

Research paper

Supplier selection problem: a comparison of the total cost of ownership and analytic hierarchy process approaches

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Abstract

Supplier selection and evaluation are arguably one of the most critical functions for the success of an organization. Several approaches exist in the literature to objectively evaluate suppliers, including analytic hierarchy process and total cost of ownership. Analytic hierarchy process provides a framework to cope with multiple criteria situations involving supplier selection, while the total cost of ownership is a methodology and philosophy, which look beyond just the price of a purchase to better understand and manage costs in selecting and maintaining relationships with suppliers. This paper illustrates the two approaches and provides a comparison.

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Introduction

Suppliers have always been an integral component of a company's management policy; however, the relationship between companies and their suppliers has traditionally been distant. In today's global economy of just-in-time (JIT) manufacturing and value-added focus, there is a heightened need to change this adversarial relationship to one of cooperation and seamless integration. JIT requires the vendor to manufacture and deliver to the company the precise quantity and quality of material at the required time. Thus the performance of the supplier becomes a key element in a company's success or failure. Companies in order to attain the goals of low cost, consistent high quality, flexibility and quick response have increasingly considered better supplier selection approaches (Vonderembse and Tracey, 1999). These approaches require cooperation in sharing costs, benefits, expertise and in attempting to understand one another's strengths and weaknesses, which in turn leads to single sourcing, supplier and long-term partnerships (Masson, 1986; Emmelhainz, 1987).

However, as has been pointed out by Quigley (1995), it takes a lot of work and patience to develop these partnerships. Since the supplier selection process encompasses different functions (such as purchasing, quality, production, etc.) within the company, it is a multi-objective problem, encompassing many tangible and intangible factors in a hierarchical manner. The evaluation of intangible factors requires the assessment of expert judgment, and the hierarchical structure requires decomposition and synthesis of these factors (Pruett, 2000).

This paper will look at the total cost of ownership (TCO) and analytic hierarchy process (AHP), as applied to the supplier selection process. The rationale for focusing on these approaches is based on the practicality of the approaches. The following section presents a brief introduction to the supplier selection process; this is followed by a description of some of the main approaches to supplier selection and an enumeration of the AHP and TCO methods. A comparison is

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then drawn of the two approaches, together an illustration of their use. The final section presents the conclusions of the paper.

The supplier selection process

Historically, an antagonistic relationship has often existed between buyers and suppliers; however, in the past few years a positive change has been observed in this relationship. Trends, such as shortened product life cycles, increased rates of technological change, and foreign sourcing, have given rise to improved communication and cooperation between buyers and suppliers, with implications on management practices, such as single source procurement.

Supplier selection is generally a lengthy evaluation process. Suppliers are evaluated on several criteria such as pricing structure, delivery (timeliness and costs), product quality, and service (i.e. personnel, facilities, research and development, capability, etc.).

Frequently, these evaluation criteria involve trade-offs. For example, one supplier may offer inexpensive parts of slightly below average quality, while another supplier may offer higher quality parts, with uncertain delivery, thus setting up trade-offs. In addition, the importance of each criterion varies from one purchase to the next and is complicated further by the fact that some criteria are quantitative (price, quality, etc.), while others are qualitative (service, flexibility, etc.). Thus, a technique is needed that can adjust for the decision maker's attitude toward the importance of each criterion and incorporates both qualitative and quantitative factors.

Existing approaches in supplier selection

While most buyers still consider cost to be their primary concern, new more interactive and interdependent selection criteria are increasingly being used. An extensive literature survey on supplier selection criteria and approaches can be found in Weber and Ellram (1993). A summary of the approaches to supplier selection favored in literature is presented below.

Total cost approach

In the total cost approach the quoted price from each supplier is taken as the starting-point and then each issue being considered is replaced by a cost factor. The process begins by first determining factors important to the organization, and then each factor is translated into a cost component that is added into a price adder formula. And finally, to each supplier's quoted price is added a debit (or credit) for each factor that is appropriate to that supplier's performance (Harding, 1998). And the business is awarded to the supplier with the lowest unit total cost. Companies wanting to implement a total cost supplier selection process often stumble over how to include non-monetary issues such as delivery and quality performance, lead time, services and social policies (Monckza and Trecha, 1988; Porter, 1993).

