**ABSTRACT**

Supplier selection is a multi-criteria decision making process encompassing various tangible and intangible factors. Both risks and benefits of using a vendor in supply chain are identified for inclusion in the evaluation process. A hybrid approach that applies to both quantitative and qualitative factors is used in the development of the model. Taguchi loss functions are used to measure performance of each supplier with respect to the risks and benefits. Analytic Hierarchy Process (AHP) is used to determine the relative importance of these factors to the decision maker. The weighted loss scores are then calculated for each supplier by using the relative importance as the weights. The composite weighted loss scores are used for ranking of the suppliers. The supplier with the smallest loss score is recommended for selection.

**INTRODUCTION**

With growth of the world economy and global marketplace the importance of outsourcing is more than ever. Many firms are engaged in outsourcing a number of their selected activities in order to take advantage of the external expertise. Although outsourcing provides the firms with many benefits, if the right activity is not chosen for outsourcing or inappropriate supplier is chosen to perform the activity the negative impacts on the firm could be drastic. Thus it is crucial for the decision makers to analyze the impacts of their outsourcing policy on their organizations. The aim of the current research is to provide a tool for performing such an analysis and make this tool accessible to the decision makers.

To allow a thorough analysis of an outsourcing decision the tool should provide ample opportunity for the decision maker to: first, be aware of pros and cons of outsourcing, second, be able to compare these positive and negative impacts in a systematic and scientific way, and finally be able to rank potential suppliers for performing the outsourcing function. The proposed model is developed in order to serve these purposes. Risk and benefit categories associated with outsourcing are identified. The subjective judgments of the decision makers on the importance of these factors are elicited through the use of AHP. The pair-wise comparisons are used to determine the priority weights of the risks and benefits. The performance of each supplier with respect to the risk and benefit categories are measured by a common value, Taguchi’s loss score. The weighted loss scores are determined by combining the loss scores and the weights from the AHP. The composite weighted loss scores are calculated for each potential supplier. The suppliers are then ranked according to their composite weighted scores.
The rest of the paper is organized as follows: The background and overview of the literature is provided in section 2. The development of the proposed model is detailed in section 3. The paper concludes with summary and conclusions in section 4.

II. LITERATURE REVIEW

In today’s economy outsourcing has become a norm rather than an exception and thus it is very important to identify the appropriate supplier to outsource to. Supplier selection is a multi-criteria decision making process encompassing various tangible and intangible factors. These factors however do not have the same weight in the decision making process. The level of importance of these criteria varies by the decision maker and the situation at hand. As a result most of the supplier selection models have been developed with the capability of addressing this issue. A brief overview of the literature is provided below. Numerous supplier selection models are uncovered in literature. These methods fall into one the following categories:

**Categorical methods** (Timmerman, 1986); Supplier’s performance on all relevant criteria are categorized as “positive”, “neutral”, and “negative”. The supplier whose performance receives the most “positive” values is the best.

**Data envelopment analysis (DEA)** (Weber & Desai, 1996; Weber et al. 1998; Liu et al. 2000); The efficiency of each supplier is calculated as the ratio of weighted sum of its output (the performance of the supplier) to the weighted sum of its input (the cost of using the supplier).

**Cluster Analysis (CA)** (Holt, 1998); Uses a classification algorithm to group a number of suppliers into clusters based on a set of numerical attribute scores.

**Linear Weighting models** (Timmerman, 1986); Weights are assigned to the criteria based on their importance. Ratings on the criteria are multiplied by their weights and summed to obtain a single score for each supplier. The supplier with the highest overall ratings is selected. Variations to the basic linear weighting models are proposed by various researchers. Analytical Hierarchy Process (AHP) is used by others (Nydick & Hill 1992; Barbarosoglu & Yazagac 1997; Masella & Rangone 2000, Sarkis & Talluri, 2000).

**Mathematical programming models** (Chaudhry et al. 1993; Weber & Desai 1998; Ghousypour & O’Brien 1998; Weber et al. 2000); The supplier selection problem is formulated in terms of an objective function. The appropriate supplier is identified by finding the optimal solution.

In most of the above models the appropriate supplier is selected based on the selection criteria. Very few models have included the risks and benefits of outsourcing in the evaluation process. Even fewer attempts have been made to provide a systematic approach for quantifying the intangible risks and benefits. To fill such a gap a hybrid approach is proposed here that could address both issues; the inclusion of risks and benefits which are both qualitative and quantitative in nature as well as a systematic approach to quantification of intangibles. AHP methodology is used to include decision makers’ judgments regarding the risks and benefits. Taguchi loss functions are used as a mechanism to quantitatively represent the suppliers’ scores by measuring their performances with respect to these risks and benefits. By employing AHP and Taguchi a
superior approach to supplier selection is provided. The development of the proposed model is detailed in the next section.

