balanced scorecard (BSC) and DEA to present a method for IT project selection with imprecise data.

Kaplan and Norton developed the balanced scorecard approach in the early 1990s to compensate for their perceived shortcomings of using only financial metrics to judge corporate performance.

* Corresponding author. Address: Faculty of Management, University of Tehran, Tehran, Iran. Tel.: +98 9123379953.

E-mail addresses: asosheh@modares.ac.ir (A. Asosheh), nalchigar@ut.ac.ir (S. Nalchigar), monajami@ut.ac.ir (M. Jamporazmey).

0957-4174/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2010.02.012

They recognized that in this "New Economy" it was also necessary to value intangible assets. Because of this, they urged companies to measure such esoteric factors as quality and customer satisfaction. By the middle 1990s, the balanced scorecard became the hallmark of a well-run company. Kaplan and Norton (2001) both emphasize that the approach is more than just a way to identify and monitor metrics. It is also a way to manage change and increase a company's effectiveness, productivity, and competitive advantage (Keyes, 2005). This study uses BSC as a comprehensive framework for evaluation criteria of IT projects.

DEA is a widely recognized technique for evaluating the efficiencies of decision making units (DMUs). Because of its easy and successful application and case studies, DEA has gained too much attention and widespread use by business and academy researchers. Selection of best vendors (Liu & Hai, 2005; Weber, Current, & Desai, 1998), evaluation of data warehouse operations (Mannino, Hong, & Choi, 2008), selection of flexible manufacturing system (Liu, 2008), assessment of bank branch performance (Camanho & Dyson, 2005), examining bank efficiency (Chen, Skully, & Brown, 2005), analyzing firm's financial statements (Edirisinghe & Zhang, 2007), measuring the efficiency of higher education institutions (Johnes, 2006), solving facility layout design (FLD) problem (Ertay, Ruan, & Tuzkaya, 2006) and measuring the efficiency of organizational investments in information technology (Shafer & Byrd, 2000) are samples of using DEA in various areas. In this paper, we introduce a new DEA model for finding most efficient DMU with imprecise data (cardinal and ordinal data) and then, using real case data from Iran Ministry of Science, Research and Technology, we show an application of model for finding most efficient IS project from 3 competing proposals.

The rest of this paper is organized as follows: In Section 2, previous related works are reviewed. Section 3, briefly describes problem in Iran Ministry of Science, research and Technology. Section 4 describes BSC and its fundamentals. Section 5 reviews previous related models in DEA. Section 6 proposes a new DEA method which ranks DMUs in presence of imprecise data and Section 7 indicates applicability of this. Finally paper is closed with some concluding remarks in Section 8.

2. Literature review

Numerous methodologies have been developed and reported for IS project selection or development during the last decades. Schniederjans and Wilson (1991) used a hybrid approach of analysis hierarchical process (AHP) and goal programming for IS project selection. Using a numerical example, they demonstrated that hybrid approaches have advantages from using these techniques separately. Schniederjans and Santhanam (1993) showed applicability of zero-one goal programming as a method for selection of IS projects. Santhanam and Kyparisis (1995) presented a multi-criteria decision model for IS project selection. The proposed model, explicitly consider interrelationships among candidate projects. Han et al. (1998) used quality function deployment (QFD) as a technique for determination of IS development priority. The proposed method considers alignment between business strategy and IS. Shafer and 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. Lee and 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. Badri et al. (2001) developed a mixed 0–1 goal programming model for IS project selection in health service institutions, considering multiple factors. Wen, Lim, and Huang (2003) using DEA, proposed a model for evaluating e-commerce efficiency. The proposed model includes not only financial and operational measures, but also e-commerce specific measures such as information and system quality. They illustrated that DEA model cannot only effectively reflect the relative efficiency of e-commerce firms, but also identify their potential efficiency problems. 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. Prioritization is based on this score. They believed that this is a significant advantage, because assessing the priority of a new added project would not affect the priority of already assessed ones. Kengpol and Tuominen (2006) using ANP, Delphi and maximize agreement heuristic (MAH), developed a framework for information technology evaluation. They showed the applicability of proposed framework for 5 logistics firms in Thailand. Wang and Yang (2007) proposed use of AHP and Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE) as aids in making IS outsourcing decisions. They mentioned that weights determined by the AHP, are considered as complete subjective weights.

Table 1 presents criteria which have been used in previous works.

Investigation of previous studies shows that identifying the best set of IT projects whit imprecise data has gained less attention. This paper tries to fill the gap by proposing a DEA model which is able to find most efficient IT projects by considering both cardinal and ordinal data. Furthermore, this paper uses BSC to define selection criteria.

3. Problem

In recent years, optimizing the size of government and initiating electronic government (e-government) have become one of major policies of Iran (Islamic Republic of) government. To meet these objectives, various ministries and governmental administrations should spend resources.

Table 1
Criteria in previous related studies.

Author	Criteria
Badri et al. (2001)	Risk, completion time required, training time required, annual cost of additional manpower, decision-makers preferences, users preferences, benefit, hardware cost, software cost, other cost
Lee and Kim (2001)	Program hours, analyst hours, hardware cost, clerical labor hours, benefit
Wen et al. (2003)	Profitability, capital utilization, capacities, e-commerce site quality, web technology investment, corporate operating cost, number of e-commerce staff
Santhanam and Kyparisis (1995)	Benefits, hardware cost, software cost, other cost, risk score
Sowlati et al. (2005)	Green dollar costs, brown dollar cost, level of urgency, potential risk, green dollar benefits, brown dollar costs, breath of benefits, intangible benefits
Mahmudi et al. (2008)	Software cost, training cost, support cost, potential risk, time reduction, system accuracy, improvement management capabilities

Meanwhile, implementing Internet Data Center (IDC) in Iran Ministry of Science, Research and Technology and has been considered as one of crucial projects. An IDC is a safe and secure facility used to house devices, services and information applications with high speed and stable communications. The goal of this project is to meeting e-government in this ministry. Moreover, this project has following objectives:

- Integrating information flows, processes and services.
- Improving service quality of this ministry.
- Reduction of costs.
- Enhancing security levels.

