International Journal of Engineering, Management, Humanities and Social Sciences Paradigms (Volume 30, Special Issue of Nov 2018)
ISSN (Online): 2347-601X and Website: www.ijemhs.com

Technical performance evaluation of ERP packages with two-stage DEA approach

Alok Kumar Mohapatra[1*], Subrat Das[2]

[1*]Assistant Professor, Department of Mechanical Engineering, Nalanda Institute of Technology, Bhubaneswar, Odisha, India

[2] Assistant Professor, Department of Mechanical Engineering, Nalanda Institute of Technology, Bhubaneswar, Odisha, India

*Corresponding author e-mail: alokkumar@thenalanda.com

Abstract

Due to its capacity to streamline and unify business operations, enterprise resource planning (ERP) systems are receiving a lot of attention from the industrial sector. Unfortunately, these systems and subsequent adjustments come with a lot of costs, thus conducting an accurate and thorough performance evaluation is a crucial step in this process. To represent how well ERP systems meet organisational needs, these evaluations should take into account both operational and technological components. In order to assess the effectiveness of ERP systems, a two-stage data envelopment analysis (DEM) model is described in this work. The first stage of the model evaluates the operational aspect, while the second stage of the model evaluates the technical aspectAccording to the results, the two most important elements that the providers should take into account are the functionality of the ERP systems and their flexibility to be tailored to the client's procedures. Also, the results of the suggested model's parameter sensitivity analysis offer profound management insights into future ERP system usability enhancements.

Keywords: Data envelopment analysis; Enterprise resource planning; two-stage DEA; ERP performance evaluation.

1. Introduction

Currently, information technology is used in the majority of corporate procedures (IT). With the advancement of Technology, businesses are processing information more quickly and accurately, which has increased their production and operational effectiveness. The number of IT service providers is growing along with IT, thus these businesses always search for distinctive and superior services to get a competitive advantage over rivals. One of the IT solutions that integrate organisational activities is enterprise resource planning software, which has shown to be quite appealing in the business world.Despite the advantages of ERP systems, such deployment of these packages in theorganizations is along with many changes in the organizational processes and routines thatmake the organizations cautious in ERP systems acceptance.

To overcome these challenges, customization of ERP packages is a solution that aims to design ERP modules according to the organizational processes. However, customization is a complicated effort and needs considerable technical abilities, besides extra efforts regarding time and cost of ERP implementation. Therefore, customization reflects the technical efficiencies of the ERP providers which increases the ERP successes and customer satisfaction. The customization also influences the quality of ERP packages. Sudhaman and Thangavel (2015) observed that customization during ERP implementation affects the quality of the final ERP packages. The change in the quality also was explained by the problems incurred in the modification of the databases, program's codes, and system design through the process of ERP customization. These problems along with the inability to debug and reduce the flaws reduced the efficiency of ERP systems.

Despite the fact that in the previous studies, the importance of the ERP customization is addressed, there are few studies that examine the customization evaluation of ERP (Nozdrina, 2009). In this regard, some researchers indicated the mismatch between ERP packages and the requested requirements (Zickert and Beck, 2013). Therefore, ERP systems evaluation with a

focus on the ERP customization is one of the main purposes of this paper, which is an emerging and interesting subject in the area of the business as well as the academic research.
In this paper, the focus of our research is to consider the efficiency of the ERP packages as a combination of technical and operational efforts allocated for deployment of them. Here, the technical aspects refer to the degree of ERP accordance with the requested organization's requirements and the operational aspects are associated with the common efforts such as time and cost paid to implement ERP functionalities. As will be discussed in the model description, these two aspects of efficiency influence each other. So measuring the efficiency of these two aspects entails a network representation of these relations. Thus, a two-stage DEA which enables to emphasize and take into account this relational network is modeled in this research.
The main contributions of this paper include the following.

1. Modeling the ERP efficiency by considering the aspects related to the specifications of the product not related to the management aspect.
2. Measuring operational, technical and the total efficiency of ERP packages using a modified two-stage DEA model, which considers network relationships of the efficiency aspects.
3. Providing managerial insights by doing the sensitivity analysis of the model parameters to improve their efficiency compared to the competitors of the ERP packages.

The following sections of this paper are as follows. In section 2, the literature is reviewed by the focus on the efficiency of DEA models and ERP packages customization. Section 3, introduces the two-stage DEA model of ERP evaluation. In section 4, our model is presented and in Section 5, the results of the model implementation and sensitivity analysis are presented which provide managerial insights. Section 6, presents the discussion and finally, in Section 7, the results of the paper are highlights and some suggestions for the future studies is stated.

2. Literature Review

It is notable that an efficient customization process should be done at the lowest possible cost and time. This fact is confirmed in a survey of 86 organizations carried by Somers and Nelson (2009). Other studies such as Tu and Yen (2013) and Gefen (2014) also referred to this fact. So, the customization evaluation should be done alongside the operational efficiency. In this paper, a two-stage data envelopment analysis (DEA) model is proposed for the ERP systems evaluation problem which measures the operational efficiency of ERP in the first stage and the customization or technical efficiency of ERP in the second stage. Finally, by integrating these two aspects of ERP, the total efficiency of ERP packages is measured. The study of Aversano and Tortorella (2013) also showed that large-scale information technology projects, such as ERP projects, often require the customization processes. Therefore, the quality and function of such projects should be evaluated before being established in an organization. In another study conducted by Mayrhauser et al. (1999), costs were considered as inputs and the number of users, electronic data interchange (EDI) and communications were considered as outputs. In that research, it was not clear whether the projects needed to customize or the standard ERP packages were sufficient for them. Therefore, the customization is especially important in evaluating the performance of software packages.

The DEA technique is used to determine the best decision units and consequently better usage of the resources and to identify the areas that have more contribution to the improvement purposes. Hence, DEA enables the decision units to determine their potential for performance improvement (Koch, 2007). DEA models analyze the efficiency of the similar decision units by considering multiple influencing factors. Charnes et al. (1978) published the first article in DEA and developed the Constant Return Scale (CRS) model of DEA. Banker et al. (1984), extended this model to the Variable Return Scale (VRS) model. In the CRS model, the outputs of the model directly reflect the level of the inputs. This means that if the inputs are doubled, the outputs will be doubled, too. However, in the VRS models, if a decision unit is an Increasing Returns to Scale (IRS) unit, then increasing the inputs leads to more increase in the outputs. On the other side, if the decision unit is a Decreasing Returns to Scale (DRS) unit, the extent of increase in the inputs is more that that of the outputs. So, before applying the DEA models, one should decides to use the CRS models or VRS models. Although in the evaluation of the traditional software development project, the CRS models have been utilized, for large-scale information technology projects such as ERP, the VRS model has been preferred by some researcher such as Stensrud and Myrtveit (2003). After deciding on the CRS or VRS models, the type of optimization in the DEA model should be scrutinized. Totally, two types of the optimization modes are studied in the DEA models. The first one is Minimum Input optimization or briefly Min-In which aims to minimize the inputs to reach a certain level of outputs. The second one is Maximum Output optimization or Max-Out in which the outputs is maximized given the certain level of the inputs. In the ERP evaluation, the Max-Out optimization mode seems to be more applicable than Min-In (Stensrud and Myrtveit, 2003).