III. DEVELOPMENT OF THE MODEL

The premise of the proposed model is that the outsourcing decision is justified both strategically and financially. That is the outsourcing decision does not compromise the firm’s competitive position, and is in line with strategic goals of the organization. In addition, the firm can take advantage of the monetary benefits by engaging in an outsourcing decision. The purpose of the proposed model is to identify the appropriate supplier to carry out the outsourcing function. The model is developed by completing the following steps:

- Identifying the risk and benefit categories associated with outsourcing.
- Determining the relative importance of each risk and benefit category.
- Determining the performance of each supplier with respect to the risk and benefit categories.
- Developing a mechanism to quantitatively measure the suppliers’ performance with respect to all the pertinent risks and benefits.
- Determining the rankings of the potential supplier and selecting the appropriate supplier.

Each of the above steps is detailed in the following sections.

Identifying risks and benefits of outsourcing

Any sourcing decision has certain benefits and risks that should be included in the evaluation process. A careful review of the literature was conducted to uncover the categories of risk and benefit associated with an outsourcing decision. A list of possible benefits and risks that could materialize from a sourcing decision is compiled from the available literature on the subject. Some benefits offered by outsourcing cited in the literature (Chalos 1995; McCarthy 1996; Parasuramann et al. 1988) are:

- Higher level of flexibility, with less restriction from the rules existing in the company.
- Increased responsiveness to customers’ needs.
- Providing special services to the customers through outsourcing without the need to hire special skill workers.
- Liability and risk reduction.
- Reduction of capital investment and labor requirements.
- Access to the innovations and developments of more specialized suppliers.
- Reduction of costs due to the supplier’s economies of scale.
- Greater focus of resources on high value-added activities and core business.
- Assurance (competence, courtesy, credibility, security).
- Responsiveness.
- Empathy (communication, access, understanding).

Some of the risks associated with outsourcing cited in the literature (Friedman 1991; Raistrick 1993) are:

- Lack of control on quality of the product/service provided by the suppliers.
- Inability to meet fluctuations in demand for the product/service that has been outsourced.
- Loss of control over suppliers.
• Negative impact on employees' morale.
• Loss of critical skills or developing the wrong skills.
• Loss of cross-functional skills.

Of course not all the risks and benefits in the above lists are pertinent to every situation and every decision maker. The list of the benefits and risks is narrowed down to include only the relevant categories. This is accomplished through a calibration procedure where the decision maker is asked to identify the benefits/risks pertinent to his/her situation. In addition, the selected categories have different level of importance to the decision maker. Thus, there is a need to determine the relative importance of each risk and benefit category. This is accomplished by completing the second phase of the model development explained in the following section.

Determining the relative importance of each risk and benefit category
The importance of each risk and benefit is subjective and varies by the decision maker. To capture the subjective judgments of the decision maker the AHP methodology is used. AHP introduced by (Saaty, 1995) is widely used for solving multi-attribute decision making problems. In the current research the AHP methodology is used to determine the relative importance of various factors considered in the evaluation of the potential suppliers. This is accomplished by performing several pair-wise comparisons where the decision maker states the importance of one criterion over the rest of the criteria on the scale of (1-9). Where 1 means least preferred and 9 means most preferred and numbers between the two extreme shows moderate importance.

The pair-wise comparisons are performed for benefits and local priorities are calculated using the approach recommended by (Saaty, 1995). These priorities represent the relative importance of the benefit categories. The local priorities for the risk categories are calculated in the same manner. These priorities are then used as weights in calculation of suppliers’ weighted loss scores. Once the importance of each risk and benefit category is determined there is a need to find out how each potential supplier perform with respect to these risk and benefit categories. This is achieved by completing the third phase of the model development as explained in the next section.

Determining the performances of suppliers with respect to the risk and benefit categories
Suppliers’ performances vary with respect to the pertinent risk and benefit categories. More importantly two decision makers might have different perception of the performance of the same supplier with respect to the exact same risk or benefit category. Thus, inclusion of the subjective judgment of the decision maker in the evaluation process is crucial. To achieve this, an elicitation procedure is performed to solicit the decision maker’s perceptions of suppliers’ performances. The decision maker often base such judgments on the historical data, reputation of the supplier, the specifics of the situation at hand, etc. Once pertinent risk and benefit categories are selected and potential suppliers are identified the elicitation process is performed. At this point the decision maker has identified all the pertinent risks and benefits, the relative importance of each are determined through application of AHP methodology. Furthermore, the decision maker’s perceptions of suppliers’ performance with respect to these risk and benefit categories have been elicited. However, to allow ranking of the potential suppliers the results of the analysis performed so far should be combined and subjective perceptions ought to be quantified to come up with a single performance score for each supplier. The Taguchi loss
function was considered as a means to accomplish this task as explained in the next phase of the model development.

**Developing a mechanism to quantitatively measure suppliers’ performances with respect to risk and benefit categories.**

Generally, three types of loss functions are used to calculate Taguchi loss (Taguchi & Hsiang 1989; Besterfield *et al.* 2003). First, two sided loss function where nominal value is the target and deviation from either side of the target is allowed as long as it remains within the specification limits. The second and third types of loss functions are one-sided functions where deviations from the target are allowed only in one direction. These loss functions are referred to as “larger-is better” and “smaller-is-better”.