Multiple attribute utility theory

Use of multiple attribute utility theory (MAUT), can help purchasing professionals to formulate viable sourcing strategies, as it is capable of handling multiple conflicting attributes inherent in international supplier selection. It also enables the purchasing manager to evaluate "what if" scenarios associated with changes in company policy (Bard, 1992; Von and Weber, 1993). In an era of global sourcing, a multinational firm's success often hinges on the most appropriate selection of its foreign suppliers. International supplier selection is very complicated and risky, owing to a variety of uncontrollable and unpredictable factors (exchange rate, tariffs, government policies) affecting the decision.

Multi-objective programming

The multi-objective programming approach is generally used in the JIT scenarios. An additional flexibility of this approach is that it allows a varying number of suppliers into the solution and provides suggested volume allocation by supplier. However, the process is complex and in many cases impractical to implement (Weber and Ellram, 1993).

Total cost of ownership

TCO is a methodology and philosophy, which looks beyond the price of a purchase to include many other purchase-related costs. This approach has become increasingly important, as organizations look for ways to understand and manage their costs better.

The TCO models are further classified by usage: supplier selection and supplier evaluation (Ellram, 1993).

Analytic hierarchy process (AHP)

AHP is an excellent approach that can be used in a multifactor decision-making environment, and especially when subjective and/or intuitive consideration has to be incorporated. AHP provides a structured approach for determining the scores and weights for the multiple criteria used and standardizes them, so that they can be compared and decisions made.

Comparison

The TCO and AHP approaches were compared on several criteria. The comparison is presented in Table I.

Integrated supply chain management encompasses all activities associated with the flow and transformations of products from the raw materials stage through delivery to the final consumer. To achieve competitive advantages firms need to emphasize outsourcing in a way that adds value to the

supply chain as a whole. A good supplier is a major component of this value creation, hence making supplier selection decision critical.

The procedures of both approaches go further than just looking at the obvious and integrate multiple issues into the selection process. However, TCO tends to focus more on the pricing issues and ignores qualitative issues, its strength being the ability to use the same model to evaluate suppliers across the board and identify the "best supplier" based on lowest transaction costs, and can be used effectively for supplier evaluation along with supplier selection. However, in today's world of quality consciousness, JIT delivery, flexibility, and vendor-supported industries, etc., AHP provides a tool to help integrate and compare seemingly uncomparable issues and forces company management to make the required trade-offs to select the optimal supplier.

AHP is more of a selection tool and is appropriate in decision-making situations, where both quantitative and qualitative factors have to be considered, whereas TCO is difficult to use in an environment where

Table I Salient features of AHP and TCO

Salient features	AHP	TCO
Procedure	Hierarchical and using ratio scales to integrate and then use pair-wise comparison and eventual synthesis to find "best" decision	Looks beyond purchase price to include all other purchase-related costs Based on the economists' "transaction cost" view
Decision-making situations	Prioritizing decision making with intangible factors, along with intuitive, qualitative, quantitative and rational aspects	Supplier selection as well as supplier evaluation
Advantages	Use in both criteria comparison and individual aspects within each criteria can be tackled Forces managers to make trade-offs Simple	Provides a clear quantitative evaluation and selection rule Changes focus from purchase cost to total cost Helps identify costs that otherwise may remain hidden Provides consistent message to supplier as regards the requirements and evaluation criteria
Disadvantages	Requires enumerations of all issues Requires intense management involvement Forces trade-offs	Complex Requires extensive tracking and maintenance of cost data Requires cultural change Often situation-specific
Categories of supplier evaluation	Performance, capability, business structure, quality system	
Applications	Multiple goal conflicts, supplier selection based on numerous factors, when price alone is not the determining factor of supplier selection	Supplier evaluation as well as selection, when cost is of high priority

subjective assessments and judgments have to be used in comparing factors.

TCO provides a consistent supplier evaluation tool, improving the value of supplier performance comparisons among suppliers and over time. It helps clarify and define supplier performance expectations for both the buyer and the supplier. Using a common model for both supplier selection and evaluation, TCO provides focus and a consistent message about what is important, creates less work, and the outcome of selection/evaluation can be used directly to pre-qualify suppliers, qualify suppliers, and even be part of the supplier certification process. Thus, all the firm's supplier measurement tools will be linked and consistent. However, the amount of complexity and the data requirements are major drawbacks of the approach.

AHP, on the other hand, is a flexible modeling tool that can accommodate a larger set of evaluation criteria and can address both qualitative and quantitative data. However, judgments that drive the process, along with being the strongest advantage, are also a limitation, because one person's judgment may differ from another's. Several consensus-building approaches have been adopted to overcome this concern.

