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Enterprise Resource Planning Selection based on a Preference Voting and Data Envelopment Analysis

Mohammadreza Shahriari *

Associate Professor, Department of industrial management, South Tehran Branch, Islamic Azad University, Tehran, Iran

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Abstract
Today, there are several reasons for the necessity of using an enterprise resource planning system (ERP) more than ever. In the competitive environment of companies, components such as flexibility, quality, management of the relationship with customers, and lower cost show this necessity more colorfully. The necessity of integration in the processes of an organization and the need for ERP as one of the important and innovative decision-making and management tools increases the competitiveness of the organization. Since the application of ERP in the world has had many successes and failures, therefore, the efficient selection of one of the companies providing ERP can play a decisive role in the survival of organizations. In this article, considering standard KPIs, a method for selecting an ERP service provider based on Data Envelopment Analysis and Preference Voting is proposed.

Keywords: Enterprise Resource Planning (ERP), Data Envelopment Analysis (DEA), Preference Voting, Competition, Functionality, Implementation.

* Corresponding author: Email: shahriari.mr@gmail.com

1. Introduction

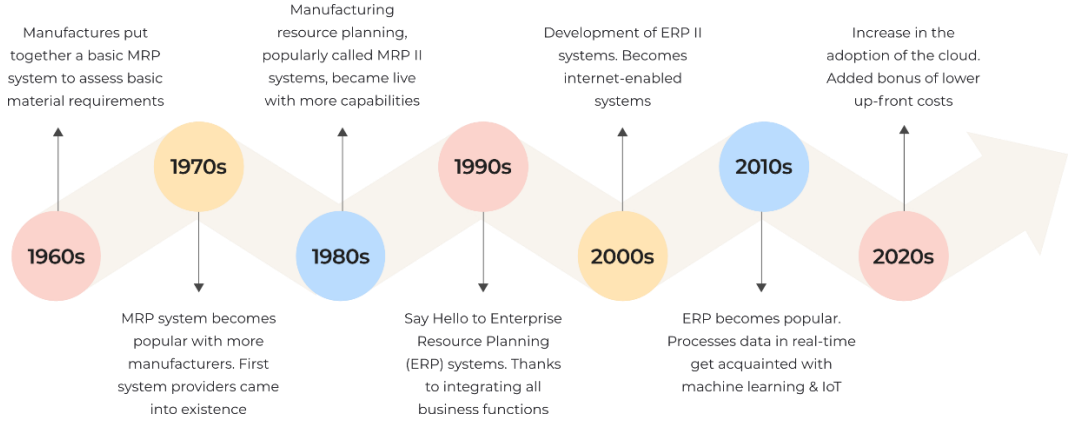
The 21 century was called the century of information and the information explosion, which is the slightest reason for information significance. Today, an expert's viewpoint may solve many seemingly complex problems easily and appropriately using an IT-based solution. E-money, which is consolidating its position, eliminates costs for printing and storing banknotes, transportation problems, and security problems and attempts to solve money-laundering problem in a suitable manner.

Meanwhile, industry has gained its share properly from such a great achievement of the age of computer, as employment of IT in industry has provided great achievements. Nowadays, imagination of the world of industry without IT is almost impossible. Several solutions have been proposed and developed rapidly in less than twenty years, which is a token of their effectiveness.

As it is noticed, ERP has been employed as the major solution in today's industry and its achievements for those organizations, which employed it, encourages other organizations to implement it. Efficiency and necessity of ERP in organizations can be compared with ISO standard series, which have been employed by most valuable industrial and business activities today. ERP will also be pervasive, as ISO prevailed in a short period.

As the flourishing of information in organizational formats, ERP designs all the information of an organization in defined formats and monopolizes all its activities. The processes, which were designed and defined while designing an organization in an ERP project, will exhibit their efficiency and effectiveness quickly within the formats of organization efficiency assessment, which are always considered as part of an ERP. The organization will improve and compete with other organizations constantly by accompanying an ERP maintenance team. By its nature, ERP executes whatever an organization has defined and do not allow anyone to violate and interfere, which is the commencement of flourishing of organizational demands.

