Providing a structured methodology for supplier selection and evaluation for strategic outsourcing

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Abstract: Strategic outsourcing plays an important role in the success of supply chain management. Since some organisations outsource some important parts of their business, the consequences of poor decisions can cause big losses to their business. In this regard, many organisations have tried to identify, evaluate, and select suitable suppliers in order to establish a successful long-term cooperative relationship. Therefore, various models for the implementation of strategic outsourcing have been developed and used; these models have been often subjective and few of them are practically convenient to implement. Considering the limitations of strategic outsourcing models, in this article, a structured methodology for strategic outsourcing is provided, in which suppliers are first evaluated while considering operational criteria such as quality, cost, and delivery time by DEA model. Eventually, efficient companies in terms of strategic criteria and their strategic alliance with the organisation are evaluated and ranked using evidential reasoning (ER) algorithm. Finally, the best companies are selected as strategic suppliers for the organisation based on using the structured methodology. The presented methodology was used in a case study on a software provider company in Iran.

Keywords: supplier selection and evaluation; data envelopment analysis; evidential reasoning; supply chain management.


Biographical notes: Mansoor Momeni is a Professor of Industrial Management at University of Tehran. His research covers a variety of subjects, including operations research, statistical analysis, and clustering, and has published articles in these fields. He is currently a faculty member of Department of Industrial Management.

Hadi Rezaei Vandchali is a PhD student of Supply Chain Management at University of Tasmania. His research is concerned with supply chain network, social network analysis and sustainability.
1 Introduction

Today, enterprises cannot do every part of their business by themselves; they try to outsource some parts of their business to different suppliers. Therefore, managing the supplier relationships is one of the most important parts of business (Araz et al., 2007; Chatain, 2011; Prajogo and Olhager, 2012; Graca et al., 2015). Selecting the right supplier and making a long-term mutually beneficial relationship with them can have significant effects on financial and operational success (Araz and Ozkarahan, 2007; Graca et al., 2015). In this way, a suitable method for selecting and evaluating suppliers is vital for enterprises, especially in terms of selecting strategic suppliers that can meet enterprise expectations effectively in a long term (Chen, 2011; Partovi, 2013). Selecting and evaluating suppliers are not easy and are so complicated, since different criteria must be considered during the decision making procedure. In traditional selection procedure, often some criteria such as cost, quality, and delivery play an important role in selection and evaluation decisions (Araz and Ozkarahan, 2007; Chatain, 2011). Although in today’s business climate, there are many other criteria that should be considered in order to make a successful supplier relationship (Mandal and Deskmukh, 1994; Talluri and Narasimhan, 2004; Dulmin and Mininno, 2003; Dowlatshahi, 2000; De Toni and Nassinbeni, 2001; Choy et al., 2002, 2003; Chatain, 2011; Prajogo and Olhager, 2012; Graca et al., 2015), large numbers of possible suppliers with different capabilities make this procedure more complicated and a multi-criteria decision making (MCDM) problem (Araz et al., 2007).

Since many enterprises need to select and evaluate strategic suppliers, many tools and models are developed in order to effectively help these organisations in prequalifying their suppliers based on their performances and selecting the best supplier. Many methods have been developed and utilised for identifying suitable suppliers. Earlier methods have applied traditional criteria such as price, delivery, and quality as a basis for comparing suppliers; but, companies have found that these criteria are not enough by themselves. Then, some other techniques have been developed that include multiple criteria concerning some other criteria related to environmental, political, and customer satisfaction aspects (Zeydan et al., 2011; Graca et al., 2015). Traditional models use only quantitative measures; but, by expanding the criteria, there are some measures that cannot be explored quantitatively. So, new techniques should be able to work with both quantitative and qualitative measures. Also, multiple attribute decision making problems have been used in these methods that can consider both quantitative and qualitative measures such as cost, quality, reliability, and safety attributes in selecting and evaluating suppliers simultaneously (Araz et al., 2007; Graca et al., 2015). Most of such qualitative attributes are subjective and can be only evaluated properly by using human judgment, although humans cannot provide complete judgment either by lack of information or the existing vagueness of meaning about attributes and their assessment (Yang et al., 2006; You et al., 2015).

In order to consider as many as criteria and also decreases the human error in evaluating them, in this article, a structured methodology is proposed which uses DEA model based on operational criteria for evaluating suppliers’ different capability aspects and then using ER algorithm based on strategic criteria for properly ranking suppliers.
2 Literature review on supplier selection and evaluation

Supply chain management concepts are increasingly growing because of their direct impacts on financial and operational results in enterprises. Owing to the growing importance of SCM concept, considering supplier relations from a strategic viewpoint has become more important than before (Sarkis and Talluri, 2002; Partovi, 2013; Kotula et al., 2015; Zhou, 2014). SCM concept is one of the most important issues related to the selection and evaluation of suppliers; so, this subject has received great attention. Many studies have tried to identify suitable criteria and many models have been developed for using these criteria. However, it is not an easy job, since strategic evaluation of suppliers needs to consider many criteria that are related to different aspects of supplier practices and capabilities (Talluri and Narasimhan, 2004; Dowlatshahi, 2000, Tang et al., 2013).