In these centers, by exploiting up to date software and hardware capabilities, high level services are provided for organizations and their subunits.

In first stage of this project, above mentioned ministry has focused on defining the overall goal of the project. According to Marchewka (2003) a project is undertaken for a specific purpose, and that purpose must be to add tangible value to organization. Defining the project's goal is the most important step in IT project. The main deliverable of first stage of project is Business case. A business case is a deliverable that documents the project's goal, as well as several alternatives or options. The feasibility, costs, benefits, and risks for each alternative are analyzed and compared, and recommendation to approve and fund one of the alternatives is made to senior management. Indeed, the purpose of a business case is to show how an IT solution can create business value (Marchewka, 2003). Developing a business case document include following steps:

1. *Select the core team:* Rather than have one person take sole responsibility for developing the business case, a core team should be recruited. If possible, developing a business case should include many of the stakeholders affected by the project or involved in its delivery.
2. *Define measurable organizational value (MOV):* To provide real value to an organization, IT projects must align with and support the organization's goals, mission, and objectives. IT project's overall goal and measure of success in referred to as the project's MOV. The MOV guides all the decisions and processes for managing the IT project and serves as a basis for evaluating the project's achievement.
3. *Identify alternatives:* Since no single solution generally exists for most organizational problems, it is imperative to identify several alternatives before dealing directly with a given business opportunity. The alternatives, or options, identified in the business case should be strategies for achieving the MOV.
4. *Define feasibility and assess risk:* Each option or alternative must be analyzed in terms of its feasibility and potential risk.
5. *Define total cost of ownership:* The decision to invest in an IT project must take into account all of the costs associated with the application system.
6. *Define total benefits of ownership:* Similarly, the total benefits of ownership must include all of the direct, on-going, and indirect benefits associated with each proposed alternative.
7. *Analyze alternatives:* Once costs and benefits have been identified, it is important that all alternatives be compared with each other consistently. Understanding the financial and numeric tools and techniques required by financial people and senior management, even for technically savvy.
8. *Propose and support the recommendation:* Once the alternatives have been identified and analyzed, the last step is to recommend one of the options. It is important to remember that a proposed recommendation must be supported (Marchewka, 2003).

In brief, developing a business case includes identification of alternatives, evaluation and selections of best options. Adopting above mentioned steps, Iran Ministry of Science, Research and Technology has defined MOVs, identified three alternatives to implement IDC. Furthermore, risks, costs and benefits of these alternatives have been assessed by specialist.

In this situation, this ministry needs a formal selection process for taking on a project. Integrating balanced scorecard (BSC) and, data envelopment analysis (DEA) this paper proposes a new method for selection and prioritization of IT projects. This method is applicable in seventh steps of developing business case.

4. Balanced scorecard

Through the years, the balanced scorecard has evolved, from the performance measurement tool originally introduced by Kaplan and Norton (1992), aimed at revealing problem areas within organizations and pointing out areas for improvement (Eilat, Golany, & Shtub, 2006), to a tool for implementing strategies (Kaplan & Norton, 1996) and a framework for determining the alignment of an organization's human, information and organization capital with its strategy (Kaplan & Norton, 2004).

The increasing use of BSCs is changing the way top managers run their companies. When envisioning a firm's future development, they no longer focus chiefly on monetary success indicators in the financial area (Rickards, 2007), Instead BSC is designed to complement "financial measures of past performance with their measures of the drivers of future performance" (Bhagwat & Sharma, 2007).

Increasing use of BSC framework in many recent researches and various management field like SCM (Bhagwat & Sharma, 2007), R&D project (Eilat et al., 2006), e-commerce (Hasan & Tibbits, 2000; Rickards, 2007), ERP (Chand, Hachey, Owhoso, & Vasudevan, 2005) and e-business (Bremser & Chung, 2005) have several reasons. First, compared with traditional measurement systems that only include financial measures, the BSC is designed to improve managers' decision making by guiding their attention to a broader vision of the company's operations (Kaplan & Norton, 1992; Rickards, 2007; Wong-On-Wing, Guo, Li, & Yang, 2007; Maltz, Shenhar, & Reilly, 2003). Second, as a holistic performance measurement system, the BSC provides causal links connecting the multiple classes of non-financial measures ("drivers of the performance") and the financial measures ("final outcome") (Campbell, Datar, Kulp, & Narayanan, 2002; Ittner, Larcker, & Randall, 2003; Bhagwat & Sharma, 2007; Wong-On-Wing et al., 2007). As such, it clearly shows the links by which specific improvements in the drivers are expected to lead to desired outcomes according to the strategy. Third, the BSC can be used as a strategic management system (Kaplan & Norton, 1996, 2001; Bhagwat & Sharma, 2007). The original balanced scorecard design identified the following four perspectives:

- *Financial perspective*: This perspective links the company to its shareholders with main attention to the question: "How do we look to our shareholders and those with a financial interest in the organization?" (). Financial goals include achieving profitability, maintaining liquidity and solvency both short term as well as long-term, growth in sales turnover and maximizing wealth of shareholders (Bhagwat & Sharma, 2007).
- *Customer perspective:* This is the second external oriented perspective that takes a look at the organization's customers, who are the crucial factor for financial success generating revenue by buying products and services. The question is: "How do our customers perceive us in term of products, services, relationships and value-added?"
- *Internal-business-process perspective:* Measures focus on the internal processes that will have the greatest impact on

customer satisfaction and achieving an organization's financial objectives. Firms should decide what processes and competencies they must excel at and specify measures for each of them.
- *Learning and growth perspective:* This perspective identifies the infrastructure that the organization must build to create long-term growth and improvement. Intense global competition requires that organizations continually improve their capabilities for delivering value to customers and shareholders. Thus the question remains: "To achieve our future vision, how will we continue to improve and create future value for our stakeholders?"

5. DEA models

Performance evaluation is an important task for a DMU to find its weaknesses so that subsequent improvements can be made. Since the pioneering work of Charnes, Cooper, and Rhodes (1978), DEA has demonstrated to be an effective technique for measuring the relative efficiency of a set of DMUs which utilize the same inputs to produce the same outputs.

Assume that there are n DMUs, (DMU_j: j = 1,2,...,n) which consume m inputs $(x_i : i = 1, 2, \ldots, m)$ to produce s outputs $(y_r : r = 1, 2, \ldots, s)$. The CCR input oriented (CCR-I) model evaluates the efficiency of DMU_o, DMU under consideration, by solving the following linear program:

$$\begin{aligned} \max \quad & \sum_{r=1}^{s} u_r\, y_{rj} \\ \text{s.t.} \quad & \sum_{i=1}^{m} w_i\, x_{io} = 1 \\ & \sum_{r=1}^{s} u_r\, y_{rj} - \sum_{i=1}^{m} w_i\, x_{ij} \leqslant 0 \quad j = 1, 2, \ldots, n \\ & w_i \geqslant \varepsilon i = 1, 2, \ldots, m \\ & u_r \geqslant \varepsilon r = 1, 2, \ldots, s \end{aligned} \tag{1}$$

where x_{ij} and y_{rj} (all nonnegative) are the inputs and outputs of the DMU_j, 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 DMU_o. Also, ε is non-Archimedean infinitesimal value for forestalling weights to be equal to zero. The CCR-I model must be run n times, once for each unit, to get the relative efficiency of all DMUs. The envelopment in CCR is constant returns to scale meaning that a proportional increase in inputs results in a proportionate increase in outputs. Banker, Charnes, and Cooper (1984) developed the BCC model to estimate the pure technical efficiency of decision making units with reference to the efficient frontier. It also identifies whether a DMU is operating in increasing, decreasing or constant returns to scale. So CCR models are a specific type of BCC models.

New applications with more variables and more complicated models are being introduced (Emrouznejad, Tavares, & Parker, 2007). In many applications of DEA, finding the most efficient DMU is desirable. Amin and Toloo (2007) proposed an integrated model for finding most efficient DMU, as follows:

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

where d_j as a binary variable represents the deviation variable of DMU_j. DMU_j is most efficient if and only if $d_j = 0$. The constraint $\sum_{j=1}^{n} d_j = n - 1$ forces among all the DMUs for only single most efficient unit. In addition, to determine the non-Archimedean epsilon, Amin and Toloo (2007) developed an epsilon model.

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 and Nalchigar (2008) proposed an integrated model which is able to find most BCC-efficient DMU. These DEA models are applicable in situations in which data of DMUs is precise. In the next section, by extending Model (2), a new DEA model is proposed which is able to find most efficient DMU while considering imprecise data.

6. Proposed approach

In this section, we combine BSC and DEA and propose a new approach for IT project selection. As mentioned above, to determine the criteria set for IT project evaluation, we use a model based on the BSC approach. In other words, the objective of the BSC for IT projects we propose here is to support the evaluation process. At the selection phase, where project proposals are evaluated, the BSC could be useful to clarify and translate the vision and strategy of the organization, and to set the appropriate criteria for a project's attractiveness (Eilat et al., 2006).

Similar to Eilat et al. (2006), our proposed BSC for IT projects looks at the five perspectives – the four original perspectives of BSC (financial, customer, internal-business-processes, learning and growth) and an uncertainty perspective, which is added to emphasize its role in IT projects. It is to be noted that the uncertainty perspective includes measures such as processes risks, human resource risks and technology risks, which are critical measures in evaluating IT projects.

First step of proposed approach is to define evaluation criteria. In this step, a decision group which includes several specialists on the field of IT management, BSC and software engineering is asked to develop a set of criteria with respect to five defined perspectives. It is to be noted that developed criteria should capture all aspects of IT projects. Consequently these experts are asked to calculate and estimate numerical values of IT projects with respect to defined criteria. The main output of first step is a decision table which includes all alternatives and their numerical data.

In second step of proposed approach, DEA method which is introduced in next section is used for ranking alternatives.

6.1. Proposed DEA method

Cooper, Park, and Yu (1999) and Kim, Park, and Park (1999) discussed that some of the outputs and inputs are imprecise data in the forms of bounded data, ordinal data, and ratio bounded data as follows:

Bounded data

$$\underline{y}_{rj} \leqslant y_{rj} \leqslant \bar{y}_{rj} \quad \text{and} \quad \underline{x}_{ij} \leqslant x_{ij} \leqslant \bar{x}_{ij} \quad \text{for} \quad r \in \text{BO}, i \in \text{BI} \tag{3}$$

where $\underline{y}_{rj}$ and $\underline{x}_{ij}$ are the lower bands and $\bar{y}_{rj}$ and $\bar{x}_{ij}$ are the upper bounds, and BO and BI represent the associated sets containing bounded outputs bounded inputs, respectively.

