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Rapid assessment and selection of engineered equipment suppliers

Marcelo M. Azambuja [a,*], William J. O'Brien [b,1]

[a] Dept. of Construction, Southern Illinois University Edwardsville, IL 62026, United States
[b] Dept. of Civil, Architectural & Environmental Engineering, University of Texas at Austin, TX 78712, United States

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ABSTRACT

This paper describes the development and implementation of a decision support system to aid the selection of engineered equipment suppliers in the early stages of capital projects. Procurement of equipment is a complex process, which requires the evaluation of multiple suppliers against project targets. Analysis is usually performed manually, is time consuming, and certain tradeoffs may be overlooked. A consistent and applicable tool to support procurement decisions has been missing. The results of this research take significant steps to fill this gap. The system integrates historical data, market assessment, and bid information to aid commercial assessment and recommendation of suppliers. The supplier selection module uses the Aspiration Interactive Method (AIM) to analyze the information. Results of two selection cases were compared against firms' recommendations. The system enables rapid evaluation and comparison of several supply alternatives, thereby improving the consistency and quality of commercial analysis in the early phases of projects.

1. Introduction

Major equipment ties up a large proportion of construction costs, has long lead times, and is usually associated with the acquisition of complex or specialized technology, significantly different from bulk materials [1]. Major equipment is engineered and fabricated specifically for the project (e.g., tanks, heat exchangers, pumps). Engineering, manufacturing, and delivery of these items are very uncertain and may disrupt construction schedule [2]. As a consequence, procurement planning for engineered equipment is critical and needs to start during the early stages of capital projects, mainly front end planning and conceptual design [3].

Additional procurement issues have motivated this research such as: complex analysis of tradeoffs during procurement, supply chain constraints, and lack of data integration to support analysis.

Procurement of long lead engineered equipment requires the evaluation of several suppliers and project targets (e.g. schedule, budget, quality, etc.). This analysis is usually performed manually, is time consuming, and certain tradeoffs may be overlooked. Therefore, there is a need to develop computer-based tools to support and speed up the work of procurement managers in better understanding the tradeoffs and risks involved in the selection of engineered equipment suppliers.

Mounting global demand for oil and gas, energy, and infrastructure has stressed the supply chain over the last few years [4], and various constraints must be taken into account when planning the execution of projects. Substantial increases in lead times and price escalation were a direct consequence of this scenario [5]. Thus, procurement has clearly become a more strategic process and assessment/selection of appropriate suppliers needs to start much earlier in the capital project lifecycle [6].

Finally, market data is not electronically integrated to support procurement decision-making. To survive in such dynamic and constrained scenario, firms need to identify sourcing alternatives, reduce supply risks and improve scheduling and cost performance. Knowledge of market conditions is essential to supporting early planning and supplier selection decisions; however, obtaining, keeping, and analyzing updated market data are difficult tasks. In most cases, construction organizations are not proficient at identifying the capabilities of their suppliers. They usually rationalize supplier selection decisions based on convenience [7] or lowest cost. Other firms, for example, large and sophisticated contractors in the industrial sector have rich market forecasting and/or historical data on suppliers' performance. However, available data is commonly found in different paper files archived inside procurement managers' drawers or stored in firms' information systems. As a result, data is currently not integrated to support analysis and decision-making.

This paper describes the development and implementation of a decision support system that enables rapid assessment and selection of engineered equipment suppliers in the early stages of capital projects. The system electronically integrates firms' available data with a decision aid method to support rapid evaluation of tradeoffs among cost, schedule, quality, shop load, and transportation variables. Users will easily retrieve suppliers' lead times, prices, past performance (e.g. quality, fabrication, delivery), and shop loads to perform their analysis. The primary users are procurement professionals of construction

* Corresponding author. Tel.: +1 618 650 3845.
E-mail addresses: mazambu@siue.edu (M.M. Azambuja), wjob@mail.utexas.edu (W.J. O'Brien).
[1] Tel.: +1 512/471 4638.

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and owner firms in the industrial construction sector since most of their projects usually involve the acquisition of several pieces of equipment. Typically, their supplier base is global and these firms evaluate suppliers from multiple geographical regions because their projects are spread around the globe.

The paper is organized as follows: first, a literature review on decision aid methods for supplier selection in construction which is then followed by a description of the Aspiration Interactive Method (AIM) used in the system. Next, the research method is detailed and the decision support system is presented. The paper concludes with the discussion of the implementation results, research findings, and contributions to the body of knowledge and construction practice.

2. Background

2.1. Methods for selection decision in construction

Decision aid methods are very useful tools used to support managers making complicated selection decisions. There are a number of techniques and software packages that have been developed in the operations research area to aid solving selection problems. Olson [8] reviewed various potential techniques and concluded that these techniques vary significantly in the type of problems they are suitable for and the amount of information required.

In construction, most selection methods tend to be ad-hoc methods that are based on experience and intuition. Unfortunately, these methods are difficult to package and use as a general framework for making decisions [9].

