An integrated Information Technology/Information System (IT/IS) Investment Evaluation Framework

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ABSTRACT
This paper presents an integrated IT/IS investment evaluation framework based on IT/IS investment evaluation and business values and IS Success factors. The proposed framework involves different parts of organization or stakeholders whom are influenced by IT/IS investment decisions. It uses Delphi technique for selecting and grouping IT/IS investment criteria. Then, selected criteria are weighted by Analytical Hierarchy Process (AHP) technique. Finally, Data Envelopment Analysis (DEA) technique is used for determining the efficient and inefficient alternatives or decision making units (DMUs). This framework is more advanced, practical and reliable than current techniques for IT/IS investments. The framework is applied to a large gas refinery and the results showed its ease of use and applicability.

Keywords: IT/IS investments evaluation, IT/IS Business value, Delphi, DEA, AHP

1 INTRODUCTION

The importance of success evaluation of IT/IS related investments is being stressed by growing amounts of capital investment in IT/IS in organizations. Doherty and McAulay (Doherty and McAulay, 2002) stated this question for future research "Is a simple evaluation framework which typically addresses costs and benefits, appropriate for the evaluation of IT?" Gunasekaran, Ngai and McGaughey (2005) stated the lack of a complete, efficient and effective methodology for justifying IT/IS on a small or large scale. To that end, this study reviewed the IT/IS investments and IS success literatures, and introduced an efficient framework based on DEA, AHP and Delphi technique to provide an easy and useful evaluation for IT/IS investments. The remaining of the article is as follow. First, the IT/IS investment and business value and IS success literatures are reviewed and presented. Next, the proposed integrated framework based on AHP, DEA and Delphi techniques is presented. Finally, the proposed framework is applied to a large gas refinery and its results are discussed and concluding remarks are presented and guidelines for future research are also presented.

2 LITERATURE REVIEW

2.1 IT/IS Investments Evaluation

IT investment studies are important, especially in the current business environment, because of the large sums of money spent on IT/IS projects (Gunasekaran, Ngai, and McGaughey, 2005). However, the justification of IT is a complex issue due to many intangibles and non-financial benefits which are inherent in the implementation of IT (Swamidass and Kotha, 1998, Irani, 1999, Irani and Ezingeard, Grieve and Race, 1999, Gunasekaran, Love, Rahimi and Miele, 2001). Farbey, Land, and Targett (1992) identified that companies that used traditional approaches to justify the implementation of IT indicated a degree of uncertainty about how to measure the full impact of their investment. They state that there is no 'best' appraisal technique that addresses 'all' project considerations. Essentially, each investment displays its own characteristics, and offers a range of benefits and costs (Gunasekaran, Love, Rahimi and Miele, 2001). There are few universally accepted guidelines for evaluating IT projects, with much research suggesting that many companies have no formal IT justification process, and lack adequate post implementation audit techniques, against which project objectives can be measured (Kumar, 1990, Kennedy and Mills, 1992, Gunasekaran, Love, Rahimi and Miele, 2001). This claim is further substantiated by Hochstrasser (1992) and Hochstrasser and Griffiths (1991) who reported in a survey, that only 16 percent of

companies sampled were using rigorous methods to evaluate their IT investments (Apostolopoul and Pramataris, 1997, Gunasekaran, Love, Rahimi and Miele, 2001).