The efficiency in the DEA models is based on the definition that measures efficiency by dividing the value of the output to the value of the input. In the DEA models, however, the weighted sum of the outputs of a decision-making unit relative to the weighted sum of its input is regarded as the unit efficiency. Then by considering the model assumptions, such as being VRS or CRS, a mathematical model is presented to measure the relative efficiency of the units. The idea behind the relative efficiency of the units in the CRS model is derived by definition of the production possibility set. Regarding X as the input vectors and Y as the output vectors, in the production possibility set, it is assumed that if X is able to produce Y, then the input vector $\bar{X} \geq X$ is also able to produce Y. Moreover, if Y could be produced by X, then $\bar{Y} \leq Y$ is also could be produced by X. Now the production possibility set assuming a constant return to scale is defined over X and Y as the following:

$$T_C = \{(X,Y) \mid X \geq \sum_{j=1}^{n} \lambda_j X_j \ \& \ Y \leq \sum_{j=1}^{n} \lambda_j . Y_j \ \& \lambda_j \geq 0,\ j = 1,\dots,n\} \tag{1}$$

Considering the possibility production set in Eq. (1), a decision-making unit p with $\left(X_p,\ Y_p\right)$ in the Min-In model is said to be relatively efficient, if there is no possibility of production that

produces Y_p or more than it with inputs less than X_p. This yields to the mathematical programming model as follows:

$$\begin{aligned}
& Min\, \theta \\
& s.t. \\
& \qquad \sum_{j=1}^{n} \lambda_j X_j \leq \theta X_p \\
& \qquad \sum_{j=1}^{n} \lambda_j . Y_j \geq Y_p \\
& \qquad \lambda_j \geq 0,\ j = 1,\dots,n
\end{aligned} \tag{2}$$

Now, if solving Eq. 2 results in $\theta < 1$, the decision-making unit p is said to be relatively inefficient.

The BCC model with the Max-Out optimization model which is suitable for ERP evaluation is also as follow. In this model, if φ^* for a decision-making unit is greater than 1, this unit is relatively inefficient and if φ^* is equal to 1, this indicates the efficiency of the unit.

$$
\begin{aligned}
&Max\varphi \\
&s.t. \\
&\qquad \sum_{j=1}^{n}\lambda_j X_j \le \hat{X}_p \\
&\qquad \sum_{j=1}^{n}\lambda_j Y_j \ge \varphi \hat{Y}_p \qquad (3) \\
&\qquad \sum_{j=1}^{n}\lambda_j = 1 \\
&\qquad \lambda_j \ge 0,\ j = 1,\dots,n
\end{aligned}
$$

In the multi-stage DEA models, there is more than one stage for evaluation of units' efficiency. In the simplest form of the multi-stage models, it is presumed that the outputs of the one stage are applied as the inputs of the subsequent stages. There are several models for the multi-stages DEA network, which each one has a different assumption. The main challenge of the multi-stage model is the dual role of some stages' outputs that act as the inputs of the subsequent stages. Therefore, if the outputs of an intermediate stage increase, the efficiency of that stage is increased, whereas the efficiency of the following stages might be decreased. For example, in the two-stage DEA model of Chen and Zhu (2004), an input based model for the first stage and an output based model for the second stage is explored. In that model, a decision-making unit could improve its efficiency by reducing its inputs in the first stage or by increasing its outputs in the second stage. Kao and Hwang (2008) introduced the efficiency of the units in a multi-stage DEA model as the product of their efficiency in the various stages. In their proposed model, also it is assumed that all of the outputs of the one stage are consumed in the later stage. In this regard, Chen et al. (2009a) developed a multi-stage DEA model in which the total efficiency is the weighted sum of the efficiency in the different stages. They also compared the efficiency of their model with Kao and Hwang (2008) using Spearman correlation coefficient and showed that there is no significant difference between two models. Chiu et al. (2010) extended the model of Chen and Zhu (2004) by considering interfering factors and present a two-stage DEA model in the presence of desirable and undesirable factors. Galagedera et al. (2016) introduced the concept of the leakage variables in the two stages DEA models. These variables act as the outputs of the first stage while they are not used in the second stage as inputs.

The multi-stages DEA models provide an appropriate framework for the evaluation of the complicated systems. Wanke and Barros (2014) measure the efficiencies of the Brazilian banks using two stages DEA model. This model includes cost efficiency in the first stage and productive efficiency in the second stage. In the first stage of the model, a number of branch and staffs used as the inputs and the staffs' cost are regarded as the output. Also, assets and deposits of the bank are considered as the outputs of the second stage. The results of that paper showed differences between the efficiency of the banks in the first and the second stage, which reflects the focus of them on one of the stages. A modified two-stage DEA model is developed in Huang et al., (2014) for measuring the efficiency of hotels in Taiwan. The proposed model evaluated the efficiency of productivity, customer attraction and catering services of the hotels and defined an efficiency index that measured all stages efficiency instead of measuring them separately. Wang et al. (2014) studied the efficiency of Chinese banks using a two-stage DEA model. The first stage of the model included the deposit of the banks and the second stage investigated the profitability of the banks. The results of the study denoted that the first stage inefficiency is more relevant in the Chinese bank while the private banks were more efficient than government banks. Wu et al. (2015) examined the efficiency of the industries in China by a two-stage DEA model. In that paper, changing the business roles in China was identified as an improving factor in firms' performance, although this modification amplified the problems such as the increment in energy consumption and pollution. Hence, in their proposed DEA model, the energy efficiency was measured in the first stage and the efficiency of the Chinese firms in the control of pollution is considered at the second stage. However, despite the remarkable use of the two-stage DEA models in some business context such as banking, this method has not been extended to the ERP evaluation to the best of our knowledge. Dos and Datta (2017) introduced a two-stage models for evaluation of Information Technology-enabled Services (ITeS) which seems to be relevant with the present research. However, in Dos and Datta (2017), the second stage of evaluation is not a DEA stage but they used the Random-Effects Tobit regression analysis to map the inputs (salaries and wages and operating expenses) and output (sales incomes) of the one- stage DEA model into the obtained efficiency score of the DEA model. Therefore, introducing the two-stage DEA model for ERP evaluation and underlining different aspects of each stage is the contribution of the present paper for ERP studies which is also applicable for other software's evaluation process.