Weak ordinal data

$$y_{rj} \leqslant y_{rk} \quad \text{and} \quad x_{ij} \leqslant x_{ik} \quad \text{for} \quad j \neq k, r \in \text{DO}, i \in \text{DI}$$

Or to simplify the presentation,

$$y_{r1} \leqslant y_{r2} \leqslant \cdots \leqslant y_{rk} \leqslant \cdots \leqslant y_{rn} (r \in \text{DO}), \tag{4}$$

$$x_{i1} \leqslant x_{i2} \leqslant \cdots \leqslant x_{ik} \leqslant \cdots \leqslant x_{in} (i \in \text{DI}), \tag{5}$$

where DO and DI represent the associated sets containing weak ordinal outputs and inputs, respectively.

Strong ordinal data

$$y_{r1} < y_{r2} < \cdots < y_{rk} < \cdots < y_{rn} (r \in \text{SO}), \quad (6)$$
$$x_{i1} < x_{i2} < \cdots < x_{ik} < \cdots < x_{in} (i \in \text{SI}), \quad (7)$$

where SO and SI represent the associated sets containing strong ordinal outputs and inputs, respectively.

Ratio bounded data

$$L_{rj} \leqslant \frac{y_{rj}}{y_{rj_o}} \leqslant U_{rj} (j \neq j_o)(r \in \text{RO}) \quad (8)$$
$$G_{ij} \leqslant \frac{x_{rj}}{x_{ij_o}} \leqslant H_{ij} (j \neq j_o)(i \in \text{RI}) \quad (9)$$

where L_{rj} and G_{ij} represent the lower bounds, and U_{rj} and H_{ij} represent the upper bounds. RO and RI represent the associated sets containing ratio bounded outputs and inputs, respectively.

By adding Eqs. (3)–(9) added to Model (2), there will be

$$\begin{aligned} M^* = \min \quad & M \\ \text{s.t.} \quad & M - d_j \geqslant 0 \quad j = 1,2,\ldots,n \\ & \sum_{i=1}^{m} w_i x_{ij} \leqslant 1 \quad j = 1,2,\ldots,n \\ & \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} w_i x_{ij} + d_j - \beta_j = 0 \quad j = 1,2,\ldots,n \\ & \sum_{j=1}^{n} d_j = n-1 \\ & 0 \leqslant \beta_j \leqslant 1, d_j \in \{0,1\} \quad j = 1,2,\ldots,n \\ & (x_{ij}) \in \varphi_i^- \\ & (y_{rj}) \in \varphi_r^+ \\ & w_i \geqslant \varepsilon \quad i = 1,2,\ldots,m \\ & u_r \geqslant \varepsilon \quad r = 1,2,\ldots,s \end{aligned} \quad (10)$$

where $(x_{ij}) \in \varphi_i^-$ and $(y_{rj}) \in \varphi_r^+$ represent any or all of Eqs. (3)–(9).

Clearly, Model (10) is nonlinear and non-convex, because some of the outputs and inputs become unknown decision variables. Since Model (10) is nonlinear and non-convex, consequently local optimum is produced and global optimum may remains unknown.

To convert Model (10) into the linear program (LP), Zhu (2003) developed a simple approach by defining

$$\begin{aligned} X_{ij} &= w_i x_{ij} \quad \forall i,j \\ Y_{ij} &= u_r y_{rj} \quad \forall r,j \end{aligned} \quad (11)$$

Then Model (10) can be converted to Model (12) which is a LP.

$$\begin{aligned} M^* = \min \quad & M \\ \text{s.t.} \quad & M - d_j \geqslant 0 \quad j = 1,2,\ldots,n \\ & \sum_{i=1}^{m} X_{ij} \leqslant 1 \quad j = 1,2,\ldots,n \\ & \sum_{r=1}^{s} Y_{rj} - \sum_{i=1}^{m} X_{ij} + d_j - \beta_j = 0 \quad j = 1,2,\ldots,n \\ & \sum_{j=1}^{n} d_j = n-1 \\ & 0 \leqslant \beta_j \leqslant 1, d_j \in \{0,1\} \quad j = 1,2,\ldots,n \\ & X_{ij} \in \tilde{\rho}_i^- \\ & Y_{rj} \in \tilde{\rho}_r^+ \\ & X_{ij} \geqslant \varepsilon^* \quad \forall i,j \\ & Y_{rj} \geqslant \varepsilon^* \quad \forall r,j \end{aligned} \quad (12)$$

where φ_i^- and φ_r^+ are replaced by $\tilde{\rho}_i^-$ and $\tilde{\rho}_r^+$ with:

- *Bounded data:* $\underline{y}_{rj} u_r \leqslant Y_{rj} \leqslant \bar{y}_{rj} u_r, \quad \underline{x}_{ij} w_i \leqslant X_{ij} \leqslant \bar{x}_{ij} w_i$.
- *Ordinal data:* $Y_{rj} \leqslant Y_{rk}, \quad X_{ij} \leqslant X_{ik} \quad \forall j \neq k$ for some r,i.
- *Ratio bounded data:* $L_{rj} \leqslant \frac{Y_{rj}}{Y_{rj_o}} \leqslant U_{rj}$ and $G_{ij} \leqslant \frac{X_{rj}}{X_{ij_o}} \leqslant H_{ij} (j \neq j_0)$.
- *Cardinal data:* $Y_{rj} = \hat{y}_{rj} u_r$ and $X_{ij} = \hat{x}_{ij}$, where $\hat{y}_{rj}$ and $\hat{x}_{ij}$ represent cardinal data.