In terms of the applications of the two approaches, TCO is better suited to those situations where cost is of high priority and detailed cost data are available to make comparisons. In the case of AHP, it is better suited to solve and decide between suppliers when several conflicting goals exist and, though cost may be an important factor, it is not the overriding one.

Total cost of ownership

Total cost of ownership (TCO) looks beyond the price of a purchase to include many other purchase-related costs (Ellram 1995a; Degraeve *et al.*, 2000). This approach has become increasingly important, as organizations look for ways to better understand and manage their costs. The TCO models are further classified by their primary usage: supplier selection and supplier evaluation (Ellram, 1993). In either of these types of models, some of the factors (such as product cost, quality cost, service cost etc.) considered are qualitative and the manager could easily evaluate them. However, not all these factors are so easily evaluated due to

their quasi-quantitative (personal cost, past experience, etc.) nature or to simply being soft issues as the relationship of the decision-maker and the supplier (Ellram, 1995b), which adds another dimension to the problem.

TCO is a complex approach requiring the buying firm to determine which costs it considers the most important or significant in the acquisition, possession, use or service of that product (Degraeve and Roodhooft, 1999). TCO may include, in addition to the price paid, elements such as order-placement costs, research costs, transportation costs, receiving, inspecting, holding and/or disposal costs.

Though there are other selection and evaluation approaches closely aligned with TCO, such as life-cycle costing (Ellram, 1993), zero-based pricing (Monckza and Trecha, 1988), cost-based supplier performance evaluation (Handfield and Pannesi, 1994), and cost-ratio method (NAPM, 1991), none of these approaches has received significant, widespread support in the literature or in practice (Soukup, 1987) for a variety of reasons. Some of the criticism of these methods includes complexity, situation-specific application, over-reliance on some factors and insufficient consideration of others and so on.

Several articles focus on the TCO approach in handling supplier selection/evaluation. For example, Handfield and Pannesi (1994) explore the underpinning of the TCO approach using the product life-cycle method. The authors note that costs are directly related to the life cycle stage of the product.

The theoretical underpinnings for the TCO approach stem from the economists' view of "transaction cost". While TCO can be used to make a make-or-buy decision, it should primarily be used after the organization has determined that it will buy rather than produce. TCO analysis is a valuable tool to support the application of the transaction cost analysis to buyer-seller relationships. Two major approaches to determining TCO are proposed, namely the dollar-based and the value-based approach (Ellram, 1995b).

An illustration of the TCO approach

An illustration of the TCO approach is presented below. A comparison is made between three suppliers supplying a given

part. Their respective costs incurred on the production are detailed below (Table I). The costs are broken down into four main categories:

- (1) manufacturing (raw material, labor, etc.);
- (2) quality (quality inspection, rework etc.);
- (3) technology (designing, engineering, etc.); and
- (4) after-sales service costs.

From Table II, it is apparent that supplier 1 has the least total cost for the given product, though, if we look at each item separately, the supplier is not the “best” in each area. Based on this evaluation and using the TCO approach, we would select “supplier 1” as our vendor.

Advantages and limitations of the TCO approach
 TCO provides many benefits that are documented in the literature (Ellram, 1993) and confirmed by case studies (Prueitt, 2000; Henry and Elfant, 1988). Some of the primary benefits of adopting a TCO approach are that it provides a consistent supplier evaluation tool, improving the value of supplier performance comparisons among suppliers and over time. It helps clarify and define supplier performance expectations for both the buyer and the supplier. TCO also provides a focus and sets priorities regarding the areas in which supplier performance would be most beneficial (supports continuous improvement), creating major opportunities for cost savings. TCO improves

the purchaser’s understanding of supplier performance issues and cost structure and provides excellent data for negotiations. It also justifies higher initial prices based on better quality/lower total costs in the long run to managers. Specifically, TCO-supported supplier selection helps in providing a consistent framework for supplier performance recognition awards and measuring ongoing supplier performance. It also helps in comparing supplier performance (benchmark) against others and self over time and in building strategic alliance efforts.

The advantages flow both ways in terms of bringing the supplier and customer closer and help in optimizing use of resources for both partners. Using a common model for both supplier selection and evaluation has many benefits (NAPM, 1991). First, the linkage provides focus and a consistent message about what is important to both suppliers and internal users. Second, using a common model will create less work, confusion and training requirements than would different models. Third, the outcome of selection/evaluation can be used directly to pre-qualify suppliers, qualify suppliers, and even be part of the supplier certification process. Thus, all the firm’s supplier measurement tools will be linked and consistent.