In supplier selection and evaluation, two issues can be considered: the first one is related to the criteria: What criteria should be chosen? How should these criteria be measured? This issue should be more complicated when some qualitative criteria are considered that cannot be measured easily and need human judgment (Zhang et al., 2003; Deng et al., 2014; Ocampo et al., 2015). Another issue is related to choosing a suitable model for comparing the suppliers. It means that even all the criteria would be measured properly; using these criteria for selecting or evaluating suppliers with different levels of capabilities is very complicated (Zhang et al., 2003). In both of these areas, different studies have been conducted.

In a survey by Dickson (1996), 23 criteria were considered by enterprises, among which quality, delivery, and performance history were more important than others. Another study by Weber et al. showed that quality was the most important factor and, afterwards, delivery performance and cost were considered. There are some other works that have emphasised qualitative criteria (Weber et al., 1991; Ellram, 1990; Dickson, 1966; Deng et al., 2014; Ocampo et al., 2015). It should be mentioned that criteria for suppliers’ selection and evaluation would vary based on the purchase situation and product types. But, in general, four most important criteria are price, delivery, quality, and service (Kannan and Tan, 2003; Verma and Pullman, 1998; Ellram, 1990; Dickson, 1966). Ho et al. (2010) provided a comprehensive list of supplier selection criteria based on different studies.

However most of these research include some limitations such as evaluation only based on operational measures and not considering strategic capabilities, using subjective assessment and simple weighting methods, lack of considering various situations of suppliers during evaluation, etc. (Talluri and Narasimhan, 200; Deng et al., 2014; Ocampo et al., 2015). Many works have tried to find a solution for these limitations and different studies have been conducted by MCDM approach (Ho et al., 2010). Ho et al. reviewed and analysed different models and approaches in this area. A summary of their findings is demonstrated in Table 1.
### Table 1: Results of studies by Ho et al. on using performance evaluation methods in brief

<table>
<thead>
<tr>
<th>Approach</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual approach</td>
<td>Data envelopment analysis</td>
</tr>
<tr>
<td></td>
<td>Linear programming</td>
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<td></td>
<td>Integer linear programming</td>
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<td></td>
<td>Integer nonlinear programming</td>
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<td></td>
<td>Goal programming</td>
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<td></td>
<td>Multi-objective programming</td>
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<td></td>
<td>Analytic hierarchy process</td>
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<td>Case-based reasoning</td>
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<td></td>
<td>Analytic network process</td>
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<td></td>
<td>Fuzzy set theory</td>
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<td></td>
<td>Simple multi-attribute rating technique</td>
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<td></td>
<td>Genetic algorithm</td>
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<td></td>
<td>Integrated AHP approaches</td>
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<td></td>
<td>AHP and bi-negotiation</td>
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<td>AHP and DEA</td>
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<td></td>
<td>AHP, DEA, and artificial neural network</td>
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<td></td>
<td>AHP and GP</td>
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<tr>
<td></td>
<td>AHP and grey relational analysis</td>
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<td></td>
<td>AHP and mixed integer nonlinear programming</td>
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<td></td>
<td>AHP and multi-objective programming</td>
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<tr>
<td></td>
<td>Integrated fuzzy approaches</td>
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<td>Fuzzy and AHP</td>
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<td>Fuzzy, AHP, and cluster analysis</td>
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<td>Fuzzy and GA</td>
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<td>Fuzzy and multi-objective programming</td>
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<td>Fuzzy and quality function deployment</td>
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<td></td>
<td>Fuzzy and SMART</td>
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<tr>
<td>Other approaches</td>
<td>ANN and CBR</td>
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<td></td>
<td>ANN and GA</td>
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<tr>
<td></td>
<td>ANP and multi-objective programming</td>
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<td></td>
<td>ANP and GP</td>
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<tr>
<td></td>
<td>DEA and multi-objective programming</td>
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<td></td>
<td>DEA and SMART</td>
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<tr>
<td></td>
<td>GA and multi-objective programming</td>
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</tbody>
</table>
The results show that individual approaches have been applied more than integrated approaches. DEA has been used more than other techniques among individual approaches and integrated AHP is the preferred one in the integrated approaches. Also, their results show that individual approaches (58.97%) have been applied more than integrated approaches. On the other hand, among the individual approaches, data envelopment analysis has been considered more than others. Also, among the integrated approaches, integrated AHP approaches are the most common one (Ho et al., 2010).