So far, some studies have been conducted on the effectiveness of ERP packages. Teltumbde (2000) presented a methodological framework that evaluated ERP projects based on management factors. In this research, the technical aspects of ERP packages were not studied. Stefanou (2001) proposed a framework for evaluating ERP software using the estimation of cost and benefits. Nozdrina (2009) presented a model based on fuzzy logic to assess the effectiveness of ERP projects from a project management perspective. Daneva (2010) reported that a low level of reuse of an ERP project implies the customization of standard components, and the high level of reuse reflects the limited customization of the ERP package. Also, it states that ERP projects usually rely less frequently on reusing program components, reflecting the low performance of ERP projects.

Some studies in the literature used DEA model to evaluate IT, ERP and software products which are discussed in the following. Stensrud and Myrtveit (2003) and Parthasarathy and Anbazhagan (2008) used DEA for evaluation of the ERP project. However, in their study, the degree of customization and length of evaluation of ERP projects was not investigated. Koch (2007) described the importance of DEA in estimating the effort required to implement ERP.

Liu et al. (2010) measured the financial and commercial efficiency of ERP with eight input variables and four output variables. Chen et al. (2009b) studied the failure factors of ERP in the viewpoint of the management and resulted that only when the major functionality of the ERP fail to meet the requirements, customization should be taken into account. Also, they showed that without preliminary evaluation of ERP customization, the customization leads to poor outcomes. Tu and Yen (2013), analyzed the efficiency of the web service providers in Taiwan. They showed that the poor operational efficiency of the service provider and proposed suggestion for improvement of them. They also demonstrated that service providers' size, bandwidth, market share and demand growth rate have a determinant role in the efficiency of the second stage. Tsai and Chou (2015) paid attention to the effect of ERP on firms' performance using a DEA model with two outputs, namely number of the resulting patents and a net profit of the firms. The results of the study showed the positive effect of ERP implementation on the growth of the patents because it facilitates the innovative activities of the firms. Moreover, based on the results, the net profit of the firms is increased as a result of ERP implementation after 3 years. Parthasarathy and Sharma (2016) defined the efficiency of the ERP packages as the ratio of the software codes and functions to the effort of ERP development in terms of time and cost. Furthermore, customization was regarded as the efficiency of the ERP packages in the viewpoint of the customer. Therefore, the relationship between the efficiency of the ERP is examined through the correlation analysis and the positive relation between these two aspects of efficiency was confirmed. In the present study, the customization definition in Parthasarathy and Sharma (2016) is utilized and we consider the customization as the efficiency of the ERP package in the second stage because it is also related to the outputs of the first stage, i.e. number of the codes and functions of the ERP package and additional efforts required to prepare the customized ERP for the customers.

In the context of ERP packages, some researchers also utilized DEA models for selection of the best ERP provider (Lall and Teyarachakul, 2006). A fuzzy DEA ranking approach also proposed by Kumar et al. (2017) for ranking software reliability growth models (SRGMs). It is notable that SRGMs models are used for estimating the reliability indexes of software such as software failure rate. In the same study, the DEA model was combined with a software components selection model for taking into account the cost of purchasing as well as the efficiency scores associated with different attributes of the components (Gupta et al., 2018). Toloo et al. (2018) also used a DEA model for project selection of information system (IS) which was combined with subjective opinions of decision makers. Brzozowski and Birfer (2017) reviewed the methods of MCDM (Multi Criteria Decision Making) technique for ERP selection. According to their results, DEA techniques had less attentions in the recent years for The ERP selection problem.

3. Proposed model

In this section, at first, some aspects of ERP customization and ERP evaluation is represented and then the DEA model measure the operational and technical efficiency of the ERP packages is provided.

ERP customization

It should be noted that standard ERP packages consider certain assumptions about processes and organizational structures. These assumptions can be varied in different organizations, and hence either need to modify organizational processes or modify the modules embedded in the ERP according to organizational requirements. Changing the processes or structure of an organization is far more difficult than applying some changes in ERP processes and procedures,

as they may lead to organizational resistance to change and discontent among managers and employees and may lead to failure of ERP projects.

Hence, due to the competitiveness of providing ERP packages, those providers that have the ability to modify ERP modules in accordance with organizational requirements and provide the customized and specialized ERP packages will be better served. Therefore, in this research, we introduce customization as one of the most important aspects of ERP's performance and efficiency.

The customization of ERP packages involves the changes and modifications to each component of ERP systems including modules, databases, code, reports, and user interfaces to provide ERP packages according to the user requirements (Lee et al., 2005). Many organizations prefer to customize their ERP packages to match their business and IT goals (Shao and Lin, 2002). In customizing ERP packages, organizations can adopt a variety of solutions such as (Brehm et al., 2001): configuring ERP packages by using software components in their organization; using the third party to implement ERP functions and modifying user interfaces and codes to match software requirements. Customizing ERP packages not only cause any changes to the organization's processes but also changes in the implementation process.

The main process in evaluating the performance of a software product is the use of an appropriate methodology to identify the functional parameters of the software package by Kitchenham and Mendes (2004). The size and the amount of effort have been made to develop a software are the two important factors to evaluate their efficiency by Kitchenham (2002). The size of a software can be determined by counting the number of program code lines (LOC) and the number of function points (FP) used in the software. The amount of time which is spent to produce a software package is an important measure in the evaluation of ERP packages. This measure shows the number of hours worked by the total workforce to complete a software. Operational aspects of ERP systems are measured by the number of hours used in software preparation, the number of lines in the program code and the number of function points. Here, the number of code lines and the number of functions is the output of the first stage and the number of person-hour of the workforce is the input of the first stage.

ERP performance evaluation

The conceptual model of our research is presented in Fig. 1.