The amount of complexity of TCO is a major barrier in the adoption of this approach. The amount of readily available costing data in many organizations is another factor, though this factor is becoming increasingly less important, as more and more organizations are implementing activity-based costing (Harrington, 1993; Ellram, 1995a, b). Another complicating factor is that there is no standard approach to TCO analysis. Research and a review of the literature have indicated that TCO models used vary widely by company and may even vary within companies depending on the class or item purchased (Soukup, 1987; Carr and Ittner, 1992; Kaplan, 1992). Further, TCO adoption may require a cultural change, a change away from price orientation towards total cost orientation. That potential for cultural change is a major reason why TCO is regarded as a philosophy rather than as merely a tool. An additional factor, which complicates TCO, is that TCO costs are often situation-specific. The costs which are significant and relevant to decision making vary on the basis of many factors – such as the

Table II Total cost of ownership

	Supplier 1	Supplier 2	Supplier 3
Manufacturing			
Raw material cost	1,000	950	1,100
Labor	500	600	550
Machine depreciation	250	200	225
	1,750	1,750	1,875
Quality costs			
Cost of inspection	200	250	150
Rework costs	50	100	45
Cost due to delay	50	75	40
	300	425	235
Technology			
Design costs	500	450	550
Engineering costs	1,500	1,250	1,500
	2,000	1,700	2,050
After-sales service	200	350	150
Total costs	8,200	8,350	8,470
Units shipped	1,000	1,000	1,000
TCO	\$8.20	\$8.35	\$8.47

nature, magnitude and importance of the buy (Ellram, 1994).

Analytic hierarchy process (AHP)

AHP provides a framework to cope with multiple criteria situations involving intuitive, rational, qualitative and quantitative aspects. AHP was developed by Saaty and published in his 1980 book, *The Analytic Hierarchy Process*. It is a decision-making method for prioritizing alternatives, when multiple criteria must be considered. Managerial judgments are used to drive the AHP approach by assigning weights to different criteria and the alternative with the highest total weighted score is selected as the best. The primary objectives affecting supplier selection criteria are grouped under three main categories: performance assessment, business structure capability assessment, and quality system assessment. AHP is used as a framework to formulize the evaluation of trade-offs between the conflicting selection criteria associated with the various suppliers' offers (Nydic and Hill, 1992; Render and Stair, 2000). When a supplier selection decision has to be made, the buyer generally establishes a set of evaluation criteria, and the AHP process makes use of these criteria to help make the decision. It first structures the problem in the form of a hierarchy to capture the basic elements of a problem and then derives ratio scales to integrate the perceptions and purposes into a synthesis. In the hierarchical structure, all the elements in a level are pair-wise compared with respect to the elements in the level above, and paired comparisons are used to elicit judgments. Then the synthesis of judgments is obtained as a result of hierarchic "re-composition" in order to find the best decision. AHP is said to be a successful theory, because its assumptions are consistent with available experimental data, it makes testable predictions based on experiments, and it explains behavior (Dae-Ho, 2001). This is the main reason for selecting AHP as the decision support model for solving the supplier selection problem, which involves many intangible factors, but still requires a logical and rational control of decisions. Generally the hierarchy has three levels: the goal, the criteria, and the alternatives. For the supplier selection problem, the goal is the best supplier, the criteria could be quality, on-time delivery, price, etc. and the alternatives are

the suppliers or proposals of the suppliers (William *et al.*, 2001).

After its introduction in 1982, AHP has been widely used in many applications enabling decision-makers to represent the interaction of multiple factors in complex and unstructured situations. The process requires the decision-maker to develop a hierarchical structure of the factors in the given problem and to provide judgments about the relative importance of each of these factors and ultimately to specify a preference for each decision alternative with respect to each factor. Although there are many scales that can be used for quantifying managerial judgments, the scale given in Table III is that commonly used for AHP analysis.

An illustration of the AHP approach

To illustrate this approach the following example is presented. It is assumed that four criteria are used to evaluate suppliers:

- (1) manufacturing costs;
- (2) quality;
- (3) technology being used; and
- (4) service offered.

We further assume that three supplier proposals are being considered. Figure 1 depicts the hierarchy of this decision.