3 DEA model

Due to the importance of evaluating the performance of an organisation, measuring efficiency has been always considered by researchers. In 1957, Farrell measured efficiency of a manufacturing company by a method similar to the ones used for efficiency measurement in engineering. For measuring efficiency, he considered an input and an output. Chames, Cooper, and Rhodes developed Farrell’s viewpoint and provided a model that was capable of measuring efficiency with multiple inputs and outputs. They converted multiple inputs and outputs into one input and one output by a linear programming and assigning weights that were obtained from solving the model. This model was called data envelopment analysis. Researchers have introduced different models for measuring efficiency using data envelopment analysis (Baker and Talluri, 1997; Braglia and Petroni, 2000; Liu et al., 2000; Forker and Mendez, 2001; Garfamy, 2006; Wu et al., 2007, Partovi, 2013; Azadi et al., 2015; Karsak and Dursan, 2014).

CCR model, assuming constant returns to scale, was introduced by Chames, Cooper, and Rhodes (Chames et al., 1978). BCC model, assuming variable returns to scale, was introduced by Banker, Chames, and Cooper (Banker et al., 1984).

In this paper, considering the scope of the research, we will introduce CCR model in brief CCR DEA model.

Imagine that 'n' decision making units (DMUj, j = 1,...,n) exist, each of which uses various amounts of input 'm' for producing various amounts of outputs. We represent the input vector DMUj by \( X_j = (x_{1j}, \ldots, x_{mj}) \) and its output vector by \( Y_j = (y_{1j}, \ldots, y_{sj}) \) and assume that:

\[
\begin{align*}
    r &= 1, \ldots, s; \quad i = 1, \ldots, m; \quad j = 1, \ldots, n \\
\end{align*}
\]

in which case, the efficiency of the unit is calculated as follows:

\[
    y_{ij} > 0 \quad y_{rj} > 0
\]

Efficiency of unit \( j = \frac{\sum_{i=1}^{m} u_i y_{ij}}{\sum_{i=1}^{m} v_i x_{ij}} \)

\( x_{ij} \) = amount of input \( i \) for unit \( j \) \((i = 1, 2, \ldots, m)\)

\( y_{rj} \) = amount of output \( r \) for unit \( j \) \((r = 1, 2, \ldots, s)\)

\( u_r \) = weight attributed to output \( r \) (price of output \( r \))
\( v_i = \text{weight attributed to input } i \text{ (cost of input } i) \)

In order to calculate the efficiency of each DMU, we must obtain the maximum efficiency index; that is, ratio of total balanced outputs (virtual output) to total balanced inputs (virtual input).

\[
\text{Max} Z_0 = \frac{\sum_{i=1}^{s} u_i y_{0i}}{\sum_{j=1}^{m} v_j x_{0j}}
\]

subject to:

\[
\begin{align*}
\sum_{i=1}^{s} u_i y_{ij} & \leq 1 \\
\sum_{i=1}^{s} v_i x_{ij} & = 1, s, i = 1, \ldots, m; j = 1, \ldots, n
\end{align*}
\]

\( u_i \geq 0, v_i \geq 0 \)

4 ER model

Uncertainty is one of the important issues in organisations. Milliken (1987) mentioned different definitions for uncertainty that are used in organisations and include: the inability to assign probabilities to future events, lack of information about cause and effect relationships, and inability to predict accuracy of outcomes of a decision. In general, uncertainty can be defined in two different categories: objective and perceived uncertainty. Objective uncertainty is related to characteristics of the environment that are difficult to predict, but can be measured objectively. Perceived uncertainty depends on individuals and cannot be measured objectively.

Uncertainties in the supplier selection and evaluation affect both enterprises and potential suppliers. Ford et al. (2006) analysed uncertainty from both viewpoints of enterprises and suppliers.

However, in order to evaluate and select suppliers, enterprises need a method that can minimise uncertainty. ER algorithm is one of the methods in this field and many researchers (Yang and Xu, 2003, 2004; Sonmez et al., 2001, 2002a, 2002b; Yang and Xu, 1998; Zhou et al., 2010; Taroun and Yang, 2011; Xu, 2009; Mokhtari et al., 2012; Fu et al., 2015; Yang et al., 2013) have applied it in order to reduce the effect of uncertainty caused by human judgment on decision making in selection.

ER approach has been developed because of growing challenging issues MCDA methods faced problems under uncertainty. Over the past two decades, different studies have been conducted on integrating artificial intelligence and operation research for dealing with problems with uncertainty (Xu, 2009). ER is one the latest approaches in MCDA area that tries to provide rational, reliable, repeatable, and transparent solutions for the problems under uncertainly conditions (Yang, 2001).
ER is based on D-S theory and uses an evidence-based process with the concept of ‘degree of belief’ to extract a decision maker’s preferences. These characteristics of ER approach make it different from traditional MCDA methods and a suitable method for handling (Yang and Singh, 1994). The concept of ‘degree of belief’ can be described as the degree of expectation that an alternative will provide on a particular criterion that highly depends on the knowledge of the subject and experience (Sonmez et al., 2001; Taroun and Yang, 2011). In addition, the ability of representing incomplete and fuzzy subjective judgment and contributing for the combination of attributes is the effective features of this method (Zhou et al., 2010).