Apostolopoulos and Pramataris (1997) proposed a certain methodology for evaluating investments in information technology, stated that the most traditional and widely used techniques for investment evaluation, both in IT and in general, are characterized by a cost-benefit analysis expressed in financial terms such as NPV and IRR. They proposed some enhancements in traditional investment evaluation methods such as adopting technical criteria, cost of changing the organizational structure and the system's operational cost, etc (Apostolopoul and Pramataris, 1997). Rodney and Sherif (Rodney and Sherif, 2002) presented a decision making framework for selecting IT/IS projects based on the multi-criteria utility theory (MCUT) and Information Economics (IE) principles. According to Farbey, Land and Targett (1992) appraisal technique matrix, the IE approach is one of the recommended investment appraisal techniques for strategic investments. IE offers a framework within which the total positive and negative impacts of IT/IS projects on enterprise can be discussed and evaluated. The major advantage to adopting an IE approach is that it goes beyond the above traditional "business value" techniques and introduces the concepts of values and risks (Rodney and Sherif, 2002). IE provides the means to analyze and select IT/IS investments that contribute to organizational performance based upon business value and risk to the organization. The business domain factors are as followings: Return on investment, Strategic match, Competitive advantage, Organizational risk. Moreover, the technology domain factors include: Strategic architecture alignment, Definitional uncertainty risk, Technology infrastructure risk. IE examines the value and risk that technology contributes to the business and technology domain separately, providing a more accurate assessment of the impact of the investment (Rodney and Sherif, 2002). Koen and Roger, Milis and Mercken (2004) studied, examined and classified evaluation techniques used to justify capital investments in ICT. They stated several reasons for not using capital investment appraisal techniques (CIAT) techniques to evaluate ICT investments:

- Involving different parties in a new ICT project.
- Conservatism: Traditional CIATs are conservative in nature and low risk projects are bolstered.
- Measuring benefits: Due to the supportive nature of ICT investments, compared with other capital investments, the ratio of tangible to intangible and hidden benefits tends to be much smaller for ICT projects;
- Measuring costs: Although costs are more easily measured than benefits, a substantial part of the costs of an ICT investment are also intangible or hidden.

Based on the inappropriateness of traditional CIATs for evaluate ICT, efforts are made to adjust current techniques or present completely different and new alternatives. Adjusted cost/benefits estimates, discount rate sensitivity are samples of adjustments to the traditional CIATs. The strategic fit, information economics (Parker and Benson, 1989) and options model are samples of new techniques. But both of above mentioned categories has their own strengths and weaknesses. Thus, several authors tried to combine different techniques and methods to rub out the weaknesses inherent to the use of a single technique. Kaplan and Norton developed a framework called BSC is one of them in which four groups of measurable items (= four scorecards) are:

1. The financial scorecard contains the traditional financial performance measures.
2. The customer scorecard deals with the question ‘‘how do customers see us?’’
3. The internal business scorecard provides goals and measures concerning the internal operations.
4. The fourth scorecard deals with the innovation and learning perspective.

This framework is a mixture of (traditional) CIATs and new evaluation methods. On the one hand, the (traditional) finance based evaluation techniques are not abandoned (financial perspective) and on the other hand, the metrics used in a balanced scorecard framework are aligned to the company’s strategy and business aims, which stimulate a strategic fit. The balanced scorecard forces management to take a broad view on ICT investments. Many different evaluation techniques can be integrated into this framework (Milis and Mercken, 2004).

Gunasekaran et al (Gunasekaran, Ngai, and McGaughey, 2005) started the development of a complete and integrated framework for IT/IS justification, but acknowledge that much work remains to be done to move it forward toward the aforementioned goal of a complete and integrated framework. Their framework classified the literature into four areas pertaining to IT/IS justification: General IT/IS evaluation concepts, Evaluation criteria for justifying IT/IS projects, Techniques and tools used for IT/IS evaluation and justification, Evaluation of the implementation of IT/IS projects. (Gunasekaran, Ngai and McGaughey, 2005).

Chou, Seng and Tzeng (2005) emphasized the need for an easy, cost-effective, and collective manner and tool for evaluation of new IT/IS investment projects and proposed a new approach based on the fuzzy multi-criteria decision model (FMCDM), featuring a 2-stage evaluation process with 26 criteria for IT/IS investment.

2.2 IT/IS Business Value and IS Success

Premkumar and King (1992) in evaluating empirically the IS planning and IS role in the organization and their relationship, defined the "role of IS" in the organization as the mission of the IS function and its actual impact on the firm's business operation. McFarlan, McKenney, and Pyburn (1983) selected "strategic grid" as framework for defining the role of IS. Their framework which is based on both the mission of IS and the actual impact of IS classified organizations in four groups: strategic, turnaround, factory and support.