Indeed Model (12) is extended version of Amin and Toloo's model. Hence, the following LP, which is extended version of Amin and Toloo (2007) epsilon model, is proposed to determine the non-Archimedean epsilon:

$$\begin{aligned} \varepsilon^* = \max \quad & \varepsilon \\ \text{s.t.} \quad & \sum_{i=1}^{m} X_{ij} \leqslant 1 \quad j = 1,2,\ldots,n \\ & \sum_{r=1}^{s} Y_{rj} - \sum_{i=1}^{m} X_{ij} \leqslant 0 \quad j = 1,2,\ldots,n \\ & X_{ij} \in \tilde{\rho}_i^- \\ & Y_{rj} \in \tilde{\rho}_r^+ \\ & X_{ij} - \varepsilon \geqslant 0 \quad \forall i,j \\ & Y_{rj} - \varepsilon \geqslant 0 \quad \forall r,j \end{aligned} \quad (13)$$

using Model (12), we propose a new method for prioritizing DMUs with cardinal and ordinal data. The proposed method, which is emanated on a simple idea, is described as follows:

Step 0: Let $T = \phi$ and e = number of DMUs to be ranked.
Step 1: Solve following model:

$$\begin{aligned} M^* = \min \quad & M \\ \text{s.t.} \quad & M - d_j \geqslant 0 \quad j = 1,2,\ldots,n \\ & \sum_{i=1}^{m} X_{ij} \leqslant 1 \quad j = 1,2,\ldots,n \\ & \sum_{r=1}^{s} Y_{rj} - \sum_{i=1}^{m} X_{ij} + d_j - \beta_j = 0 \quad j = 1,2,\ldots,n \\ & \sum_{j=1}^{n} d_j = n-1 \\ & d_j = 1 \quad \forall j \in \text{T} \\ & 0 \leqslant \beta_j \leqslant 1, d_j \in \{0,1\} \quad j = 1,2,\ldots,n \\ & X_{ij} \in \tilde{\rho}_i^- \\ & Y_{rj} \in \tilde{\rho}_r^+ \\ & X_{ij} \geqslant \varepsilon^* \quad \forall i,j \\ & Y_{rj} \geqslant \varepsilon^* \quad \forall r,j \end{aligned} \quad (14)$$

Suppose in optimal solution $d_t^* = 0$.

Step 2: Let $\text{T} = \text{T} \cup \{t\}$.
Step 3: If $|\text{T}| = e$, then stop; otherwise go to Step 1.

Indeed in Step 1 of proposed algorithm, a DMU is identified as most CCR-efficient unit. After entering this DMU to T in Step 2, in Step 3 if all DMUs are ranked, the algorithm finishes, else it goes to next iteration. By continuing the iterations to e times, decision maker is able to rank DMUs in presence of both cardinal and ordinal data. In second step of suggested approach, this DEA method could be used to prioritize IT projects on the basis of decision table. In the next section, applicability of proposed approach for ranking IT projects with imprecise data is illustrated.

7. Illustrative example

As mentioned in Section 2, Iran Ministry of Science, Research and Technology identified three alternatives for implementing IDC project. To evaluate the attractiveness of project proposals, or the success of on-going or completed projects, appropriate criteria should be determined. At the minimum, it should include criteria that managers feel are most important, and for which they can provide hard data or firm opinions. It is also important that it be complete but not redundant, and that it be linked to the short- and long-term objectives of the organization (Eilat et al., 2006). To do this, a set of experts were selected in mentioned ministry. By reviewing criteria in previous researches and on basis of 5 perspectives, these specialists developed a set which includes 14 criteria. The criteria that are to be minimized are viewed as inputs whereas the criteria to be maximized are considered as outputs. Table 2 presents data of alternatives. Because of difficulties in calculation of precise data, some data are in ordinal format, some are interval. For instance, calculation of a precise numerical value for "scalability" and "Compliance with stakeholders needs" of alternatives is difficult for specialists. Hence, these qualitative variables are measured on an ordinal scale. In addition, data for "Customer satisfaction" and "Service Availability" are bounded.

In first alternative, all project activities are done by Iran Ministry of Science, Research and Technology and its internal resources and mentioned ministry owns IDC. To do this, technical capabilities, include technical specialty and skills and budget should be provided by ministry. It is to be noted that technical specialty and skills affect time required to complete the project. Moreover, this alternative cause ministry to have a comprehensive control on the project activities and resources. As a shortcoming, this alternative is complex for ministry and does not match with usual process and functions of ministry.

In second alternative, which is joint venture, mentioned ministry signs a contract with external companies. Because of contribution of private sector, this alternative provides ministry with more expertise and specialty than first alternative. However, this alternative is less secure than first one.

In third alternative, which is service oriented, all services will be prepared and maintained by a third party. The ministry, in this method, will define the functional and non-functional requirement for the needed services. The required services will be implemented by the third party and employed by the ministry under a service level agreement contract for a specific time and cost.