For instance, Yang et al. (2007) mentioned that, when you want to select a machine, you might have five evaluation grades:

\[ H = \{ \text{poor}(H_1), \text{average}(H_2), \text{good}(H_3), \text{excellent}(H_4), \text{top}(H_5) \} \]

Imagine that \( K \) alternatives \( O_j \) (\( j = 1, \ldots, K \)) exist and we want to select them out of \( M \) criteria \( A_i \) (\( i = 1, \ldots, M \)) by five grades. Evaluation of alternative \( O_i \) in criterion \( A_1 \) is represented as \( S(A_1(O_i)) \).

In general:

\[ S(A_1(O_i)) = \{ (H_n, \beta_{n,i}), (H_n, \beta_{n,i}), (H_n, \beta_{n,i}), (H_n, \beta_{n,i}), (H_n, \beta_{n,i}) \} \]

where \( \beta_{n,i} \) indicates the degree of belief, in which criterion \( A_1 \) is evaluated through evaluating grade \( H_n \); on the other hand:

\[ 0 \leq \beta_{n,i} \leq 1 \quad (n = 1, \ldots, N; i = 1, \ldots, L) \]

\[ 0 \leq \sum_{n=1}^{N} \beta_{n,i} \leq 1 \quad (i = 1, \ldots, L) \]

In order to further clarify the function of this algorithm, using an example in his article, Yang completely explained this algorithm (Yang et al., 2007).

Imagine that alternative \( O_1 \) is to be evaluated by the two criteria \( A_1 \) and \( A_2 \); thus:

\[ S(A_1) = \{ (H_1, \beta_{1,1}), (H_2, \beta_{1,2}), (H_3, \beta_{1,3}), (H_4, \beta_{1,4}), (H_5, \beta_{1,5}) \} \]

And:

\[ S(A_2) = \{ (H_1, \beta_{2,1}), (H_2, \beta_{2,2}), (H_3, \beta_{2,3}), (H_4, \beta_{2,4}), (H_5, \beta_{2,5}) \} \]

On the other hand, this point must be explained that evaluation grades can be also quantitative. For instance:

\[ U(H_1) = 0, U(H_2) = 0.25, U(H_3) = 0.5, U(H_4) = 1 \]

By taking into account the weight of each criterion and representing it as \( w_i \), the following equation is provided:

\[ 1 \geq w_i \geq 0 \quad \text{and} \quad \sum_{i=1}^{L} w_i = 1 \]

In order to integrate the evaluation of alternative \( O_i \) using the two criteria \( A_1 \) and \( A_2 \), ER algorithm uses integration rules in Dempster-Shafer theory as follows:
Providing a structured methodology for supplier selection

\[ S(A_1(\Omega)) \oplus S(A_2(\Omega)) \]

\[ m_{n,1} = \omega_1 \beta_{n,1} \quad (n = 1, \ldots, 5) \text{ and } \bar{m}_{H,1} = \omega_1 \left(1 - \sum_{n=1}^{5} \beta_{n,1}\right) \]

\[ \bar{m}_{H,1} = 1 - \omega_1, \quad m_{H,1} = \bar{m}_{H,1} + \bar{m}_{H,1} \]

\[ m_{n,2} = \omega_2 \beta_{n,2} \quad (n = 1, \ldots, 5) \text{ and } \bar{m}_{H,2} = \omega_2 \left(1 - \sum_{n=1}^{5} \beta_{n,2}\right) \]

\[ \bar{m}_{H,2} = 1 - \omega_2, \quad m_{H,2} = \bar{m}_{H,2} + \bar{m}_{H,2} \]

where \( m_{n,1} \) and \( m_{n,2} \) are basic probability masses and \( m_{H,1} \) and \( m_{H,2} \) are unassigned probability masses. Probability masses are integrated using the following equations:

\[ m_n = K \left[ m_{n,1} m_{n,2} + m_{H,1} m_{n,1} + m_{H,2} m_{H,1} \right], \quad (n = 1, \ldots, 5) \]

\[ \bar{m}_n = K \left[ \bar{m}_{H,1} \bar{m}_{H,2} + \bar{m}_{H,1} \bar{m}_{H,1} + \bar{m}_{H,2} \bar{m}_{H,1} \right] \]

\[ \bar{m}_H = K \left[ \bar{m}_{H,1} \bar{m}_{H,2} \right] \]

\[ k = \left[ 1 - \sum_{i=1}^{5} \sum_{n=1}^{5} m_{n,1} m_{n,2} \right]^{-1} \]