Organizations in the "strategic" group are critically dependent on the smooth functioning of IS applications for their daily operations and have applications under development that are vital to their competitive success. Organizations in the "turnaround" group are not dependent on IS support for their current operations. However they have applications under development that are vital for their long-term strategic objectives. Organizations in the "factory" group are critically dependent on IS for their daily operations, but their future application development is not critical. Organizations in the "support" group are critically dependent on IS for neither their present operations nor their future operations. They may have large IS departments but they are not critical to the organization's business (Premkumar and William, 1992).

Cronk and Fitzgerald (1999) stated that absence of an adequate definition of "IS business value" is a major omission in this research area. The term "IS business value" had its roots in the IS effectiveness literature of the 1980s and its meaning has been evolving through the 1990s. They stated that part of the current confusion may be due to the plethora of terms used to describe the concept. These include IS effectiveness (Iivari and Ervasti, 1994), IS success (DeLone and McLean, 1992), IS influence (Mason, 1978), IS impact (Vogel and Nunamaker, 1990, Gurbaxani and Whang, 1991), and "IS business value". However, of all these terms, common usage suggests that IS effectiveness and "IS business value" are the most closely related (Cronk and Fitzgerald, 1999).

DeLone and McLean's (DeLone and McLean, 1992) model is considered the most comprehensive information system assessment model available in the information system literature (Myers, Kappelman and Prybutok, 1997). Mirani & Lederer (Mirani and Lederer, 1998) in identifying and operationalizing dimensions of organizational benefits of IS projects, based on Weil (Weil, 1992) framework, which was derived and extended from Turner and Lucas (1985) known organizational objectives of IT investments as strategic, informational and transactional objectives. Strategic IT changes an organization's product or the way in which organization competes. Informational IT provides the information and communication infrastructure of the organization. Transactional IT supports operational management and cuts costs. It is possible for an IS to have objectives of all three kinds (Mirani and Lederer, 1998).

2.3 Analytical Hierarchy Process (AHP) and Data Envelopment Analysis (DEA)

AHP was developed by Saaty (Saaty, 1980) to determine the relative priorities or weights to be assigned to different criteria and alternatives that characterize a decision (Lin and Yang, 1996). This method divides a complicated system under study into a hierarchical system of elements. Pair-wise comparisons are made of the elements of each hierarchy by means of a nominal scale. Then, comparisons are quantified to establish a comparison matrix, after which the eigenvector of the matrix is derived, signifying the comparative weights among various elements of a certain hierarchy. Finally, the Eigenvalue is used to assess the strength of the consistency ratio of the comparative matrix and determine whether to accept the information.

DEA is a non-parametric method that uses linear programming to calculate the efficiency in a given set of decision-making units (DMUs). In this section we only describe the DEA models used in our framework. Due to this reason that, we only uses DEA for determining efficient and inefficient DMUs and we need not ranking efficient DMUs, we select constant returns to scale (CRS) and known as CCR model. On the other hand, according to the nature of our study, in which we want to determine alternative IT/IS investments benefits through the resources which they use, we selected output-oriented model. In other word, with constant inputs we want to determine extent that each power alternative IT/IS investments benefits the organization Zhu (Zhu, 2003).

Max θ

s.t.

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \mathrm{X}_{\mathrm{io}} \quad i = 1,2,...m$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{r0}\,\theta \quad r = 1,2,...s$$

$$\lambda_j \geq 0$$

2.4 Delphi Technique

The Delphi method, which was designed to overcome the interpersonal behavior problems of group and to converge the use of expert opinion through polling was introduced by Helmer and Dalkey in the early 1960s. Linstone and Turoff (Linston and Turoff 1975) explain the process of conventional Delphi as follows: ``A small monitor team designs a questionnaire which is sent to a larger respondent group. After the questionnaire is returned, the monitor team summarizes the results and, based on the results, develops a new questionnaire for the respondent group. The respondent group is given at least one opportunity to re-evaluate its original answer based on examination of the group response. To a degree, this form of Delphi is a combination of polling procedure and a conference procedure which attempts to shift a significant portion of the effort needed for individuals to communicate from the larger respondent group to the smaller monitor team.