The evidence today helps us to predict the day on which no organization would survive without ERP information systems, as preserving organizational fundamental concepts and achieving the concepts such as customer orientation, consequentialism, process-based management, leadership and objectives stability, development and participation of staff, continuous learning and innovation, business cooperation development, and practicing organization's social responsibilities will be fruitless without employing mechanized systems. Today's world will not provide any room for a single unit life for both humans and organizations. [1,2,3]



In today's world and among the tight competition of companies and organizations, performance evaluation is a decision-making factor for managers. Determining budgets and allocated costs, eliminating a subset of a supply chain, determining productivity, and many important decisions in organizations are based on performance evaluation. Data Envelopment Analysis (DEA) is a method based on linear programming that is used to evaluate decision-making units (DMU) in multi-input and multi-output mode [4]. The importance of DEA is that this method determines efficiency based on an accessible model. One of the important challenges in DEA is the free choice of input and output weights, which are determined in the most optimistic case for each DMU. One of the ways to overcome this problem is to choose weight limits and trade-offs between inputs and outputs [5,6].

From making a simple decision to go to the cinema or theater in the family or big decisions like choosing politicians, choosing the best football player all needs to gather people's opinions. Voting is a simple way to do this, where voters communicate their decisions to the community without fear of expressing their opinions. Preferential voting is a method in which voters rank candidates according to their preferences. This means that first they choose the candidate as the first priority, and then they choose the next candidate as the second priority, and so on until the last priority. Not only today, but for a long time, gathering the opinion of experts in preferential voting has been the favorite issue of researchers. This problem can be found in the findings of researchers more than two centuries ago. that Borda [7] used weighting to aggregate opinions in his research. Cook et al. [8] used an optimistic view based on data envelopment analysis to select the weight of each preference to rank the candidates. Noguchi et al. [9] introduced a confidence region for the weights that considered a robust ordering of preferences. From the recent research in this regard, we can refer to Sharafi et al. [10] who considered a method based on fuzzy theory to rank candidates based on the qualitative opinions of voters.

The structure of this article is as follows. In the second part, the statement of the problem, challenges, and necessity of choosing ERP system provider companies is stated. In the third part, the proposed method based on DEA and preferential voting for the ranking of ERP system provider companies is introduced. In the fourth part, the proposed method for ranking the well-known ERP system service provider companies for a desired industry is stated. In the final part, the conclusion is presented along with suggestions for future research.

2-Problem Definition

What is discussed as the major problem in this paper is how to select an ERP system among more than three hundred systems, as the selection would be the best choice with respect to all aspects. What becomes clear at the first glance is the main identity of the problem, which makes it clear as a mere decision-making problem [11].

An optimal ERP system for an organization is a system capable of manifesting flourishing of information clearly, accurately, and in an integrated manner in operational formats and its different levels and covering all pertinent arenas. As far as the writers' experiences and the viewpoints of firms and expert advisors are concerned, the criteria such as system expenses, technical support facilities, seller company's records, convenient usage, method of implementation, flexibility, and most important of all the technical and

specialized capabilities of a system are considered for selecting such a system [12].

As selection of an inappropriate ERP system may lead to the collapse of an organization and loss of financial resources and human resources, selection of an ERP system is considered as one of critical points of an ERP project. However, few organizations have such a potential of skilled staff to have a proper understanding of an organization, know ERP systems and the strengths and weaknesses of each system, and be able to make a correct decision [13,14].

What is performed today as the classification of superior systems by the world's credible resources is merely accomplished through comparing solutions by only general criteria. The classifications are generally based on comparing comprehensiveness of solutions in any field of an organization such as production, etc. They are never considered as a reason for selection based on the classification made by organizations, as the field of activity of organizations varies and each field is of a particular importance for any organization. Meanwhile consulting firms claim that they find the best solution for an organization and attempt to be the best provider for it by offering many questions. The classifications can be considered as a solution by themselves due to lack of consideration of organizations' requirements and other factors that may happen. On the other hand, the assessments made based on the solution's functions and their adaptation to the needs of the organization cannot be effective because compatibility or incompatibility of the demands with no equal weights cannot be a factor for decision making [15].