When the number of criteria is more than 2, the third criterion must be integrated after integrating the first and second criteria. In other words, the third criterion will be integrated with the combination of the first and second criteria. But, in case the number of criteria is 2:

After integrating all the evaluation criteria, maximum and minimum performance of each alternative and also its average performance are calculated as follows (Yang et al., 2007).

\[ \beta_n = \frac{m_n}{1 - \bar{m}_H}, \quad (n = 1, \ldots, 5), \quad \beta_H = \frac{\bar{m}_n}{1 - \bar{m}_H} \]

\[ u_{\max} = \sum_{n=1}^{N} \beta_n u(H_n) + (\beta_N + \beta_H) u(H_0) \]

\[ u_{\min} = (\beta_1 + \beta_H) u(H_1) + \sum_{n=2}^{N} \beta_n u(H_n) \]

\[ u_{\text{avg}} = \frac{u_{\max} + u_{\min}}{2} \]

5 Research methodology

The structured methodology used in this research for the evaluation and selection of outsourcing candidates includes three phases:
In the first phase, organisation’s competitive strategy is used to create the framework of the indicators and required operational and strategic criteria. It should be noted that, in today’s dynamic competitive environment, organisations must consider the strategic perspective for managing their supply chain successfully. Therefore, the evaluation framework should be the consequence of organisation strategy as well as considering operational and strategic criteria (Chen, 2011). Then, each of the candidates’ performance is determined based on these criteria. Furthermore, it is found that there is difficulty in evaluating suppliers based on strategic criteria with respect to data collecting process. Most of the research argued that uncertainty arise due to lack of information about suppliers (Mele and Sangiorgi, 2015; Scholten et al., 2015). To accommodate these difficulties we divided the evaluation criteria in two categories. In the first categories, we used operational criteria which have mostly quantitative nature to evaluate supplier’s efficiency and in the second category we applied strategic criteria to rank those suppliers which were considered efficient based on operational criteria.

In the second phase, we are going to search for the potential candidates and select the suitable candidates. For this purpose, first, we divide the identified criteria in the previous phase into input criteria and output criteria in order to use DEA model. Then, by using DEA, efficient candidates are identified that may be qualified for long term cooperation. The main reason that we used DEA in this step is about the difficulty in aligning data
collection process throughout suppliers. In fact we applied DEA not only for computing suppliers efficiency but also it helped us to reducing the number of supplier (those suppliers which were efficient) in order to be able of evaluating them based on strategic criteria. Thus, the output of this phase was about recognising the number of suppliers which were efficient and those which were not. Due to scope of this article, we left those inefficient suppliers behind and those efficient suppliers went to next phase.

In the third phase, in order to establish a long term relationship with the selected candidates, we need to evaluate the suppliers using the strategic criteria identified in the first phase. Since in this phase, the criteria are mostly qualitative and, in fact, uncertainty in the evaluation of qualitative criteria is high, ER algorithm is used to rank the suppliers in this phase. The ability of ER approach to deal with problems with ignorance, a kind of probabilistic uncertainty was the main impetus to use this model. In other word, those pure fuzzy MADA approaches have no clue in terms of handling probabilistic uncertainties such as ignorance (Guo et al., 2009). This is further echoed after consulting with experts in our case study when they told us that the identified strategic criteria would be probabilistic regarding to measurement in their suppliers.

In summary, according to difficulties which is involved in strategic criteria in terms of obtaining relevant information, we split up evaluation process based on operational criteria (which data could be easily obtained via various method for all suppliers) and used DEA to measure the suppliers efficiency. And based on strategic criteria (which data was obtainable for limited number of supplier due to cost of collecting data or amount of uncertainties), ER approach applied to measure and rank the efficient suppliers.

6 Case study

For this research, 26 suppliers of a software vendor were selected. Based on the selected approach for measuring efficiency, DEA, input-oriented CCR model was used to measure the technical efficiency of the suppliers with regard to operational criteria. Then, suppliers were divided into two groups: efficient and inefficient companies. Finally, using ER algorithm, performance of the companies identified in the previous phase was evaluated by four strategic criteria and then they were ranked.

6.1 System Group Company

System Group Company was established in 1987 and is now the largest software vendor company in Iran. In order to develop its operation, this company first started the outsourcing installation of software in the late 2000s. Since 2005, for increasing sales volume, the company decided to outsource the sales activities as well. So, sales and installation activities were integrated and assigned to the outsourced companies.

6.2 System Group’s suppliers

System Group’s suppliers perform the sales, installation, and deployment of the System Group products in Tehran according to its quality standards. These companies have been founded by the experienced experts of System Group Company, who form the central core of these companies. The members of the supplier are developed through training provided by System Group Company and they receive the required certificates for
providing services in various fields. It is noteworthy that field of service of these companies is defined by the certificates received from this organisation.