The next step is to develop a set of pairwise comparisons to prioritize the criteria based on a measurement scale such as that shown in Table III. The AHP procedure begins with the development of a matrix that compares each criterion with the others under consideration. The matrix for the four criteria considered in this illustration is given in Table IV. In general, for any pairwise comparison matrix, we place 1s down the diagonal from the upper left-hand corner to the lower right-hand corner. Then comparing the respective criteria, we populate the rest of

Table III Measurement scale

Verbal judgment or preference	Numerical rating
Extremely preferred	9
Very strongly to extremely preferred	8
Very strongly preferred	7
Strongly to very strongly preferred	6
Strongly preferred	5
Moderately to strongly preferred	4
Moderately preferred	3
Equally to moderately preferred	2
Equally preferred	1

Source: Render and Stair (2000)

Figure 1 Hierarchy of decision

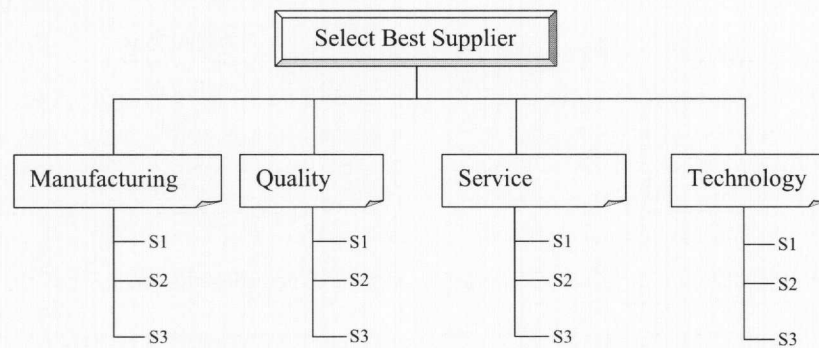


Table IV Criteria matrix – original matrix

	Original matrix			
	Manufacturing	Quality	Service	Technology
Manufacturing	1	3	9	7
Quality	1/3	1	5	7
Service	1/9	1/5	1	5
Technology	1/7	1/7	1/5	1
Column totals	1 3/5	4 1/3	15 1/5	20

the cells. In our example, we assume that manufacturing costs are moderately preferred to quality; hence starting at the upper left-hand corner of the original matrix we place three. Using the same scale, manufacturing cost is extremely preferred to service; hence we have nine at the intersection of manufacturing and service in row 1. And, as manufacturing costs are very strongly preferred to technology, we place seven in the top right-most cell, hence completing row 1. Similarly, the other cells can be populated. On the flip side of the diagonal we have 1/3, 1/7 and 1/9 in column 1 for the comparison of quality with manufacturing costs, technology with manufacturing costs and service with manufacturing costs respectively. Other cells are filled in an identical manner.

Once these comparisons have been made, the data are used for determining weights; the process can be summarized in three steps:

- (1) sum the elements in each column;
- (2) divide each value obtained by its column total; and
- (3) compute row averages.

The calculations are shown in the adjusted matrix in Table V. In this example the final weights of manufacturing, quality, service and technology are 0.566, 0.280, 0.108 and 0.047 respectively. The next step is to compare the three suppliers on how they compare on these criteria. Table VI depicts the supplier matrix

for each criterion. The process followed for determining the scores of each supplier with respect to the criteria under consideration is identical to that described above.

The final score obtained for each supplier across each criterion is given in Table VII. These scores are calculated by multiplying the weight of each factor from Table V with the weight of each supplier from Table VI, which then results in the final scores given in Table VII, i.e. supplier 1 has a weight of 0.607 in the adjusted matrix with respect to manufacturing costs and the manufacturing cost criterion has a criterion score of 0.566; hence the product of these two weights in Table VII is 0.3248. Looking at Table VII, we see that supplier 3 has the highest overall score of 0.31185. Based on the AHP approach, our decision would be to select supplier 3.

AHP, as seen above, is a very useful methodology, which provides a framework to evaluate between seemingly conflicting selection criteria.