The writers believe that a pattern should be presented to provide a correct and scientific decision making condition for all organizations with any field of activity. Meanwhile, the proposed algorithm should contain suitable criteria for decision-making, appropriate weights should be calculated with respect to the organization's condition for any criterion, and the organization's viewpoint should be considered in it.

For this purpose, the writers attempt to present a pattern for decision-making with the following specifications:

- All organization's conditions are considered in it functionally.
- It should be flexible enough to be applied by all organizations.
- It should be comprehensive and complete to provide a high reliability for the decision made.
- It should be applicable.

3- Proposed Solution

In this section, a method for selecting the efficient ERP system provider companies are mentioned. To make it easier to express the subject, the step-by-step structure of the proposed method is shown below.

Step 1- Determining the input and output indicators affecting the performance of the ERP system

First, the indicators affecting the performance of ERP systems are determined and classified into two categories: input and output.

Step 2- Using preferential voting to aggregate experts' opinions

At this stage, the experts are asked to sort the inputs and outputs according to their preferences in the ballot using the preferential voting approach. Preference voting has been used to weight ERP input and output indicators. In this way, in two separate stages, input and output indicators are put to vote by experts. In other words, in this case, voters are experts and indicators are candidates.

Step 3- Determining the weight of inputs and outputs using preferential voting

Table 1: The results of counting the ballots

Alternative	The number of votes in the first priority	The number of votes in the second priority	⋯	The number of votes in the K priority
Index 1	v_{11}	v_{12}	⋯	v_{1k}
Index 2	v_{21}	v_{22}	⋯	v_{2k}
⋮		-	-	-
Index t	v_{t1}	v_{t2}	⋯	v_{tk}

At this stage, after counting the ballots, the number of votes for each indicator considered as a candidate is determined. The counted values of the votes are the same as the table below.

The experts have been asked to sort the indicators in k order based on their opinions. For this purpose, v_{rj}, is defined the number of votes of the j[th] $(j = 1,\ldots,t)$index in the r[th] $(r = 1,\ldots,k)$priority. The weight of pam index is obtained based on the following model. The result of solving model (1) is the weights that are considered for the indicators.

$$Z_p = Max \quad \sum_{r=1}^{k} w_r v_{rp} \qquad (1)$$

$$s.t. \quad \sum_{r=1}^{k} w_r v_{rj} \le 1, \qquad j = 1,...,t,$$

$$w_1 \ge 2w_2 \ge ... \ge kw_k, \quad r = 1,...,k-1,$$

$$w_k \ge \frac{2}{Lk(k+1)}$$

Step 4- Determining trade-offs between inputs and outputs and using DEA

At this stage, based on the weights obtained based on the summation of experts' opinions, the weight limits are mentioned between inputs and outputs. After determining the trade-off between inputs and outputs, the following models are used to evaluate the performance and ranking of ERP system provider companies, which are considered as DMU. The following model is called the SBM model [16], along with Trade-off based on Davoudi et al [17].

$$\text{Min} \frac{1-\frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{ip}}}{1+\frac{1}{s}\sum_{r=1}^{s}\frac{s_r^+}{y_{rp}}} \qquad (2)$$

$$s.t. \sum_{j=1}^{n}\lambda_j x_{ij} + \sum_{g=1}^{m}\sum_{t=1}^{m}\mu_{g,t} p_{g,t,i} + s_i^- = x_{ip}, i = 1,...,m;$$

$$\sum_{j=1}^{n}\lambda_j y_{rj} + \sum_{u=1}^{s}\sum_{h=1}^{s}\gamma_{u,h} q_{u,h,r} - s_r^+ = y_{rp}, r = 1,...,s;$$