6.3 First phase: analysis of the organisation’s competitive strategy

6.3.1 Criteria for evaluating and ranking the supplier

It should be noted that prior to selecting any evaluation criterion, the goals and strategies of an organisation must be determined. In this phase, organisation’s competitive strategy was used in order to form a framework for identifying and developing the criteria. The framework of evaluation and ranking criteria was determined by holding meetings and interviewing with organisation experts.

The following are some of the important goals and strategies of the System Group Company that are related to supplier management:

- providing solutions instead of only selling software to the customers
- strengthening relationships with customers
- improving internal processes
- developing subsidiaries and suppliers
- analysing market and segmentation
- focusing on the process-oriented solutions

After determining the framework of the criteria for evaluating and ranking the suppliers, out of 65 criteria (42 operational criteria and 23 strategic criteria), 40 criteria (26 operational criteria and 14 strategic criteria) were selected as the primary ones based on the meetings with the senior management and considering the issues such as ‘following the identified strategies’, ‘fitness to IT industry’, ‘limitation of information infrastructures in organisation’, ‘consistency with the type of activities of System Group Company’, etc. Then, questionnaires including these criteria were distributed among 43 organisation experts. To show the significance of each of the criteria, Likert scale with significance values ranging from ‘very little = 1’ to ‘very much = 5’ was used. After collecting the data and conducting one-sample t-test using SPSS software, 11 criteria were selected as the final criteria, out of which 7 were related to operational area and 4 were related to strategic area.

Taking into account the H0 assumption (the average value equal to 3), the significance values of operational criteria of ‘quality assurance’, ‘level of expertise’, ‘sales amount’, ‘capacity’, ‘on time delivery’, ‘technical capability’, and ‘market development’ as well as strategic criteria of ‘performance’, ‘ease of communication’, ‘sales quality management system’, and ‘deployment quality management system’ were considered.

6.4 Second phase: selection and evaluation of the suppliers

6.4.1 Introducing input and output criteria

As mentioned in the previous section, by identifying the related criteria in the literature, collecting the information about their significance in System Group Company, and finally
conducting statistical analysis, seven criteria were selected as operational criteria for evaluating the suppliers. To extract these factors, in addition to using the related academic papers, Delphi method was used for gathering information from some experts in software industry and also documents that were published by the company were studied and analysed. These seven criteria included ‘capacity’, ‘level of expertise’, and ‘technical capability’ and four output criteria of ‘sales amount’, ‘on time delivery’, ‘market development’, and ‘quality assurance’ were selected for this research. They were used as EMS software input in the next phase.

Using the values of Table 2 and efficiency measurement system (EMS) software, the model was implemented using the data from 26 suppliers and its output was as follows:

<table>
<thead>
<tr>
<th>Number</th>
<th>Supplier</th>
<th>Efficiency score</th>
<th>Benchmarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1</td>
<td>53.38%</td>
<td>26 (1.07)</td>
</tr>
<tr>
<td>2</td>
<td>S2</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>S3</td>
<td>52.08%</td>
<td>26 (1.04)</td>
</tr>
<tr>
<td>4</td>
<td>S4</td>
<td>57.56%</td>
<td>9 (0.10)</td>
</tr>
<tr>
<td>5</td>
<td>S5</td>
<td>52.94%</td>
<td>9 (0.22)</td>
</tr>
<tr>
<td>6</td>
<td>S6</td>
<td>80.07%</td>
<td>26 (1.07)</td>
</tr>
<tr>
<td>7</td>
<td>S7</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>S8</td>
<td>58.17%</td>
<td>7 (0.14)</td>
</tr>
<tr>
<td>9</td>
<td>S9</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>S10</td>
<td>64.86%</td>
<td>26 (0.86)</td>
</tr>
<tr>
<td>11</td>
<td>S11</td>
<td>79.05%</td>
<td>26 (1.05)</td>
</tr>
<tr>
<td>12</td>
<td>S12</td>
<td>72.97%</td>
<td>26 (0.97)</td>
</tr>
<tr>
<td>13</td>
<td>S13</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>S14</td>
<td>89.72%</td>
<td>9 (0.01)</td>
</tr>
<tr>
<td>15</td>
<td>S15</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>S16</td>
<td>42.97%</td>
<td>26 (0.72)</td>
</tr>
<tr>
<td>17</td>
<td>S17</td>
<td>97.86%</td>
<td>7 (0.12)</td>
</tr>
<tr>
<td>18</td>
<td>S18</td>
<td>78.12%</td>
<td>26 (1.04)</td>
</tr>
<tr>
<td>19</td>
<td>S19</td>
<td>58.24%</td>
<td>7 (0.58)</td>
</tr>
<tr>
<td>20</td>
<td>S20</td>
<td>97.92%</td>
<td>26 (0.98)</td>
</tr>
<tr>
<td>21</td>
<td>S21</td>
<td>93.96%</td>
<td>7 (0.94)</td>
</tr>
<tr>
<td>22</td>
<td>S22</td>
<td>63.24%</td>
<td>26 (1.05)</td>
</tr>
<tr>
<td>23</td>
<td>S23</td>
<td>69.18%</td>
<td>9 (0.57)</td>
</tr>
<tr>
<td>24</td>
<td>S24</td>
<td>94.59%</td>
<td>26 (0.95)</td>
</tr>
<tr>
<td>25</td>
<td>S25</td>
<td>48.42%</td>
<td>7 (0.09)</td>
</tr>
<tr>
<td>26</td>
<td>S26</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>
As can be observed, considering the results of the above table, efficiency scores of S2, S7, S9, S13, S15, and S26 supplier were 100%. They were identified as efficient companies.