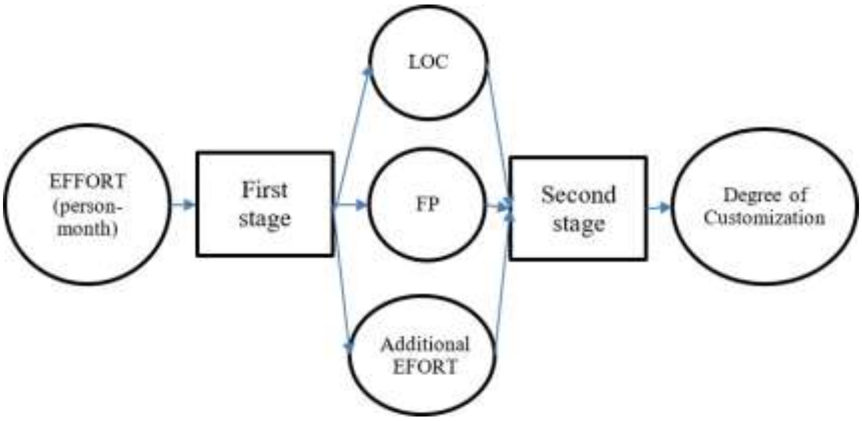

Figure 1. The conceptual model of ERP evaluation

The output of the first stage is the codes and functions that are used in the software package. As in the coding process mostly some advanced programming principles, such as using object-oriented programming and functions, are used, so it will be easier to modify. The output of this stage is the number of codes in terms of the number of program lines and functions in the ERP package. The second stage is the implementation and establishment of ERP system in the requested company. To this end, the buyer expects to have a great deal of consistency between ERP and its organizational processes. In the process of the customization, the ERP provider make appropriate changes to the offered software package based on the customers' requirements. Moreover, the degree of the customization is dependent to the ability of the ERP providers as well as their additional efforts dedicated to the process of the customization. In this regard, an efficient and skillful ERP providers is the one with the sophisticated codes and functions which enable it to make the highest level of the customization with the least additional effort. Therefore, we call the second stage of the proposed model "technical efficiency" or "customization efficiency. The second phase of the DEA network model in this study is the customization function. In order to calculate the degree of customization of ERP packages we can use the Software Requirements Specification (SRS) (Parthasarathy and Sharma, 2016). By using these worksheets, we can make the necessary changes, including adding, deleting, and modifying the configuration characteristics, design and functionality requirements. Then we can obtain the degree of customization using the equation $D = ((X + Y + Z) / R) \times 100$. In this equation, X is the number of configuration requirements, Y defined as the number of functional requirements and Z is the number of design requirements in the ERP package, which need to be customized, and R is the sum of the above requirements, which must be in accordance with the worksheet of the SRS of the ERP client organization. Types of customization are defined in Table 1. Also, Table 2 shows the inputs and outputs of the DEA model and its measurement units.

Table 1. Types of customization of ERP packages (Parthasarathy and Sharma, 2016)

Type of customization	Descriptions	Example
Configuration	Customize the configuration of ERP packages	In this method, the ERP packages are configured to fit the needs of the client organization. For example, if ERP packages are going to use in different countries, then the tax rate should be adjusted according to the local auditing and calculated according to the customer's geographical location. These changes are categorized as the ERP configuration changes, so there are no changes in the programming codes.
Functionality	Customize ERP packages to enhance the technical requirements	In this type of customization, new functions need to be added to the ERP packages or, in some cases, a number of existing functional requirements should be corrected.
Design	User interface changes	In this case, changes are made in the design of the software, and subsequently, programming codes are rewritten.

Table 2. Inputs and outputs of different stages of ERP performance evaluation

Parameter	Type of Parameter	Measurement Unit
Time of ERP developing	The input of the first stage	Person per month
Number of ERP system's codes	The input of the second stage	# of code lines
Number of functions	The input of the second stage	# of functions
The effort for the ERP customization	The input of the second stage	Person per month
ERP customization rate	The output of the second stage	#Percent of customization

The parameters and variables of the proposed model are explained in Table 3 and Table 4, respectively.

Table 3. Parameters of the proposed models

Parameter	Description
j	Index of decision-making units
o	Index of the reference unit
i	Index of the first stage inputs
d	Index of the first stage outputs
l	Index of the second stage inputs which are not the outputs of the first stage
r	Index of the second stage output
n	Number of decision-making units (ERP provider or seller)
m	Number of inputs in the first stage
D	Number of outputs in the first stage
Q	Number of the inputs in the second stage which are not the outputs of the second stage
S	Number of the outputs in the second stage
x_{ij}	Amount of input *i* used by DMU *j*
z_{dj}	Amount of output *d* provided by DMU *j*
y_{rj}	Amount of output *r* provided by DMU *j*
s_{lj}	Amount of input *l* used by DMU *j*

Table 4. Variables of our models

Variable	Description
w_1	the weight of the efficiency in the first stage
w_2	the weight of the efficiency in the second stage
η_d	the weight of output *d* in the first stage
v_i	the weight of input *i* in the first stage
u_r	the weight of output *r* in the second stage

β_l	the weight of input l in the second stage
θ_o^*	the relative efficiency of decision-making unit o

Our proposed model is based on the two-stage DEA model that proposed by Chen et al. (2009). By using the aforementioned parameters and variables, we formulated our model as follows.

$$\theta_0^* = \max\left(w_1 \frac{\sum_{d=1}^{D} \eta_d z_{d0}}{\sum_{i=1}^{m} v_i x_{i0}} + w_2 \frac{\sum_{r=1}^{S} u_r y_{r0}}{\sum_{d=1}^{D} \eta_d z_{d0} + \sum_{l=1}^{Q} \beta_l s_{l0}} \right) \quad (4)$$

$s.t.$

$$\frac{\sum_{d=1}^{D} \eta_d z_{dj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1 \quad , \quad j = 1,\ldots,n \quad (5)$$

$$\frac{\sum_{r=1}^{S} u_r y_{rj}}{\sum_{d=1}^{D} \eta_d z_{dj} + \sum_{l=1}^{Q} \beta_l s_{lj}} \le 1 \quad , \quad j = 1,\ldots,n \quad (6)$$

$$\eta_d, v_i, u_r \ge 0 \quad , \quad d = 1,\ldots,D \; , \quad i = 1,\ldots,m \quad , \quad r = 1,\ldots,S \quad (7)$$

In the above model, the Eq. 4 shows the relative efficiency of the o[th] decision-making unit, which is the weighted sum of the first stage performance and its second stage performance. Eqs. 5 and 6 describe the efficiency of the first and second stages cannot be greater than 1, and finally, the constraints Eqs. 6 and 7 describe the types of decision variables.

In the above model, w_1 and w_2 are the weight of stages 1 and 2 such that: $w_1 + w_2 = 1$. These weights represent the relative importance of each stage and are equal to the ratio of the inputs or resources of each stage to the total inputs or resources of the decision-making unit, so we can define them as follows:

$$w_1 = \frac{\sum_{i=1}^{m} v_i x_{i0}}{\sum_{i=1}^{m} v_i x_{i0} + \sum_{d=1}^{D} \eta_d z_{d0} + \sum_{l=1}^{Q} \beta_l s_{l0}} \quad (8)$$

$$w_2 = \frac{\sum_{d=1}^{D} \eta_d z_{d0} + \sum_{l=1}^{Q} \beta_l s_{l0}}{\sum_{i=1}^{m} v_i x_{i0} + \sum_{d=1}^{D} \eta_d z_{d0} + \sum_{l=1}^{Q} \beta_l s_{l0}} \quad (9)$$