The Analytic Hierarchy Process (AHP) is well known and used in various selection problems in construction such as: advanced construction technologies [10], contractor selection [11], and selection of equipment (e.g. tower cranes, concrete pumps) for construction projects [12]. Jiang et al. [13] has shown the potential use of AHP to support supply chain selection. The authors proposed a framework based on the AHP for ranking different supply chain configurations. This study however was based on hypothetical data and their framework was not validated.

The Multi-attribute Utility Theory (MAUT) has also been implemented in construction research. Few studies report the application of this approach to select dewatering systems [14], and for IT-related problems, such as selecting the appropriate computer networking technology [15] and appropriate data capture technologies for a construction materials testing laboratory [9].

Very little has been published on methods to aid managers making selection decisions on suppliers in construction. Bernold and Treseler [16] presented a vendor analysis system that is based on the best-buy concept. A vendor-rating approach to secure the best buy in construction was proposed and analyzed. According to these authors, benefits of the formal vendor-analysis and rating system include the standardization of evaluation criteria, which provided consistency and transparency. The best buy approach allows users to consider and weight their preferences; however, it does not provide the capability to identify the optimal vendor based on project and procurement targets.

Benton and McHenry [7] described three general types of supplier evaluation systems used today: categorical method, the cost-ratio method, and the linear averaging method. The categorical method involves categorizing each supplier's performance in specific areas defined by a list of relevant performance variables. It is a simple and informal system in the sense that detailed performance achievements or shortcomings are not measured. The cost-ratio method evaluates supplier performance using standard cost analysis. The total cost of each purchase is calculated as its selling price plus the buying organization's internal operating costs associated with the quality, delivery, and service elements of the purchase. The main advantage of this method is that the results are cost oriented, however, the associated costs must be known. Moreover, this method does not take into account other aspects of supplier performance. The linear averaging method is probably the most commonly used. Specific quantitative performance factors such as quality, price, and delivery are used to evaluate supplier performance. The method assign appropriate weights to each performance factor, such that the total weights of each factor add up to 100. The assignment of these weights is a matter of judgment and top management preferences. These weights are subsequently used as multipliers for individual ratings on each of the performance factors. This method is relatively easy to implement once all factors and weights have been determined. According to the authors [7], the guiding factors in determining which system is best are ease of implementation and overall reliability of the system.

AHP and MAUT are usually excellent methods to support decision when qualitative criteria need to be quantified to support judgment, and when the decision maker is presented with a small set of alternatives. These methods are based on subjective assessments, which may introduce bias in the selection process. According to Olson [8], the AHP pair-wise comparison process is somewhat tedious, subjective and several comparisons may affect accuracy because users tend to focus their effort on obtaining speed to complete the process. MAUT requires that a utility function be developed – based on interviews – that will quantify qualitative decision criteria. The interview process takes too long to be feasible for most situations, and skills must be developed before the results of an interview can be reliably employed.

The decision support system proposed in this research intends to provide an objective and rapid method for tradeoff analysis to compare a large number of alternatives against multiple targets, and to support quantitative criteria analysis. The goal is to eliminate the subjectivity associated with weight assignment and final decision making. None of the methods previously described properly support these purposes, especially the AHP. The Aspiration Interactive Method (AIM), an objective technique from the operations research area, on the other hand, seemed to be a very appropriate method based on the purposes set by the research team and feedback from experienced procurement managers. The method is explained in the following section.

2.2. The Aspiration Interactive Method — AIM

The Aspiration Interactive Method (AIM) provides a technique useful to help decision makers learn about the tradeoffs among criteria considered in the selection of alternatives from large sets of available choices [17]. The idea is to adjust aspiration levels of the objectives – which are used as targets for decision makers – and obtain the feedback regarding the feasibility of the aspiration levels.

As these aspirations are adjusted, the nearest solution changes. Weights are generated by the aspiration levels and the nearest solution is determined by calculating a score for each alternative and ranking them according to the attainment levels against the set of aspiration levels. The method is straightforward and does not require complex mathematical iterations and knowledge from users.

AIM involves the definition of few sequential steps (Fig. 1). First, decision makers need to establish a set of objectives (k), usually maximization or minimization from targets (Ak). Second, Ideal (Ik) and Nadir (Nk) objective levels need to be identified from the data set. The Ideal objective represents the best case scenario (highest value for maximization or the lowest value for minimization) and Nadir the worst case scenario (lowest value for maximization or highest value for minimization). The difference between the ideal and nadir values establishes the working distance over which attainments are evaluated. Third, a set of weights is calculated by dividing the distance from the aspiration level to the nadir level by the distance between the ideal and the nadir level: $Wk = (Ak - Nk)/(Ik - Nk)$. This set of values is normalized by dividing each ratio by the sum of ratios. Finally, AIM allows the user to explore alternatives and tradeoffs. Each alternative's (Xk) distance from the current aspiration levels is measured, indicating the proportional attainment over the range aspiration–nadir, or $Dk = (Xk - Nk)/(Ak - Nk)$. The maximum score is 1 (no extra credit for exceeding the