Use of the AHP approach offers a number of benefits. One of the important advantages is its simplicity. The AHP can also accommodate uncertain and subjective information, and allows the application of experience, insight and intuition in a logical manner. Perhaps the most important advantage, however, is in developing the hierarchy itself. This forces buyers to seriously

Table V Criteria matrix – adjusted matrix

	Manufacturing	Quality	Service	Technology	Weights (row average)
Manufacturing	0.630	0.691	0.592	0.350	0.566
Quality	0.210	0.230	0.329	0.350	0.280
Service	0.070	0.046	0.066	0.250	0.108
Technology	0.090	0.033	0.013	0.050	0.047

Table VI Pair-wise comparison of suppliers with respect to each evaluation criterion – original and adjusted matrices

	Original matrix			Adjusted matrix			Weights
	Supplier 1	Supplier 2	Supplier 3	Supplier 1	Supplier 2	Supplier 3	
Manufacturing							
Supplier 1	1	3	3	3/5	9/13	3/7	0.574
Supplier 2	1/3	1	3	1/5	3/13	3/7	0.286
Supplier 3	1/3	1/3	1	1/5	1/13	1/7	0.140
Column totals	1 2/3	4 1/3	7				
Quality							
Supplier 1	1	1/3	1/9	1/13	1/13	1/13	0.077
Supplier 2	3	1	1/3	3/13	3/13	3/13	0.231
Supplier 3	9	3	1	9/13	9/13	9/13	0.692
Column totals	13	4 1/3	1 4/9				
Technology							
Supplier 1	1	1/5	1/9	1/15	1/21	1/13	0.064
Supplier 2	5	1	1/3	1/3	5/21	3/13	0.267
Supplier 3	9	3	1	3/5	5/7	9/13	0.669
Column totals	15	4 1/5	1 4/9				
Service							
Supplier 1	1	1/9	1/7	1/17	1/13	1/29	0.057
Supplier 2	9	1	3	9/17	9/13	21/29	0.649
Supplier 3	7	1/3	1	7/17	3/13	7/29	0.295
Column totals	17	1 4/9	4 1/7				

Table VII Overall score calculation

Manufacturing	Quality	Technology	Service	Score
Supplier 1 0.32451	+ 0.02152	+ 0.00688	+ 0.00264	= 0.35556
Supplier 2 0.16205	+ 0.06457	+ 0.02887	+ 0.03017	= 0.28566
Supplier 3 0.07916	+ 0.19371	+ 0.07221	+ 0.01370	= 0.35878

consider and justify the relevance of the criteria. Other extensions of this basic approach have been suggested to rebuke criticism of the approach and to overcome issues such as consensus building.

Advantages and limitations of AHP

AHP is used for evaluating the sources of supply in a materials management situation.

AHP can help managers in formulating decisions under the following scenarios; analyzing the impact of supply sources on multiple goals of an organization, facilitating the interactive flow of inputs and evaluating the sources from a strategic perspective.

There are a variety of extensions to the AHP approach, which can increase its

usefulness for managerial decision making. First, the AHP is a flexible modeling tool that can accommodate a larger set of evaluation criteria. The criteria can be compared pair-wise first and then the individual criteria can be pair-wise compared within each category. In this way, a larger number of criteria can be included within the hierarchy without generating an extremely large pair-wise matrix. Similar other extensions, including calculation of consistency indices and ratios etc., have been suggested and used by various researchers; however, the core procedure remains identical across these extensions (Sun, 2001; Render and Stair, 2000).

However, several criticisms have also been leveled at this approach, some of them being; like other judgmental techniques, this process too is driven by judgments of the decision maker and there is no independent (analytic) way of verifying the results. All criteria are relative, so no absolute measures can be given to them and, when a new criterion is added, then the whole process has to be repeated. In their articles Dyer (1990) and Belton (1986) voice some concerns including the lack of operational meaning of the responses obtained to questions on the relative importance of criteria and the effects of "rank reversal".

Conclusions

Supplier selection is arguably the single most important phase of the purchasing process. The objective of this phase is to find the optimal supplier not necessarily the supplier, offering the best technical service or the lowest price or the shortest delivery. Thus, firms must consider multiple criteria in their attempts to distinguish between items offered by potential suppliers.

This paper highlighted two main approaches that managers can use to make effective decisions regarding supplier selection. Both these approaches are flexible to accommodate most selection criteria yet remain simple enough to be easily applied. Both approaches can be used in negotiations and in helping to optimize and concentrate resources where they are most needed. However, AHP can help evaluate and compare suppliers on different evaluation criteria and, if cost data are included as they

are in TCO, AHP can provide a more robust tool for managers to select and evaluate suppliers across the board, enabling them to make sound selections based on both qualitative and quantitative criteria.

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