By substituting w_1 and w_2 in the previous model, Eq. 10 is obtained as follows:

$$\begin{aligned}
& \max \; \theta_0^* = \sum_{d=1}^{D} \eta_d z_{d0} + u^1 + \sum_{r=1}^{S} u_r y_{r0} + u^2 \\
& s.t. \\
& \sum_{i=1}^{m} v_i x_{i0} + \sum_{d=1}^{D} \eta_d z_{d0} + \sum_{l=1}^{Q} \beta_l s_{l0} = 1 \\
& \sum_{d=1}^{D} \eta_d z_{dj} - \sum_{i=1}^{m} v_i x_{ij} + u^1 \le 0 \quad , \; j = 1,\ldots,n \\
& \sum_{r=1}^{S} u_r y_{rj} - \sum_{d=1}^{D} \eta_d z_{dj} - \sum_{l=1}^{Q} \beta_l s_{lj} + u^2 \le 0 \quad , \; j = 1,\cdots,n \\
& \eta_d, v_i, u_r, \beta_l \ge 0 \quad , \quad d = 1,\ldots,D \; , \quad i = 1,\ldots,m \quad , \quad r = 1,\ldots,S, \; l=1,\ldots,Q \\
& u^1, u^2, free
\end{aligned} \quad (10)$$

It is obvious that in Eq. 10, all the outputs of the first stage are consumed in the second stage. Finally, if θ_o^* is equal to 1, the decision-making unit would be considered as an efficient unit, otherwise, the decision-making unit would be identified as inefficient relative to other units.

4. Model performance evaluation

To evaluate the performance of the proposed method, we adopted the same cases as presented in Parthasarathy and Sharma (2016) which include the information about the user, the time required to implement the software, the number of operating codes, the number of functional codes, and the level of customization of each of the ERP packages. These packages are nominated as A_1 to A_8 and the details of them are presented in table 5. Table 6 presents the details of customized ERP packages:

Table 5. Data on the operational efficiency of ERP packages (Parthasarathy and Sharma, 2016)

ERP package	Number of LOC	Number of FP	EFFORT (person-month)
A_1	41737	599	8.93
A_2	72401	2291	31.7
A_3	39377	799	11.5
A_4	8800	1180	6.63
A_5	13417	982	11.9
A_6	18901	1943	14.8
A_7	90303	1786	16.5
A_8	90401	2391	40

Table 6. The efficiency of customization of ERP packages (Parthasarathy and Sharma, 2016)

ERP package	X	Y	Z	R	Additional EFORT
A_1	9	6	6	39	2.1
A_2	8	7	12	34	2.3
A_3	8	8	8	35	3.4
A_4	9	10	9	34	4.8
A_5	6	9	12	34	2.6
A_6	11	10	12	39	2
A_7	2	2	4	55	3.8
A_8	5	5	6	7	1.8

In the following section, we determine the operating efficiency, customization efficiency, and overall efficiency of ERP packages using the proposed two-stage DEA model.
Also, It should be pointed out that all models; the operational efficiency, the customization efficiency and the two-stage model of the total efficiency; have been coded and solved using GAMS software v. 22.9 on a computer with core i5 CPU and 4.0 GB RAM. Doing so, we utilize the concept of the dynamic sets in GAMS to run all DEA models for all the references ERP packages in just one implementation. Furthermore, each model for each reference ERP package is solved in less than one second due to the linearity of the proposed models.

Measuring the operational efficiency of the ERP packages

Table 7 shows the efficiency of the ERP packages in the first stage namely operational efficiency. Also, the values of the variable $\lambda_j \mid j = 1,..., n$ in model (3) for each reference ERP package are shown in Table 8.

Table 7. The operational efficiency of ERP packages

ERP package	ϕ^*
A_1	1.000

A_2	1.000
A_3	1.415
A_4	1.000
A_5	1.670
A_6	1.000
A_7	1.000
A_8	1.000

Table 8. The values of λ_j for ERP packages relative to the reference units in the first stage

Reference ERP package	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8
A_1	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
A_2	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
A_3	0.482	0.000	0.000	0.137	0.000	0.000	0.381	0.000
A_4	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
A_5	0.000	0.000	0.000	0.376	0.000	0.521	0.102	0.000
A_6	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000
A_7	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
A_8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

According to the results of Table 7, the ERP packages A_1, A_2, A_4, A_6, A_7, and A_8 are efficient ERP packages operationally ($\phi^*=1$), while A_3 and A_5 compared to other REP packages are relatively inefficient. It is also notable that for an inefficient reference ERP packages, if λ_j (associated with decision-making unit *j*) is positive then the unit *j* unit is known as a dominant unit for that reference package. In this regard, the raw of A_3 in Table 8 has $\lambda_j > 0$ for ERP packages A_1, A_4 and A_7 and this fact denotes that A_1, A_4 and A_7 are dominant decision-making units for ERP package A_3. Similarly, A_4, A_6, and A_7 are identified as the dominant unit for the inefficient ERP package A_5. Obviously, for the efficient ERP package *j**, we have $\lambda_{j*}=1$ and $\lambda_j = 0 \mid j \neq j^*$, because this ERP package is just dominated by itself.

Measuring the customization efficiency of the ERP packages

In calculating the customization efficiency of ERP packages, the number of function points, as well as the number of program codes and the number of person-month spent for customization, are used as the inputs in the single-stage DEA model of customization efficiency, and the level of customization is the output of this model. The required information about this stage is available in Tables 5 and 6. Table 9 shows the efficiency of the ERP package in the second stage, and in Table 10, the values of the λ_j for ERP package relative to the reference units are shown.

Table 9. The customization efficiency of ERP packages

ERP package	ϕ^*
A_1	1.000
A_2	1.000
A_3	1.145
A_4	1.000
A_5	1.000
A_6	1.000
A_7	5.640
A_8	2.610

Table 10. The values of λ_j for ERP packages relative to the reference units in the second stage

Reference ERP package	A_1	A_2	A_3	A_8	A_4	A_5	A_6	A_7	A_8
A_1	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
A_2	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
A_3	0.480	0.000	0.000	0.000	0.000	0.522	0.000	0.000	0.000
A_4	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
A_5	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
A_6	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000
A_7	0.000	0.000	0.000	0.200	0.000	0.000	0.800	0.000	0.000
A_8	0.000	0.280	0.000	0.000	0.000	0.000	0.720	0.000	0.000

According to Table 9, ERP packages A_1, A_2, A_4, A_5, and A_6 are fully efficient in the customization stage, while A_3, A_7 and A_8 are relatively inefficient. Also, based on Table 10, the reference units of an inefficient unit A_3 consist of A_1 and A_5. In addition, A_2 and A_6 are dominant units of A_8. In the next subsection, it is explained that if the function and program codes will be larger in a software package, then it would be possible to customize it with better performance. For example, A_2 and A_6, which has a large number of function and codes and this might lead to lower efficiency in the second stage (for large input values), but the low additional

effort (person-month) needed to customize them still results in higher efficiency in the second stage.