3 THE PROPOSED FRAMEWORK

Due to the inadequacy in traditional justification methods which have been used for IT/IS investments, this article attempt to propose a framework that overcome the mentioned problems in evaluation of IT/IS investments. It has been suggested that in evaluation of IT/IS investments, one must consider variety of variables such as strategic, tactical, intangible and technical aspects (Apostolopoul and Pramataris, 1997, Gunasekaran, P. and Love and Rahimi and Miele, 2001). According to the literature review, there are several criteria for IT/IS evaluation. Several researches proposed hierarchical or categorized structure such as balanced scorecard (BSC) framework (Milis and Mercken, 2004) and hierarchical criteria (Rodney and Sherif, 2002; Chou and Seng and Tzeng, 2005). Gunasekaran, Ngai and McGaughey (2005) stated the lack of an integrated model for IT/IS investments evaluation and therefore this study presents an integrated Delphi, analytical hierarchical process (AHP) and data envelopment analysis (DEA) approach for IT/IS investment evaluation. Delphi technique is used for selecting appropriate IT/IS investment inputs and outputs, AHP is used for weighting hierarchical structure and DEA is used for evaluation of IT/IS investment. According to the fact that different constituencies have different perspectives, we must consider the stakeholders who do the evaluation (Mirani and Lederer, 1998, Chou and Seng and Tzeng, 2005). For instance, users, IS professionals and managers may differ about the nature of benefits and costs associated with an IS development projects. The proposed framework is shown in Figure 1 and is composed of the following steps:

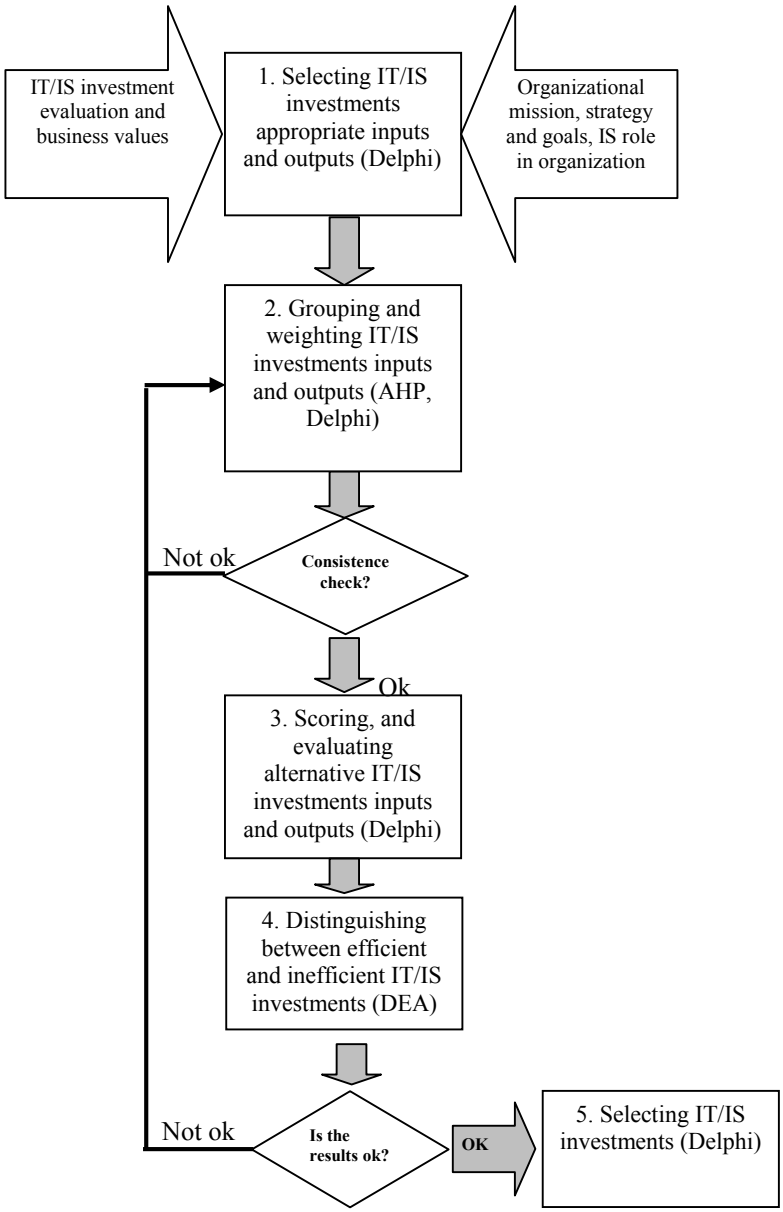

Figure 1: The integrated Delphi, AHP and DEA framework

1. Selecting IT/IS investment inputs and outputs: Organizations must identify the proposed IT/IS investments criteria. 26 validated criteria are selected for IT/IS investment projects (Chou, Seng and Tzeng, 2005). The IT business value and IT impact on organization literature also provide good insights on IT/IS investments evaluation for defining and selecting IT/IS investments. Then, we must define the objectives of evaluating IT/IS with reference to organizational mission, strategy and goals (Gunasekaran, Ngai and McGaughey, 2005). The strategic significance of IT/IS in organizational performance and the nature of business, drives the need for a particular system. Other important factor is IS role in organization. For example based on the framework for the role of IS, organizations in the "turnaround" group, may not select the criteria about existing IT portfolio relationships with proposed IT/IS investments (McFarlan, McKenney and Pyburn, 1983). By considering the above factors, organizations must select their criteria.

2. There are several criteria for IT/IS investments evaluation. On the other hand, some criteria are similar in type. For example, 3 main groups of indicators in the framework are costs, benefits and risks. Especially by decreasing the number of inputs and outputs for constant number of IT/IS investments, the result of DEA model will improve. Therefore organizations must group their selected criteria in a hierarchical structure. The integrated Delphi AHP and DEA framework of this study groups criteria according to Figure 2 for IT/IS investment evaluation