6.5 Third phase: ranking the suppliers for outsourcing the supply of new products using ER algorithm

6.5.1 Ranking efficient suppliers in strategic criteria using ER algorithm

DEA model was used in the previous phase based on suppliers’ six-month operational results for evaluation, because it is of particular importance to the organisation to find out how much output each company has had in terms of its capacity and potential. However, in this phase, since the organisation seeks to establish a long term cooperative relationship, it needs to evaluate their performance with a holistic view.

In this phase, following the identification of efficient units, we need to rank these companies in order to establish a long term cooperative relationship for supplying new products using strategic criteria. Because the identified strategic criteria are qualitative and judgments are intuitive, a method was needed which could provide suitable and valid information in spite of the involved uncertainty. Therefore, taking into consideration the particular conditions of System Group Company and its interaction with the suppliers and, most importantly, the evaluators’ lack of full understanding required for comprehensive evaluation of the suppliers, ER algorithm was used.

As indicated by the results of solving the DEA model, the studied companies were divided into two categories of efficient and inefficient. Inefficient units can be ranked based on their efficiency score. A unit with higher efficiency will have a better rank. However, in order to distinguish between efficient suppliers in this phase, the strategic criteria identified through the questionnaire were used, which included ‘sales quality management system’, ‘deployment quality management system’, ‘ease of communication’, and ‘performance’. Out of the four identified strategic criteria, ‘performance’ was quantitative and the rest of the criteria were qualitative. To obtain the data related to the quantitative criterion of performance, efficiency values obtained from Anderson-Peterson (AP) or super efficiency method (Table 3) were considered as the scores of efficient companies. Yet, for the three other qualitative criteria, a questionnaire was designed and distributed among ten middle managers. Since middle managers had the highest interaction with the suppliers, they were selected as organisation experts for collecting valid qualitative information. Thus, by sending questionnaires and describing the issue to each of these managers, qualitative data required for implementing ER model were extracted.

In Table 3, using AP model, efficiency of efficient suppliers is shown, which was used as the operational criteria input in the second phase.
Providing a structured methodology for supplier selection

### Table 3  Efficiency of efficient suppliers using AP model

<table>
<thead>
<tr>
<th>Supplier</th>
<th>AP efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2</td>
<td>102.79%</td>
</tr>
<tr>
<td>S7</td>
<td>214.29%</td>
</tr>
<tr>
<td>S9</td>
<td>101.85%</td>
</tr>
<tr>
<td>S13</td>
<td>174.87%</td>
</tr>
<tr>
<td>S15</td>
<td>100.77%</td>
</tr>
<tr>
<td>S26</td>
<td>153.10%</td>
</tr>
</tbody>
</table>

On the other hand, extensive research on the ER approach over the recent years has led to the development of Windows-based software called ‘intelligent decision system’ (IDS) for implementing the algorithm and making users more convenient.

To this end, a questionnaire was designed and sent to middle organisation managers. After collecting data of the qualitative criteria and efficiency score of performance criterion, these data were implemented by IDS software, the results of which for the first evaluator are demonstrated in Figure 2. Accordingly, the same procedure was conducted for all the ten evaluators. From the viewpoint of the organisation experts, these 10 evaluators had the same weight; thus, the results were integrated.

**Figure 2** Results of the first evaluator for efficient supplier using ids

![Ranking of Alternatives on Overall Performance](chart)