Calculation of Total Efficiency

To calculate the total efficiency, we use the presented model in (10) which is a modified model of the one proposed by Chen and Kho (2009). Therefore, the total efficiency of the ERP packages will be according to Table 11.

Table 11. Performance of customization of ERP packages

ERP package	ϕ^*
A_1	0.998
A_2	1.000
A_3	0.742
A_4	1.000
A_5	0.870
A_6	1.000
A_7	0.686
A_8	0.831

Based on the obtained results shown in Table 11, the A_2, A_4, and A_5 are fully efficient, and A_1,

A_3, A_5, A_7, and A_8 are identified as the inefficient ERP packages. In the previous subsections, we observed that A_3 is inefficient in both stages and it has a total efficiency of 0.743, which indicates this package is also totally inefficient. In addition, A_5, A_7, and A_8 were inefficient in one of the two stages, and they are totally inefficient too. These results indicate that if one of the software packages were not being efficient in at least one stage of evaluation, it would not be measured as a completely efficient ERP package.

Sensitivity analysis of model results

In this section, we will consider whether changing the inputs of each of the network analysis stages could make inefficient ERP packages into an efficient one or not. In the calculation of operational efficiency, it was shown that A_3 and A_5 are inefficient. We expect that by reducing the inputs of these packages or increasing their outputs, we can increase the relative efficiency of these decision-making units. By changing the inputs of A_3 which was illustrated in Table 5 and 6, changes in the efficiency of A3 are shown in Table 12. Also, in Table 13, the operational efficiency of A_5 versus different values of its input is presented.

Table 12. The operational efficiency changes of the A_3 relative to the input changes

Input value	8.5	9.5	10.5	11.5
Efficiency	1	1.07	1.24	1.45

Table 13. The operational efficiency changes of the A_5 relative to the input changes

Input value	6.9	7.9	8.9	9.9	10.9	11.9
Efficiency	1	1.29	1.38	1.48	1.57	1.67

Based on the results of Tables 12 and 13, it is clear that by decreasing the inputs, the relative efficiency of inefficient ERP packages will increase. Also, in calculating the relative efficiency of the second stage, it was shown that the performance of ERP packages A_3, A_7 and A_8 is not completely customizable. In Table 14 to 16, the efficiency changes of these decision-making units are shown.

Table 14. Customization efficiency changes of the A_3

Output value	79	69	59
Efficiency	1	1	1.45

Table 15. Customization efficiency changes of the A_7

Output value	85	75	65	55	45	35	25	15
Efficiency	1	1.12	1.3	1.53	1.8	2.4	3.38	5.64

Table 16. Customization efficiency changes of the A_8

Output value	92	82	72	62	52	42	32
Efficiency	1	1.09	1.16	1.34	1.6	1.9	2.61

The results of Tables 14 to 15, shown that increasing the outputs will lead to an increase in the relative efficiency of inefficient decision-making units in such a way they can be converted into the efficient units.

In order to increase the total efficiency of inefficient units, we can reduce the inputs of them in both stages while these inputs do not act as outputs of the first stage. Also increasing the output of the second stage could improve the total efficiency as shown in Table 13 to 15. However, increasing the outputs of the first stage, which act as both input and output parameter, their effect on the total efficiency cannot be explained without using the proposed model. In determining the total efficiency, the ERP packages A_1, A_3, A_5, A_7, and A_8 were identified as inefficient decision-making units. In this section, we investigate the effect of input and output changes on the performance of these units. Table 17 shows the different combinations of inputs from the first stage and the second stage (not the output of the first stage), and the outputs of the second stage and their effects on the total efficiency of the decision-making unit A_1.

Table 17. Changes in the total performance of the A_1 by changing the outputs and inputs

Type of Parameter	Type of Change		Percent of Change	Total Efficiency
	increase	decrease		
The Inputs of The First Stage		*	40 %	1
The Inputs of The First Stage		*	20 %	1
The Inputs of The First Stage		*	10 %	1
The Outputs of The First Stage		*	60 %	0.943
The Outputs of The First Stage		*	40 %	0.95
The Outputs of The First Stage		*	10 %	0.98
The Outputs of The First Stage	*		60 %	1
The Outputs of The First Stage	*		40 %	1
The Outputs of The First Stage	*		10 %	1
Outputs of The Second Stage	*		60 %	1
Outputs of The Second Stage	*		40 %	0.998
Outputs of The Second Stage	*		10 %	0.998

The results of Table 17 denote that reducing the inputs of the first stage and increasing the output of the second stage leads to an increase in the total efficiency of A_1. However, by changing the outputs of the first stage, a certain pattern could not be recognized. Therefore, managers must carefully analyze changes in inputs and outputs of systems in order to increase the efficiency of their decision-making unit. The model presented in this study showed that the results of changes in the model parameters are in line with expectations and this could confirm the validity of the model.

Therefore, the proposed model could be used as a framework for evaluating the efficiency of an ERP package and also the establishment of improvement strategies in comparison with other ERP packages. For other inefficient units, a similar analysis like as the parameter sensitivity analysis of A_1 can be done. Among these inefficient decision-making units, A_3 has both inefficiencies in the first and second stage and therefore needs deeper analysis to improve its efficiency. In Table 18, the efficiency changes with inputs and outputs changes for this decision-making unit are shown.

Table 18. Changes in the total performance of A_3 by changing its outputs and inputs

Type of Parameter	Type of Change		Percent of Change	Total Efficiency
	increase	decrease		
The Inputs of The First Stage		*	40 %	0.987
The Inputs of The First Stage		*	20 %	0.967
The Inputs of The First Stage		*	10 %	0.775
The Outputs of The First Stage		*	60 %	0.711
The Outputs of The First Stage		*	40 %	0.722
The Outputs of The First Stage		*	10 %	0.737
The Outputs of The First Stage	*		60 %	0.763
The Outputs of The First Stage	*		40 %	0.760
The Outputs of The First Stage	*		10 %	0.747
Outputs of The Second Stage	*		60 %	0.820

Outputs of The Second Stage	*	40 %	0.742
Outputs of The Second Stage	*	10 %	0.742

In accordance with the results of Table 17, reducing the inputs of the first stage and increasing the inputs of the second stage will increase the efficiency of A_3. In addition, increasing the outputs of the first stage cannot produce results with a specific pattern. However, in order to increase the efficiency of this unit, which is inefficient in both stages and does not have total efficiency, various combinations including simultaneous reduction of inputs and outputs can be analyzed. For example, a 60% increase in the output of the second stage and a 40% decrease in inputs will result in a total relative efficiency of this unit.