For the purpose of this study, one-sided minimum specification limit Taguchi loss function (larger-is-better) has been used to quantify the impact of outsourcing benefits. The rationale is that the more outsourcing benefits received from a supplier compared to performing the function in-house is better. 100% possibility of receiving an outsourcing benefit over the in-house performance is the target value. The deviation from this target value is possible only in one direction and the magnitude of allowable deviation is set by the decision maker. Such a loss function is formulated as $L(X) = k \left( 1/X^2 \right)$ where $X$ is a vector representing desired specification limits set by the decision maker for the pertinent benefit categories. Thus, if the number of relevant benefit categories is denoted by $n$ then $x_i : i=1,2,...,n$. $L(X)$ is the loss for specific value of $X$, and $k$ is the loss coefficient whose value depends on the specification limits set by the decision maker.

Using such a one-sided loss function, 100% Taguchi loss occurs at the lowest specification limit. For instance, the decision maker might set the lowest specification limit for delivery of a benefit category, compared to performing the function in-house, at 70%. Then the Taguchi loss is 100% for a supplier that performs at this level. The value of the loss coefficient $k$ is calculated as $100 \times (0.70)^2 = 49$, and the loss function for this particular benefit category is identified as $L(X) = 49(1/X^2)$. Thus, the loss score for suppliers whose performance meet the specification limit can be calculated using this loss function. Appropriate loss functions for all the benefit categories are determined in similar manner. Supplier’s loss scores are then calculated using these loss functions. As a result each supplier will end up with several separate loss scores for all the pertinent benefit categories. However, a single value is desirable to allow the comparison of the performance of the potential suppliers. To achieve this, for each supplier a weighted loss score for all the benefit categories is calculated. The weights used in the calculation are the relative importance of each benefit category that has already been determined through AHP methodology.

The one-sided maximum specification limit loss function (smaller-is-better) is used to quantify the impact of the risk categories on an outsourcing decision. The target value is zero, thus the loss is zero when delivery of a risk category by a supplier is unlikely. The loss is 100% when the risk is at its upper specification limit. Such a loss function is formulated as $L(Y) = kY^2$; Where vector $Y$ represents the specification limits set by the decision maker for the relevant risk categories. If $m$ denotes the number of these risk categories, then $y_i : i=1, 2,...,m$. $L(Y)$ is the loss for specific value of $Y$ and $k$ is the loss coefficient.
Using decision maker’s specification limits and the above loss function, the loss coefficient $k$ can be calculated. For instance, a decision maker might set the specification limit of 5 days for responding to fluctuations in demand. Then the Taguchi loss for a supplier who can respond immediately is zero while the loss for a supplier who responds in 5 days is 100%. The loss coefficient is calculated as $k = 100 / (5)^2 = 4$, and the loss function for this risk category is determined as $L(Y) = 4Y^2$. Thus, suppliers’ loss scores for those who can respond faster than the limit of 5 days can be calculated using this loss function. The loss functions for the rest of the risk categories are determined in a similar fashion. The supplier’s loss score for these risk categories are calculated using the appropriate loss functions. In order to come up with a single loss score for all the risk categories, the supplier’s individual loss scores and the relative importance of these risk categories are used to calculate a weighted loss score.

To select the appropriate supplier, potential suppliers need to be ranked based on their composite loss scores that combine the weighted loss scores for benefits and risks. The calculation of the composite loss scores and ranking of the suppliers are performed in the final stage of the model as detailed in the following section.

**Determining rankings of the suppliers**

At this point each supplier has received a weighted loss score for all pertinent benefit categories as well as a weighted loss score for all relevant risk categories. However, to compare performances of the potential suppliers, a single loss score for each supplier is desirable. To accomplish this task, the average loss score for each supplier is determined by calculating the average of the weighted loss scores for benefit and cost categories that have already been calculated.

The suppliers are then ranked based on their average loss scores. In this study, a final unified loss score was obtained by using the average of the loss scores for benefits and risks. Of-course, the calculation of the composite loss score can vary by the company and/or the decision maker. The proposed model can be used to consider various factors for ranking of the suppliers.

**IV. CONCLUSIONS**

A decision model is developed to help decision makers with selection of the appropriate supplier for the outsourcing purposes. Although outsourcing provides certain benefits for the company it carries with it several risks as well. The proposed decision model is an attempt to consider all aspects of an outsourcing decision in the evaluation process. To accomplish this task first all benefit and risk categories associated with outsourcing are identified. The importance of each category along with decision maker’s perception of supplier’s performance with respect to these categories is elicited. AHP is used to determine the relative importance of each category and Taguchi loss functions are applied to quantitatively measure the supplier’s performance. Individual loss scores for each benefit/cost category are calculated. The weighted and composite loss scores are then determined and used for ranking of the potential suppliers. The supplier with the lowest composite loss score is chosen to perform the outsourcing function.

(References are available upon request from Sharon Ordoobadi)