$$\sum_{j=1}^{n}\lambda_j = 1;$$

$$\sum_{j=1}^{n}\lambda_j y_{rj} + \sum_{u=1}^{s}\sum_{h=1}^{s}\gamma_{u,h} q_{u,h,r} \ge 0, \qquad i = 1,...,m;$$

$$\sum_{j=1}^{n}\lambda_j y_{rj} + \sum_{u=1}^{s}\sum_{h=1}^{s}\gamma_{u,h} q_{u,h,r} \ge 0, \qquad r = 1,...,s;$$

$$s_i^- \ge 0 (\text{i} = 1,...,\text{m}); s_r^+ \ge 0 (r = 1,...,\text{s});$$

$$\lambda_j \ge 0 (\text{j} = 1,...,\text{n}); \mu_{g,t} \ge 0 (g, t = 1,...,m);$$

$$\gamma_{u,h} \ge 0 (u, h = 1,...,\text{s}).$$

And the model (3) presented below is the SUPER_SBM model. In fact, by removing the DMU under evaluation, it ranks the DMUs based on the super-efficiency approach.

$$\text{Min}\ \frac{1-\frac{1}{m}\sum_{i=1}^{m}\frac{|s_i^-|}{R_I^-}}{1+\frac{1}{s}\sum_{r=1}^{s}\frac{|s_r^+|}{R_O^+}} \qquad (3)$$

$$s.t.\sum_{j=1}^{n}\lambda_j x_{ij}+\sum_{g=1}^{m}\sum_{t=1}^{m}\mu_{g,t}p_{g,t,i}-s_i^-=x_{ip}, \qquad i=1,...,m;$$

$$\sum_{j=1}^{n}\lambda_j y_{rj}+\sum_{u=1}^{s}\sum_{h=1}^{s}\gamma_{u,h}q_{u,h,r}+s_r^+=y_{rp}, \qquad r=1,...,s;$$

$$\sum_{j=1}^{n}\lambda_j=1;$$

$$\sum_{j=1}^{n}\lambda_j y_{rj}+\sum_{u=1}^{s}\sum_{h=1}^{s}\gamma_{u,h}q_{u,h,r}\geq 0, \qquad i=1,...,m;$$

$$\sum_{j=1}^{n}\lambda_j y_{rj}+\sum_{u=1}^{s}\sum_{h=1}^{s}\gamma_{u,h}q_{u,h,r}\geq 0, \qquad r=1,...,s;$$

$$\lambda_j\geq 0(\text{j}=1,...,\text{n});\ \mu_{g,t}\geq 0(g,t=1,...,m);$$

$$\gamma_{u,h}\geq 0(u,h=1,...,\text{s}).$$

With the explanation that in model (3) auxiliary variables are free.

4- Selection of ERP system providers

In this section, the steps of selecting ERP system providers in one of Iran's automotive companies are described with the proposed method. The steps are presented step by step below.

first stage: Based on the studies of the R&D unit, the inputs and outputs affecting the performance of the ERP system have been selected and displayed in table 2.

Table (2): Effective inputs and outputs of ERP performance

Inputs		Outputs	
I1	Delivery Time	O1	Functionality
I2	price	O2	User friendly
I3	set up time	O3	Compatibility
I4	Maintenance Price	O4	Support Quality
		O5	Maintenance
		O6	Brand Reputation
		O7	Reliability

Table (3): The results of counting the ballot papers of the entrants

	First priority	Second priority	Third priority	Fourth priority
Delivery Time	0	5	10	3
price	15	3	0	0
set up time	0	0	3	15
Maintenance Price	3	10	5	0

Table (4): The results of counting the exit ballots

	First priority	Second priority	Third priority	Fourth priority	Fifth priority	Sixth priority	Seventh priority
Functionality	12	6	0	0	0	0	0
User friendly	3	8	3	0	0	0	4
Compatibility	3	4	8	0	0	0	3
Support Quality	0	0	4	11	3	0	0
Maintenance	0	0	3	4	8	0	3
Brand Reputation	0	0	0	0	0	18	0
Reliability	0	0	0	3	7	0	8