After collecting data from the middle managers, as shown in Table 4, the results obtained from distributing questionnaires among ten middle managers as well as the quantitative values obtained from the AP table were implemented using IDS software that eventually led to ranking the suppliers.
<table>
<thead>
<tr>
<th>Rank</th>
<th>Score</th>
<th>Evaluator 10</th>
<th>Evaluator 9</th>
<th>Evaluator 8</th>
<th>Evaluator 7</th>
<th>Evaluator 6</th>
<th>Evaluator 5</th>
<th>Evaluator 4</th>
<th>Evaluator 3</th>
<th>Evaluator 2</th>
<th>Evaluator 1</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.9411</td>
<td>0.5684</td>
<td>0.6052</td>
<td>0.6839</td>
<td>0.6452</td>
<td>0.5992</td>
<td>0.6374</td>
<td>0.5655</td>
<td>0.5114</td>
<td>0.4992</td>
<td>0.6257</td>
<td>S2</td>
</tr>
<tr>
<td>4</td>
<td>4.0659</td>
<td>0.3704</td>
<td>0.4244</td>
<td>0.4705</td>
<td>0.3704</td>
<td>0.423</td>
<td>0.4285</td>
<td>0.3797</td>
<td>0.3901</td>
<td>0.4174</td>
<td>0.3915</td>
<td>S7</td>
</tr>
<tr>
<td>6</td>
<td>3.1654</td>
<td>0.3066</td>
<td>0.2837</td>
<td>0.3971</td>
<td>0.3119</td>
<td>0.2905</td>
<td>0.2993</td>
<td>0.2905</td>
<td>0.3168</td>
<td>0.339</td>
<td>0.3361</td>
<td>S9</td>
</tr>
<tr>
<td>2</td>
<td>5.3912</td>
<td>0.5344</td>
<td>0.4671</td>
<td>0.6135</td>
<td>0.5316</td>
<td>0.5596</td>
<td>0.5273</td>
<td>0.5332</td>
<td>0.5327</td>
<td>0.5486</td>
<td>0.5432</td>
<td>S13</td>
</tr>
<tr>
<td>3</td>
<td>4.8229</td>
<td>0.4882</td>
<td>0.4745</td>
<td>0.3635</td>
<td>0.4901</td>
<td>0.4877</td>
<td>0.5058</td>
<td>0.5249</td>
<td>0.5015</td>
<td>0.4985</td>
<td>0.4882</td>
<td>S15</td>
</tr>
<tr>
<td>5</td>
<td>3.4473</td>
<td>0.342</td>
<td>0.5079</td>
<td>0.2969</td>
<td>0.3346</td>
<td>0.3015</td>
<td>0.3063</td>
<td>0.3446</td>
<td>0.3549</td>
<td>0.342</td>
<td>0.3166</td>
<td>S26</td>
</tr>
</tbody>
</table>
Considering equal weights for the evaluators, the final results of ranking the six suppliers were as follows (Figure 3):

**Figure 3**  Final results of ranking the six suppliers

![Figure 3](image_url)

As shown in Figure 3, final ranking of efficient companies was as follows (Table 5):

**Table 5**  Final ranking of efficient companies

<table>
<thead>
<tr>
<th>Rank</th>
<th>Score</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5941</td>
<td>S2</td>
</tr>
<tr>
<td>2</td>
<td>0.5391</td>
<td>S13</td>
</tr>
<tr>
<td>3</td>
<td>0.4823</td>
<td>S15</td>
</tr>
<tr>
<td>4</td>
<td>0.4066</td>
<td>S7</td>
</tr>
<tr>
<td>5</td>
<td>0.3447</td>
<td>S26</td>
</tr>
<tr>
<td>6</td>
<td>0.3165</td>
<td>S9</td>
</tr>
</tbody>
</table>

**7 Conclusions**

In this article, a structured methodology was proposed for strategic outsourcing. The model provided in this article was implemented in a software provider company. In fact, by combining DEA model and ER algorithm, we achieved the proper ranking of suppliers for selecting the most suitable suppliers for a long term cooperative relationship. In this regard, both strategic and operational criteria were used in order to identify the suppliers. These data were collected through questionnaires. Among the benefits of employing this model was the point that, in the first phase, the suppliers were evaluated in terms of their potential and input. In fact, DEA model enabled us to evaluate the suppliers’ output in the operational area in proportion to their potential and identify efficient companies. In the next phase, in order to create a long term cooperative relationship criteria other than
operational criteria are involved, efficient companies were evaluated by using these criteria. Since in this article, this type of criteria was mostly qualitative and the evaluators did not have full experience and understanding for evaluating the suppliers by these criteria, ER algorithm was selected as the ranking method due to the features dealt with in the article. This algorithm enabled us to conduct evaluations that remained far from uncertain subjective judgments. ER algorithm was capable of conducting a proper evaluation under the conditions of uncertainty and shortage of information using the integration rules in Dempster-Shafer theory. Since many organisations do not have comprehensive understanding of or required experience about the performance of efficient suppliers concerning the intended criterion, they will be unable to declare a specific point as the final score. In this regard, by enabling the evaluator to use a set of grades, instead of a single grade for evaluation, ER algorithm was selected as the suitable tool for this research and finally efficient companies were ranked by using the strategic criteria identified by this algorithm.

It should be mentioned the result of using these two methods simultaneously provides a supplier ranking considering both operational and strategic factors as well as managing uncertainty that are highly accepted by experts and senior managers.

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References


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