Now, by using data depicted in Table 2, we show applicability of proposed method. Data in Table 2 could be presented as follows:

- Cost:

  $\varphi_1^- = \{x_{11} = 110084; x_{12} = 97007.2; x_{13} = 28243\}$ (Cardinal data)

- Time:

  $\varphi_2^- = \{x_{21} = 40; x_{22} = 34; x_{23} = 15\}$ (Cardinal data)

- Human resource:

  $\varphi_3^- = \{x_{31} = 65; x_{32} = 25; x_{33} = 5\}$ (Cardinal data)

- Cost reduction:

  $\varphi_1^+ = \{y_{11} = 20; y_{12} = 15; y_{13} = 70\}$ (Cardinal data)

- Control:

  $\varphi_2^+ = \{y_{21} = 85; y_{22} = 65; y_{23} = 50\}$ (Cardinal data)

- Security:

  $\varphi_3^+ = \{y_{31} = 90; y_{32} = 80; y_{33} = 55\}$ (Cardinal data)

- Reliability:

  $\varphi_4^+ = \{y_{41} = 85; y_{42} = 65; y_{43} = 50\}$ (Cardinal data)

- Customer satisfaction:

  $\varphi_5^+ = \{40 \leqslant y_{51} \leqslant 50; 70 \leqslant y_{52} \leqslant 85; 80 \leqslant y_{53} \leqslant 90\}$ (Bounded data)

- Service availability:

  $\varphi_6^+ = \{20 \leqslant y_{61} \leqslant 30; 45 \leqslant y_{62} \leqslant 53; 60 \leqslant y_{63} \leqslant 70\}$ (Bounded data)

- Compliance with stakeholders needs:

  $\varphi_7^+ = \{y_{73} \leqslant y_{71} \leqslant y_{72}\}$ (Ordinal data)

- Scalability:

  $\varphi_8^+ = \{y_{81} \leqslant y_{81} \leqslant y_{83}\}$ (Ordinal data)

- Processes risks:

  $\varphi_9^+ = \{y_{91} = 32.1; y_{92} = 49.8; y_{93} = 32.45\}$ (Cardinal data)

- Human resource risks:

  $\varphi_{10}^+ = \{y_{101} = 27; y_{102} = 29.9; y_{103} = 12.2\}$ (Cardinal data)

- Technology risks:

  $\varphi_{11}^+ = \{y_{111} = 25.8; y_{112} = 25.05; y_{113} = 23.15\}$ (Cardinal data)

According to Zhu's approach,

$$X_{ij} = w_i x_{ij} \quad \forall i, j$$
$$Y_{ij} = u_r y_{rj} \quad \forall r, j$$

Hence,

$$\tilde{\rho}_1^- = \{X_{11} = 110084w_1; X_{12} = 97007.2w_1; X_{13} = 28243w_1\}$$
$$\tilde{\rho}_2^- = \{X_{21} = 40w_2; X_{22} = 34w_2; X_{23} = 15w_2\}$$
$$\tilde{\rho}_3^- = \{X_{31} = 65w_3; X_{32} = 25w_3; X_{33} = 5w_3\}$$
$$\tilde{\rho}_1^+ = \{Y_{11} = 20\mu_1; Y_{12} = 15\mu_1; Y_{13} = 70\mu_1\}$$
$$\tilde{\rho}_2^+ = \{Y_{21} = 85\mu_2; Y_{22} = 65\mu_2; Y_{23} = 50\mu_2\}$$
$$\tilde{\rho}_3^+ = \{Y_{31} = 90\mu_3; Y_{32} = 80\mu_3; Y_{33} = 55\mu_3\}$$
$$\tilde{\rho}_4^+ = \{Y_{41} = 85\mu_4; Y_{42} = 65\mu_4; Y_{43} = 50\mu_4\}$$
$$\tilde{\rho}_5^+ = \{40\mu_5 \leqslant Y_{51} \leqslant 50\mu_5; 70\mu_5 \leqslant Y_{52} \leqslant 85\mu_5; 80\mu_5 \leqslant Y_{53} \leqslant 90\mu_5\}$$
$$\tilde{\rho}_6^+ = \{20\mu_6 \leqslant Y_{61} \leqslant 30\mu_6; 45\mu_6 \leqslant Y_{62} \leqslant 53\mu_6; 60\mu_6 \leqslant Y_{63} \leqslant 70\mu_6\}$$
$$\tilde{\rho}_7^+ = \{Y_{73} \leqslant Y_{71} \leqslant Y_{72}\}$$
$$\tilde{\rho}_8^+ = \{Y_{82} \leqslant Y_{81} \leqslant Y_{83}\}$$
$$\tilde{\rho}_9^+ = \{Y_{91} = 32.1\mu_9; Y_{92} = 49.8\mu_9; Y_{93} = 32.45\mu_9\}$$
$$\tilde{\rho}_{10}^+ = \{Y_{101} = 27\mu_{10}; Y_{102} = 29.9\mu_{10}; Y_{103} = 12.2\mu_{10}\}$$
$$\tilde{\rho}_{11}^+ = \{Y_{111} = 25.8\mu_{11}; Y_{112} = 25.05\mu_{11}; Y_{113} = 23.15\mu_{11}\}$$

Solving Model (13) by WinQSB for data presented in Table 2 results in $\varepsilon^* = 0.01819132$. Using this value and solving Model (14) by WinQSB, DMU_3 is easily identified as most efficient alternative $\left(d_3^* = 0, d_{j\neq 3}^* = 1\right)$. In second iteration of proposed method, a constraint $d_3 = 1$ is added to model. This added constraint ensure that in second iteration of algorithm, DMU_3 will not again identified as most efficient unit. By solving Model (14) in second iteration, optimal solution is $\left(d_2^* = 0, d_{j\neq 2}^* = 1\right)$ which implies that DMU_2 is second efficient alternative. Obviously, DMU_1 has lowest rank among three alternatives. Table 3 summarizes the results of proposed method.