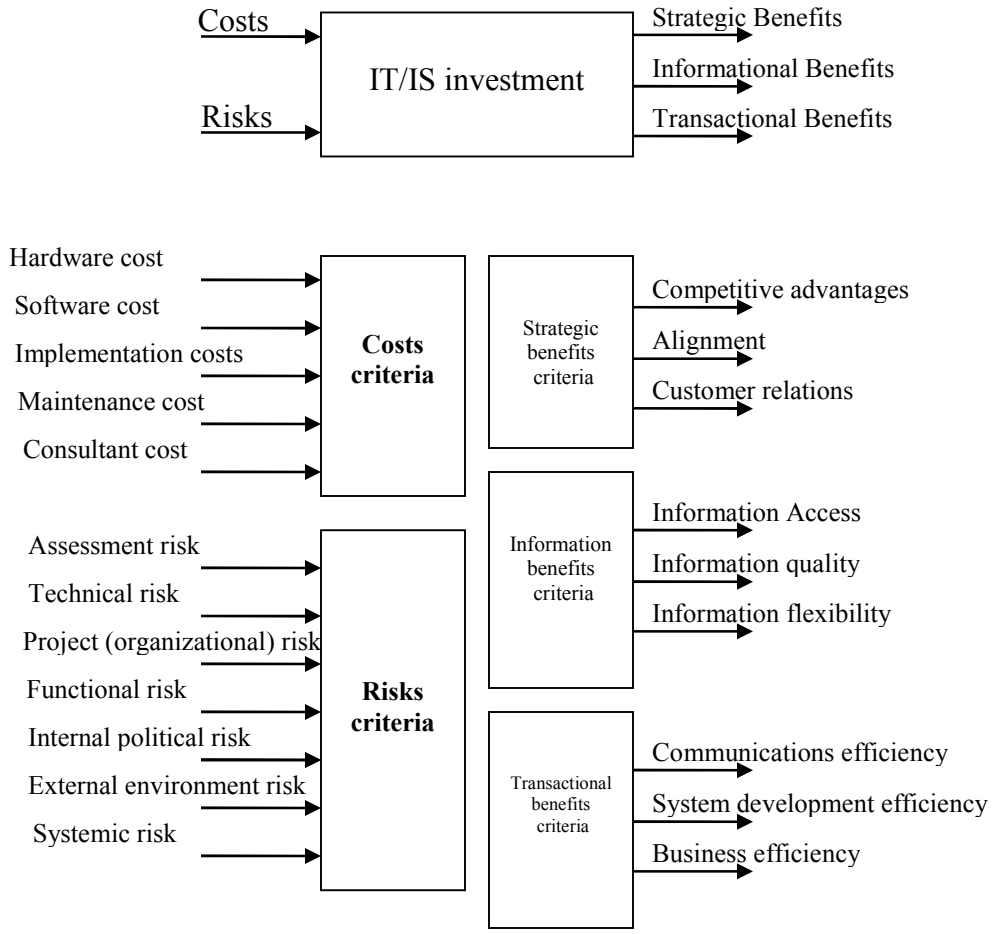

Figure 2: Grouping criteria in the integrated Delphi, AHP and DEA framework

Since not all criteria are likely to be counted equally important in evaluation, weighting techniques are used to reflex the relative importance of each criteria in hierarchical structure. Among these techniques, a ratio weighting process through pair wise comparison among criteria (Saaty, 1990) is considered for the ease of use. Therefore, AHP is selected to catch the weights of criteria. A consistence check, i.e., CR (consistence ratio) < 0.1, is embedded in this step.

3. Most of criteria in literature and known frameworks are intangibles and involve some degree of subjective assessment. In this step, a point scoring system of 0 to 20 is proposed for scoring alternative IT/IS investments (Table 1). The scoring system is used for all sub-criteria in hierarchical structure and by using Delphi method the stakeholders would be able to score them. Finally, the value of higher criteria is calculated by summing the product of its sub criteria score to its weight.

Table 1: The point scoring of the integrated framework

Criteria	Sub-criteria value	Sub-criteria value definition	Score
Costs	Very low cost	The IT/IS investment charges organization with very low cost	0-4
	Low cost	The IT/IS investment charges organization with low cost	5-8
	Moderate cost	The IT/IS investment charges organization with moderate cost	9-12
	High cost	The IT/IS investment charges organization with high cost	13-16
	Very high cost	The IT/IS investment charges organization with very high cost	17-20
Risks	Very low probability	This risk with very low probability will happen to IT/IS investment	0-4
	Low probability	This risk with low probability will happen to IT/IS investment	5-8
	Moderate probability	This risk with moderate probability will happen to IT/IS investment	9-12
	High probability	This risk with high probability will happen to IT/IS investment	13-16
	Very high probability	This risk with very high probability will happen to IT/IS investment	17-20
Benefits	Very high value	The IT/IS investment add very high benefit to organization	17-20
	High value	The IT/IS investment add high benefit to organization	13-16
	Moderate value	The IT/IS investment add moderate benefit to organization	9-12
	Low value	The IT/IS investment add little benefit to organization	5-8
	Very low value	The IT/IS investment add no benefit to organization	0-4

4. In this step, ach alternative IT/IS investment with its main criteria (e.g. costs, risks and benefits) is treated as Decision Making Unit (DMU). Then, DEA models is developed and executed. The results of the DEA with efficient DMUs are those alternatives which can be selected for investment. Inefficient DMUs are alternatives which can not be recommended for investment in organization. If the potential alternative IT/IS investments (Efficient DMUs) and unselected IT/IS investments are not consistent with stakeholders expectations, and then we need to go back to the step 2.
5. Finally, the IT/IS investments in efficient set of DMUs is selected by using Delphi technique. The selected set of IT/IS investments will be smaller than their efficient set.