The proposed models are beneficial for determining, combining and distinguishing the efficiency measures of each stage of ERP evaluation process. Moreover, the sensitivity analysis discussed here is a worthwhile technique for determining the required changes in the areas which lead to more improvement in the efficiency of each stage or the whole process of evaluation. However, this model is a static model which doesn’t account for the efficiency improvement over time. Hence, developing the proposed models to the ones which consider the efficiency evaluation over time is a valuable research in line with the present research. Doing such studies enables the decision makers to understand the influences or effectiveness of their managerial or technical efforts dedicated to improve the performance of their organizations. In this manner, the Malmquist productivity index could be referred as a dynamic concept in the context of DEA models which measures the changes in the managerial efficiency, technical efficiency and productivity of a decision making unit over time. This index also could explain that the improvement in the productivity of a firm is as a result of the investment in the firm's technology or as a result of the firm's managerial initiatives (Ahn and Min, 2014). Therefore the sensitivity analysis of the proposed models and developing the Malmquist productivity index which is proposed for the future studies could provide a guidance tool for firms in order to measure, compare, manage and control their efficiency and productivity measures.

5. Discussion

In line with the previous studies, in this paper explained that the customization of ERP packages could be considered as a competitive advantage for ERP sellers to satisfy and attract the customers. However, we discuss that evaluation of the ERP customization is a multi-stage process, which needs a network analysis, such as the two-stage DEA model proposed in this paper. In this regard, we explain that customization needs great programming skills and reflects this fact in the model by considering the number of functions and codes applied in the ERP packages. It was stated that the more sophisticated functionality and codes could facilitate the customization process on one hand and it could affect the operational efficiency on the other hand. So in order to evaluate the customization efficiency of the ERP packages, we integrate the operational and the customization efficiency in a two-stage network that finally could be regarded as a framework to measure the total efficiency of the ERP packages. However, despite the fact that the proposed framework is suitable to consider technical features of the ERP packages in the evaluation process, but one could modify the proposed model by considering other technical features such as distinguishing the different programming techniques embedded in the ERP packages. Nevertheless, the idea of considering the ERP evaluation process in a two-stage model is the novelty of the paper that could be regarded as a new and more comprehensive framework which enhance the results confidence more than one stage models and also could provide the managerial insights by doing the sensitivity analysis explained in this paper.

6. Conclusion

In this paper, a new model for efficiency evaluation of ERP packages was proposed. To do so, the efficiency was measured in terms of the software features including a number of codes and functions and the customization stage, which reflects the degree of ERP accordance with the organizational processes of buyers. Furthermore, we considered the operational aspects of efficiency by regarding the spend time and costs of ERP development. The ERP efficiency was modeled by a two-stage DEA model, which measured operational efficiency of ERP packages in the first stage and the customization efficiency in a second stage. The two-stage DEA models have already utilized in efficiency evaluations of some decision making units such as banks and hotels and extending this concept to the evaluation of ERP packages was the novelty of the paper. Integrating the operational and customization efficiency of ERP packages in the two stages was in line with the idea that more sophisticated and comprehensive codes and functions that might lead to the less operational efficiency of ERP packages, ultimately facilitates the customization of ERP packages and consequently improves the customization efficiency. Therefore, these two aspects of the ERP packages should be measured in an integrated manner to reflect the total efficiency. The results of the paper indicated that ERP providers with higher operational efficiency and the ability to customize ERP packages have better performance than others. However, the sensitivity analysis of the parameters of the proposed model could provide managerial insights for the less efficient ERP providers to improve their efficiencies and are categorized as the efficient ERP providers in the competitive market of ERP packages.
The customization is stated as an approach that could ensure the survival and profitability of the ERP providers in the growing market of ERP. However, customization achievement needs great ability in software development, such as the BoB (Best of Bread) techniques employed by SAP organization ("System Analysis and Program Development") as one of the largest providers of the ERP packages. In BoB, the components of standard packages are combined or customized. So, the goal is to develop ERP systems by integrating the standard modules which are suitable for business requirements that have some degree of overlap or similarity with the modules (Light et al., 2001). To augment such ability, the management practices such as the establishment of performance quality evaluation of floss projects: Application to ERP systems appraisal and employee incentive system could be notable. Moreover, the team members could facilitate the customization process using the techniques such as brainstorming, Delphi method, and deployment of good customer relationship systems.

The practical implications of the paper could be explained as follow. First, two aspects of ERP efficiency were introduced namely "operational efficiency" and "customization efficiency". The first aspect emphasizes on the processes which are important in the viewpoint of ERP provider's organizations. The second one relates the operational efficiency with the concern of the customers. The proposed framework suggests that an ERP provider could improve its efficiency by reducing the organizational efforts through some performance management best practices while trying to increase the customers' satisfaction by customizing its ERP packages. Actually, these two aspects are in line with the value-adding activities in the organizations and their relationships are addressed in the present paper by a two-stage DEA model. Second, we show through a sensitivity analysis how an inefficient ERP provider could increase its efficiency in each stage and totally. Collectively, the proposed optimization models regard the efficiency of an ERP firm in relations with other firms and these relations somehow demonstrate the competitive advantages of the firms over each other.

For the future research, using other decision-making models such as AHP and ANP models is suggested that could use other criteria to evaluate ERP packages besides the operational and customization criteria explored in this paper. Also one could extend the model of this paper to the models that examine changes in the efficiency over time such as a Malmquist productivity index as explained before. Finally, it should be pointed out that in the proposed two-stage DEA models, the output of ERP providers in terms of the customers' satisfaction were modeled as the level of customization. However, other factors such as the prices of ERP packages and other proposed service of ERP providers could affect the satisfaction of the customers and consequently the market share of ERP packages. So, one could add the third stage to the models for representing the market share. In that stage, the level of customization, price and other services act as the inputs and the sales income or the market share is the stage's output.

References

Ahn, Y. H., and Min, H., (2014). "Evaluating the multi-period operating efficiency of international airports using data envelopment analysis and the Malmquist productivity index", *Journal of Air Transport Management*, Vol. 39, pp. 12-22.

Aversano, L., and Tortorella, M., (2013). "Quality evaluation of floss projects: Application to ERP systems", *Information and Software Technology*, Vol. 55, No. 7, pp. 1260-1276.

Banker, R. D., Charnes, A., and Cooper, W. W., (1984). "Some models for estimating technical and scale inefficiencies in data envelopment analysis", *Management science*, Vol. 30, No. 9, pp. 1078-1092.

Brehm, L., Heinzl, A., and Markus, M. L., (2001). "Tailoring ERP systems: a spectrum of choices and their implications", In *System Sciences, 2001. Proceedings of the 34th Annual Hawaii International Conference on* (pp. 9-pp). IEEE.

Brzozowski, M., and Birfer, I., (2017). "Applications of MCDM Methods in the ERP System Selection Process in Enterprises", *Handel Wewnętrzny*, (3 (368) Tom I), pp. 40-52.

Charnes, A., Cooper, W. W., and Rhodes, E., (1978). "Measuring the efficiency of decision making units", *European journal of operational research*, Vol. 2, No. 6, pp. 429-444.