On the basis of this result, alternative 3 is recommended to Iran Ministry of Science, Research and Technology. This ministry could utilize BSC as a comprehensive method for defining IS projects

Table 2
Data of alternatives.

DEA	BSC perspectives	Criteria	Alternatives		
			1	2	3
Inputs	Resources (Investment)	Cost (Million Rials)	110084	97007.2	28243.6
		Time (Months)	40	34	15
		Human resource	65	25	5
Outputs	Financial perspective	Cost reduction	20	15	70
	Internal business perspective	Control	85	65	50
		Security	90	80	55
	Customer perspective	Reliability	85	65	50
		Customer satisfaction (bounded data)	[40–50]	[70–85]	[80–90]
		Service availability (bounded data)	[20–30]	[45–53]	[60–70]
		Compliance with stakeholders needs (ordinal data)[a]	2	1	3
	Learning perspective	Scalability (ordinal data)	2	3	1
	Uncertainty perspective	Processes risks	32.1	49.8	32.45
		Human resource risks	27	29.9	25.05
		Technology risks	32.45	12.2	23.15

[a] Ranking such that 1 ≡ highest rank,. . .,3 ≡ lowest rank ($y_{72} \geqslant y_{71} \geqslant y_{73}$).

Table 3
Ranking of alternatives.

Rank	Alternative
1	3
2	2
3	1

evaluation criteria. More over proposed DEA method makes this ministry able to identify and rank best proposals.

8. Conclusion

The use of IT to gain strategic dominance and its widespread use in many business functions has made IT project selection a major component of effective IT management. Selecting the right projects is a critical business activity that has been recognized and repeatedly emphasized by many researchers. In this paper, integrating widely recognized techniques, BSC and DEA, a new approach for ranking IT projects has been introduced. The proposed approach exploits BSC as a framework for defining IT project selection criteria. It is to be noted that proposed BSC for IT projects considers five perspectives – four original perspectives of BSC and an uncertainty perspective, which is added to emphasize its role in IT projects. Furthermore, a new DEA method for ranking IT projects with imprecise data introduced in this paper. As an advantage, this method finds most efficient IT project by solving just one LP. It should be noted that to rank n DMU, proposed method requires decision maker to solve $n-1$ LPs. Applicability of proposed approach has been shown in Iran Ministry of Science, Research and Technology.

References

Amin, Gholam R., & Toloo, M. (2007). Finding the most efficient DMUs in DEA: An improved integrated model. *Computers and Industrial Engineering, 52*, 71–77.

Badri, M. A., Davis, D., & Davis, D. (2001). A comprehensive 0–1 goal programming model for project selection. *International Journal of Project Management, 19*, 243–252.

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiency in data envelopment analysis. *Management Science, 30*, 1078–1092.

Bhagwat, R., & Sharma, M. K. (2007). Performance measurement of supply chain management: A balanced scorecard approach. *Computers and Industrial Engineering, 53*, 43–62.

Bremser, W., & Chung, Q. B. (2005). A framework for performance measurement in the e-business environment. *Electronic Commerce Research and Applications, 4*, 395–412.

Camanho, A. S., & Dyson, R. G. (2005). Cost efficiency measurement with price uncertainty: A DEA application to bank branch assessments. *European Journal of Operational Research, 161*, 432–446.

Campbell, D., Datar, S., Kulp, S., & Narayanan, V. (2002). Using the balanced scorecard as a control system for monitoring and revising corporate strategy. *Working paper*. Harvard NOM Research.

Chand, D., Hachey, J. H., Owhoso, V., & Vasudevan, S. (2005). A balanced scorecard based framework for assessing the strategic impacts of ERP systems. *Computers in Industry, 56*, 558–572.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2*, 429–444.

Chen, C. T., & Cheng, H. L. (2008). A comprehensive model for selecting information system project under fuzzy environment. *International Journal of Project Management*. doi:10.1016/j.ijproman.2008.04.001.

Chen, X., Skully, M., & Brown, K. (2005). Banking efficiency in China: Application of DEA to pre- and post-deregulation eras: 1993–2000. *China Economic Review, 16*, 229–245.

Cooper, W. W., Park, K. S., & Yu, G. (1999). IDEA and AR-IDEA: Models for dealing with imprecise data in DEA. *Management Science, 45*, 597–607.

Edirisinghe, N. C. P., & Zhang, X. (2007). Generalized DEA model of fundamental analysis and its application to portfolio optimization. *Journal of Banking and Finance, 31*, 3311–3335.

Eilat, H., Golany, B., & Shtub, A. (2006). R&D project evaluation: An integrated DEA and balanced scorecard approach. *Omega*. doi:10.1016/j.omega.2006.05.002.

Emrouznejad, A., Tavares, G., & Parker, B. (2007). A bibliography of data envelopment analysis (1978–2003). *Socio-Economic Planning Sciences, 38*, 159–229.

Ertay, T., Ruan, D., & Tuzkaya, U. R. (2006). Integrating data envelopment analysis and analytic hierarchy for the facility layout design in manufacturing systems. *Information Sciences, 176*, 237–262.

Han, C. H., Kim, J. K., Choi, S. H., & Kim, S. H. (1998). Determination of information system development priority using quality function development. *Computers and Industrial Engineering, 35*, 241–244.