4 CASE STUDY

We applied the framework to a large multi-disciplinary power holding organization. It is producing different parts of power transfer equipments in its different sub-organizations. There has been 12 proposed IT/IS investments from different parts of organization. By using Delphi technique, our proposed hierarchical structure of IT/IS investment criteria has been reviewed and checked with organization mission and strategies. It has been accepted with minor change in detailed levels. Then, the relative importance of each criteria is determined in scale of 1 to 9. The consistence ratio for 5 main upper criteria (costs, risks, strategic benefits, informational benefits, transactional benefits) is calculated by AHP through Expert Choice V.11. Pair wise weights and CR for costs and its sub-criteria is demonstrated in Table 2.

Table 2: Pair wise weights and consistence ratio for costs and its sub-criteria

Criteria	Sub-criteria	Pair wise weight/ software cost	Pair wise weight/ implementation cost	Pair wise weight/ Maintenance cost	Pair wise weight/ consultant cost	Inconsistency ratio (be<0.1)	Overall weight
Costs	Hardware	3	5	7	8	0.01	0.528

	Software		2	3	4		0.211
	Implementation			2	3		0.126
	Maintenance				2		0.076
	Consultant						0.049

In the next step, by using a point system of 0 to 20 is used to score 12 IT/IS investment alternatives. The costs investigation results for 2 alternatives are demonstrated in Table 3.

Table 3: The costs investigation results for 2 alternatives

Criteria	Sub-criteria	Weight	Alternative 1 /scores	Alternative 1 / costs value	Alternative 2 /scores	Alternative 2 / costs value
Costs	Hardware	0.528	4	6.162	6	8.644
	Software	0.211	7		10	
	Implementation	0.126	12		13	
	Maintenance	0.076	3		15	
	Consultant	0.049	17		12	

Finally, by calculating all 5 main criteria for the 12 alternatives, we developed the DEA output-oriented CCR model. Then it is executed and the efficient and inefficient DMUs or alternatives are determined and shown in Table 4.

Table 4: The inputs, outputs and results of DEA CCR

DMU	Inputs		Outputs			Efficiency	Efficient/ inefficient	Selected?
	Costs value	Risks value	Strategic benefits	Informational benefits	Transactional benefits			
1	8.2	12.2	14.1	16.8	15.7	0.603971	Inefficient	No
2	4.6	10.1	17.2	8.1	18	0.869565	Inefficient	No
3	12.1	7.1	16.7	14.1	10.3	0.675672	Inefficient	No
4	13.2	8	12.1	17.1	19.1	0.701357	Inefficient	No
5	14.1	12.1	13	16	10.1	0.495779	Inefficient	No
6	13.6	12	8	5	9.9	0.264971	Inefficient	No
7	4.1	7.1	15.1	13	15	0.867415	Inefficient	No
8	7	2	10	9	12	1	Efficient	Yes
9	10	6	13.1	17.3	16.6	0.942036	Inefficient	No
10	6.7	8.2	9.1	12.2	16.4	0.733183	Inefficient	No
11	5.1	12	14	12	11.7	0.582758	Inefficient	No
12	3.8	7.2	17.9	15.6	17.1	1	Efficient	Yes

As can be seen, only 2 of the 12 IT/IS alternative investments are efficient and can be selected for investment. The stakeholders selected the 2 efficient investments. They confirmed and validated the results of the framework.

5 CONCLUSION AND RESULTS

This paper comprehensively reviewed IT/IS evaluation and IS success literature and presented a comprehensive, complete, and efficient approach for evaluating and selecting IT/IS investments in organizations. This methodology is simple enough to be conducted by a small cost and may be comprehended by different stakeholders in organizations. This methodology involves different stakeholders who are inherent decision-makers in organizations (Chou, Seng and Tzeng, 2005) and provides a guideline to influence the decisions about IT/IS investments. Also, the prescribed methodology considered the organizational mission, goals and strategies, which must be considered in evaluating IT/IS investments (Gunasekaran, Ngai and McGaughey, 2005). Delphi is used to select suitable criteria for organizations. Then, AHP and DEA techniques determine the benefits of IT/IS investments for organizations. The proposed framework can be used in organizations for evaluating IT/IS investments and justifying them.

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