Table (5): Weight of effective inputs and outputs of ERP performance

Inputs		Weight	Outputs		Weight
I1	Delivery Time	0.585	O1	Functionality	0.244

I2	price	0.287	O2	User friendly	0.574
I3	set up time	1.000	O3	Compatibility	0.513
I4	Maintenance Price	0.398	O4	Support Quality	0.410
			O5	Maintenance	0.655
			O6	Brand Reputation	0.812
			O7	Reliability	1.000

Table (6): Performance results and ranking of ERP system provider companies

	EFFICIENCY	SUPER-EFFICIENCY	RANKING
Oracle	0.31961685		6
SAP	0.14259445		8
Sage	1	1.29871499	2
Microsoft Dynamics	1	1.10409217	4
SYSPRO	0.15566918		7
IFS	0.10107164		9
Kinetic	1	1.30140599	1
DELMIAworks	0.38749975		5
SyteLine	1	1.15074789	3

Second stage: After voting among the experts and counting the votes, the results are shown in tables (3) and (4). Table (3) is the prioritization of inputs and Table (4) is the prioritization of outputs by experts.

Third stage: Based on the data in table (3) and (4) and solving the model (1), the obtained weights for each of the inputs and outputs are as follows.

Fourth stage: In this stage, based on the weights obtained in the third stage, weight limits between inputs and outputs are made. which are displayed in weighted sub-constraints between input factors.

$$0.585 \times W(I_3) \geq W(I_1), \quad (4)$$
$$0.287 \times W(I_3) \geq W(I_2),$$
$$0.398 \times W(I_3) \geq W(I_4),$$
$$0.287 \times W(I_1) \geq 0.585 \times W(I_2),$$
$$0.398 \times W(I_1) \geq 0.585 \times W(I_4),$$
$$0.398 \times \times W(I_4) \geq 0.287 \times W(I_2).$$

Now, based on these weight limits, the exchange relationships are considered in the cover form. For better understanding of the topic, sample GAMS code of this section is given below.

```
LOOP(G,LOOP(T,LOOP(I,P(G,T,I)=0)));   (5)
LOOP(G,
  LOOP(T,
    IF(W1(G)>W1(T),
        P(G,T,G)= W1(T);
        P(G,T,T)=-W1(G);
    );
  );
);

LOOP(U,LOOP(H,LOOP(R,Q(U,H,R)=0)));
LOOP(U,
  LOOP(H,
    IF(W2(U)>W2(H),
        Q(U,H,U)=-W2(H);
        Q(U,H,H)= W2(U);
    );
  );
);
```

Then, the efficiency of ERP provider companies is obtained after solving model (2) and model (3) is solved for efficient DMUs, the results of which are as follows.

5-Conclution

Today, managers use every opportunity to improve due to the tight competition of commercial companies. Methods that improve the decision-making process can provide many opportunities for any company or organization. ERP is one of these opportunities. This database is a comprehensive set of information that every business needs to manage its basic processes (from accounting and financial management to inventory management, production, orders and human resources). It is by using such data that the ERP system has various modules. It creates and thereby automates and integrates the organization's workflow, tracks and analyzes operations and ultimately makes the decision-making process in the organization faster and smarter. This paper proposed a targeted and step-by-step method to choose the best ERP system for any organization. In the proposed method, preferential voting is used to aggregate the opinions of experts in weighting the effective factors in the performance of the ERP system. This issue solves the problem of lack of proper access to experts, and there is no need for a matrix of paired comparisons to weight the effective factors. The existence of a matrix of pairwise comparisons in large dimensions always confuses experts in expressing priorities. In the following, data envelopment analysis was used to evaluate and rank ERP service provider companies. The model used is a non-radial model that considers all inefficiencies. The proposed method was designed for one of the automobile companies in Iran and its results were stated.

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