Hasan, H., & Tibbits, H. (2000). Strategic management of electronic commerce: An adaption of the balanced scorecard". *Electronic Networking Applications and Policy, 10*(5).

Holtsnider, B., & Jaffe, D. (2007). *IT manager's handbook: Getting your new job done* (2nd ed.). Morgan Kaufmann Publishers.

Ittner, C., Larcker, D., & Randall, T. (2003). Performance implications of strategic performance measurement in financial services firms. *Accounting, Organizations and Society, 28*, 715–741.

Johnes, J. (2006). Measuring teaching efficiency in higher education: An application of data envelopment analysis to economics graduates from UK Universities 1993. *European Journal of Operational Research, 174*, 443–456.

Kaplan, R. S., & Norton, D. P. (1992). The balanced scorecard: Measures that drive performance. *Harvard Business Review* (January–February), 71–79.

Kaplan, R. S., & Norton, D. (1996). *The balanced scorecard – translating strategy into action*. Boston, MA: Harvard Business School Press.

Kaplan, R. S., & Norton, D. (2001). *The strategy-focused organization*. Harvard: Harvard Business School Press.

Kaplan, R. S., & Norton, D. P. (2004). Organizational capital: Leadership, alignment, and teamwork. *Balanced Scorecard Report. Article Reprint B0403A*, March–April, 1–7.

Kengpol, A., & Tuominen, M. (2006). A framework for group decision support systems: An application in the evaluation of information technology for logistics firms. *International Journal of Production Economics, 101*, 159–171.

Keyes, J. (2005). *Implementing the it balanced scorecard, aligning IT with corporate strategy*. Auerbach Publications Taylor and Francis Group.

Kim, S. H., Park, C. G., & Park, K. S. (1999). An application of data envelopment analysis in telephone offices evaluation with partial data. *Computers and Operations Research, 26*, 59–72.

Lee, J. W., & Kim, S. H. (2001). An integrated approach for interdependent information system project selection. *International Journal of Project Management, 19*, 111–118.

Liu, F. H. F., & Hai, H. L. (2005). The voting analytic hierarchy process method for selecting supplier. *International Journal of Production Economics, 97*, 308–317.

Liu, S. T. (2008). A fuzzy DEA/AR approach to the selection of flexible manufacturing systems. *Computers and Industrial Engineering, 54*, 66–76.

Mahmudi, J., Nalchigar, S., & Ebrahimi, S. B. (2008). Selecting the most efficient information system project using data envelopment analysis: Case Study of Iran Ministry of Commerce. In *Proceeding of 2008 international joint conference on e-Commerce, e-Administration, e-Society, and e-Education*, March.

Maltz, A., Shenhar, A., & Reilly, R. (2003). Beyond the balanced scorecard: Refining the search for organizational success measures. *Long Range Planning, 36*, 187–204.

Mannino, M., Hong, S. N., & Choi, I. J. (2008). Efficiency evaluation of data warehouse operations. *Decision Support Systems, 44*, 883–898.

Marchewka, J. T. (2003). *Information technology project management, providing measurable organizational value*. John Wiley and Sons.

Rickards, R. C. (2007). BSC and benchmark development for an e-commerce SME. *Benchmarking: An International Journal, 14*, 222–250.

Ruiz-Mercader, J., Merono-Cerdan, A. L., & Sabater-Sanchez, R. (2006). Information technology and learning: Their relationship and impact on organisational performance in small businesses. *International Journal of Information Management, 26*, 16–29.

Santhanam, R., & Kyparisis, J. (1995). A multiple criteria decision model for information system project selection. *Computers and Operations Research, 22*, 807–816.

Schniederjans, M. J., & Santhanam, R. (1993). A multi-objective constrained resource information system project selection method. *European Journal of Operational Research, 70*, 244–253.

Schniederjans, M. J., & Wilson, R. L. (1991). Using the analytic hierarchy process and goal programming for information system project selection. *Information and Management, 20*, 333–342.

Shafer, S. M., & Byrd, T. A. (2000). A framework for measuring the efficiency of organizational investments in information technology using data envelopment analysis. *Omega, 28*, 125–141.

Sowlati, T., Paradi, J. C., & Suld, C. (2005). Information systems project prioritization using data envelopment analysis. *Mathematical and Computer Modeling, 41*, 1279–1298.

Toloo, M., & Nalchigar, S. (2008). A new integrated DEA model for finding most BCC-efficient DMU. *Applied Mathematical Modelling*. doi:10.1016/j.apm.2008.02.001.

Tseng, S. M. (2008). The effects of information technology on knowledge management systems. *Expert Systems with Applications, 35*, 150–160.

Wang, J. J., & Yang, D. L. (2007). Using a hybrid multi-criteria decision aid method for information systems outsourcing. *Computers and Operations Research, 34*, 3691–3700.

Weber, C. A., Current, J. R., & Desai, A. (1998). Non-cooperative negotiation strategies for vendor selection. *European Journal of Operational Research, 108*, 208–223.

Wen, H. J., Lim, B., & Huang, H. L. (2003). Measuring e-commerce efficiency: A data envelopment analysis (DEA) approach. *Industrial Management and Data Systems*(103/9), 703–710.

Wong-On-Wing, B., Guo, L., Li, W., & Yang, D. (2007). Reducing conflict in balanced scorecard evaluations. *Accounting, Organizations and Society, 32*, 363–377.

Zhu, J. (2003). Imprecise data envelopment analysis (IDEA): A review and improvement with an application. *European Journal of Operational Research, 144*, 513–529.