Chen, Y., and Zhu, J., (2004). "Measuring information technology's indirect impact on firm performance", *Information Technology and Management*, Vol. 5, No. 1, pp. 9-22.

Chen, Y., Cook, W. D., Li, N., and Zhu, J., (2009). "Additive efficiency decomposition in two-stage DEA', *European Journal of Operational Resea*rch, Vol. 196, No. 3, pp. 1170-1176

Daneva, M., (2010). "Balancing uncertainty of context in ERP project estimation: an approach and a case study", *Journal of Software: Evolution and Process*, Vol. 22, No. 5, pp. 329-357.

Das, P., and Datta, A., (2018). *Performance Evaluation of Indian Information Technology-enabled Services (ITeS) Industry: An Application of Two-Stage Data Envelopment Analysis, IJAME.*

Galagedera, D. U., Watson, J., Premachandra, I. M., and Chen, Y., (2016). "Modeling leakage in two-stage DEA models: An application to US mutual fund families", *Omega*, Vol. 61, pp. 62-77.

Gefen, D., (2004). "What makes an ERP implementation relationship worthwhile: Linking trust mechanisms and ERP usefulness", *Journal of Management Information Systems*, Vol. 21, No. 1, pp. 263-288.

Gupta, P., Mehlawat, M. K., and Mahajan, D., (2018). "Data envelopment analysis based multi-objective optimization model for evaluation and selection of software components under optimal redundancy", *Annals of Operations Research*, pp. 1-24.

Huang, C. W., Ho, F. N., and Chiu, Y. H., (2014). "Measurement of tourist hotels′ productive efficiency, occupancy, and catering service effectiveness using a modified two-stage DEA model in Taiwan", *Omega*, Vol. 48, pp. 49-59.

Kao, C., and Hwang, S. N., (2008). "Efficiency decomposition in two-stage data envelopment analysis: An application to non-life insurance companies in Taiwan", *European journal of operational research*, Vol. 185, No. 1, pp. 418-429.

Kitchenham, B., and Mendes, E., (2004). "Software productivity measurement using multiple size measures", *IEEE Transactions on Software Engineering*, Vol. 30, No. 12, pp. 1023-1035

Koch, S., (2007). "ERP implementation effort estimation using data envelopment analysis", *Technologies for business information systems*, pp. 121-132.

Kumar, V., Singh, V. B., Garg, A., and Kumar, G., (2018). "Selection of Optimal Software Reliability Growth Models: A Fuzzy DEA Ranking Approach", *Quality, IT and Business Operations*, pp. 347-357.

Lall, V., and Teyarachakul, S., (2006). "Enterprise resource planning (ERP) system selection: a data envelopment analysis (DEA) approach", *Journal of Computer Information Systems*, Vol. 47, No. 1, pp. 123-127.

Lee, S., Lee, K., and Kang, I. W., (2005). "Efficiency analysis of controls in EDI applications', *Information & Management*, Vol. 42, No. 3, pp. 425-439.

Light, B., Holland, C. P., and Wills, K., (2001). "ERP and best of breed: a comparative analysis", *Business Process Management Journal*, Vol. 7, No. 3, pp. 216-224.

Liu, D. W., and Ye, X. B., (2010). "Study on the Objectives of SCM in E-commerce Based on ERP Application", In *Applied Mechanics and Materials*, Vol. 20, pp. 22-27.

Mayrhauser, A. V., Wohlin, C., and Ohlsson, M. C., (2000). "Assessing and understanding efficiency and success of software production", *Empirical Software Engineering*, Vol. 5, No. 2, pp. 125-154.

Nozdrina, L., (2009). "Applying of fuzzy logic modeling for the assessment of ERP projects efficiency", In Proc. 5th Int. Sci. Conf. Project Management: Status and Opportunities.

Parthasarathy, S., and Anbazhagan, N., (2008). "Evaluating ERP projects using DEA and regression analysis", *International Journal of Business Information Systems*, Vol. 3, No. *2*, pp. 140-157.

Parthasarathy, S., and Sharma, S., (2016). "Efficiency analysis of ERP packages—A customization perspective", *Computers in Industry*, Vol. 82, pp. 19-27.

Shao, B. B., and Lin, W. T., (2002). "Technical efficiency analysis of information technology investments: a two-stage empirical investigation", *Information & Management*, Vol. 39, No. 5, 391-401.

Somers, T. M., and Nelson, K., (2001, January). "The impact of critical success factors across the stages of enterprise resource planning implementations", In System Sciences, 2001. Proceedings of the 34th Annual Hawaii International Conference on. IEEE.

Stefanou, C. J., (2001). "A framework for the ex-ante evaluation of ERP software", *European Journal of Information Systems*, Vol. 10, No. 4, pp. 204-215.

Stensrud, E., and Myrtveit, I., (2003). "Identifying high performance ERP projects", *IEEE Transactions on Software Engineering*, Vol. 29, No. 5, pp. 398-416.

Sudhaman, P., and Thangavel, C., (2015). "Efficiency analysis of ERP projects—software quality perspective", *International Journal of Project Management*, Vol. 33, No. 4, pp. 961-970.

Teltumbde, A., (2000). "A framework for evaluating ERP projects", *International journal of production research*, Vol. 38, No. 17, pp. 4507-4520.

Toloo, M., Nalchigar, S., and Sohrabi, B., (2018). "Selecting most efficient information system projects in presence of user subjective opinions: a DEA approach', *Central European Journal of Operations Research*, pp. 1-25.

Tsai, B. H., and Chou, S. B., (2015). "Application of multiple output data envelopment analysis in interpreting efficiency improvement of enterprise resource planning in integrated circuit firms", *The Journal of Developing Areas*, Vol. 49, No. 1, pp. 285-304.

Tu, H. J., and Yen, W. C., (2013). "Measuring the operating efficiency of internet channels using the two-stage DEA approach", *Asia Pacific Management Review*, Vol. 18, No. 3, pp. 257-274.

Wang, K., Huang, W., Wu, J., and Liu, Y. N., (2014). "Efficiency measures of the Chinese commercial banking system using an additive two-stage DEA", *Omega*, Vol. 44, pp. 5-20.

Wanke, P., and Barros, C., (2014). "Two-stage DEA: An application to major Brazilian banks", *Expert Systems with Applications*, Vol. 41, No. 5, pp. 2337-2344.

Wu, J., Xiong, B., An, Q., Sun, J., and Wu, H., (2015). "Total-factor energy efficiency evaluation of Chinese industry by using two-stage DEA model with shared inputs", *Annals of Operations Research*, pp.1-20.

Zickert, F., and Beck, R., (2013). "A mapping model for assessing project effort from requirements", *Information Systems and e-Business Management*, Vol. 11, No. 3, pp. 377-401.