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A PURCHASING DECISION: SELECTING A SUPPLIER FOR A CONSTRUCTION COMPANY

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Abstract

Supplier selection is one of the most crucial activities performed by organizations because of its strategic importance. Supplier selection is a multi-objective problem involving both quantitative and qualitative criteria. Over the years a number of quantitative approaches have been tried. Although the Analytic Hierarchy Process (AHP) has previously been used in supplier selection problems, one major weakness of the application-oriented AHP literature is that it tends to focus on the mechanics of AHP instead of on the theoretical and practical implications associated with finding a solution. Though it is one of the most extensively used Multiple Criteria Decision Analysis methodologies, our literature search indicated that most studies found the best solution and stopped there, ignoring sensitivity analysis. Performing sensitivity analysis is very important for practical decision making, sometimes even as important as finding the best solution. In this paper for the first time a comprehensive application of AHP for a real-world case is presented along with sensitivity analysis in choosing the best suppliers for a Turkish construction company. As a result of this study the company decided to allocate the order quantities between the two top suppliers.

Keywords: Vendor Selection, Analytic Hierarchy Process, Multicriteria Decision Making

1. Introduction

Since the purchasing function has become vital in determining the profitability and survival of business organizations, it has been receiving considerable attention. As Sarkis and Talluri (2002) indicated, buyer-supplier relationships based solely on price are no longer acceptable. The increasing importance of supplier selection decisions is forcing organizations to rethink their purchasing and evaluation strategies because a successful purchasing decision directly depends on selecting the "right" vendor.

The major premise of the studies in the literature is that many organizations spend a

considerable amount of time evaluating their supply chain partners because of the strategic importance of supplier selection. Ellram (1990) examined the issue using case studies of firms involved in buyer-supplier relationships and developed some additional factors that should be considered in selecting supply partners in addition to quality, cost, on-time delivery, and service and categorized them into four groups: financial issues, organizational culture and strategy, technology and a group of miscellaneous factors. She concluded that there is no single model that fits every situation. Weber *et al.* (1991) reviewed 74 articles published between 1966 and 1991 which address vendor selection criteria in manufacturing and retail environments. From this review they provided a comprehensive list of the criteria that had been considered in supplier selection decisions. Quality, delivery and net price received the greatest amount of attention. The suppliers' production facilities, geographical locations, financial positions and capacities generated an intermediate amount of attention. Nydick and Hill (1992) considered four criteria in supplier selection: quality, price, delivery, and service. Research carried out among 139 managers by Verma and Pullman (1998) studied the tradeoffs among quality, cost, on-time delivery, delivery lead-time and flexibility when choosing a supplier. They found that in the end most managers perceive quality to be most important supplier attribute, followed by on-time delivery and cost. Park and Krishnan (2001) examined supplier selection practices among 78 small business executives focusing on 15 criteria from Ellram's (1990) study: strategic fit, top management compatibility, management attitude/outlook for the future, feeling of trust, compatibility across levels and functions of buyer and supplier firms, supplier's organizational structure and personnel, assessment of current manufacturing facilities/capabilities, assessment of future manufacturing capabilities, supplier's design capabilities, supplier's speed in development, economic performance/financial outlook, financial stability, supplier's safety record, business references, and supplier's customer base. Karpak *et al.* (2001) considered cost, quality and delivery reliability to be the basic vendor selection criteria. Bhutta and Huq (2002) used four criteria to evaluate suppliers: manufacturing costs, quality, technology, and service. Typically, these studies present different buying situations for different industries so there is no unified list of vendor selection criteria in the literature.

This paper describes the case of a construction firm in Turkey which needed to identify the best lime supplier. In this study, for the first time, a comprehensive application of the AHP to a real-world case is presented along with sensitivity analysis. This paper is organized as follows: section two gives a review of the quantitative approaches to vendor selection problems; the methodology of this study is explained in section three; the fourth section shows the application of AHP; sensitivity analysis is presented in the fifth section; and the conclusion is given in section six.

2. Existing Vendor Selection Methods

A number of studies have been devoted to examining vendor selection methods. A common theme is that supplier selection is a

multiobjective decision (Karpak *et al.*, 2001; Nydick and Hill, 1992; Ghodyspour and O'Brien, 1998; Boer *et al.,* 2001). Weber *et al.* (1991) reviewed the quantitative approaches to vendor selection problems and found that linear weighting models, mathematical programming models and statistical/probabilistic approaches have been most favored approaches. Weber and Current (1993) developed a multiobjective programming approach. Boer *et al.* (2001) presented a review of decision methods reported in the literature for supporting the supplier selection process. They found that several suitable Operations Research methods such as data envelopment analysis, total cost approaches, linear programming, linear weighting models, statistical methods, artificial-intelligence-based models have been used. Karpak *et al.* (2001) implemented a Visual Interactive Goal programming (VIG) approach in a multiple-replenishment purchasing problem. The AHP has previously been used in supplier selection by e.g. Narasimhan (1983), Nydick and Hill (1992), Barbarasoglu and Yazgac (1997), Bhutta and Huq (2002), and Handfield *et al.* (2002). Bhutta and Huq (2002) presented two approaches related to supplier selection decisions: AHP and Total Cost Ownership (TCO) and compared them. Handfield *et al.* (2002) proposed an AHP model that included relevant environmental criteria in supplier selection decision. Ghodyspour and O'Brien (1998) proposed integrating AHP and linear programming in a model to choose the best supplier.

3. Methodology Background

In many existing decision models for supplier selection only quantitative criteria are considered; it is, however, a multi-objective problem, encompassing many quantitative as well as qualitative factors. Since the AHP is capable of dealing with these kinds of decision problems, the AHP was selected as the decision analysis tool and *Expert Choice*© which implements the AHP was selected as the software. In this section the AHP and the research carried out at AKG Inc. are explained.

3.1. Analytic Hierarchy Process

The AHP is designed to solve complex multi-criteria decision problems. It is based on the innate human ability to make sound judgments about small problems. It facilitates decision making by organizing perceptions, feelings, judgments, and memories into a framework that exhibits the forces that influence a decision. The AHP has been applied in a variety of decisions and planning projects in nearly 20 countries (Saaty, 2001).

In AHP a problem is structured as a hierarchy. Once the hierarchy has been constructed, the decision-maker begins the prioritization procedure to determine the relative importance of the elements in each level. The scale used for making pairwise comparisons in the AHP enables the decision-maker to incorporate experience and knowledge intuitively and indicate how many times an element dominates another with respect to a property they have in common (Saaty, 2005). Dominance is often interpreted as importance when comparing the criteria and as preference when comparing the alternatives with respect to a criterion. The decision-maker can express his judgment on dominance between each pair of elements

verbally as *equally important*, *moderately more important*, *strongly more important*, *very strongly more important*, and *extremely more important*. These descriptive judgments would then be translated into numerical values 1, 3, 5, 7, 9 respectively with 2, 4, 6, and 8 as intermediate values for comparisons between two successive qualitative judgments. Reciprocals of these values are used for the corresponding transposed judgments.

Finally, all the comparisons are synthesized to rank the alternatives. The output of AHP is a prioritized ranking of the decision alternatives based on the overall preferences expressed by the decision maker. Sensitivity analysis is used to investigate the impact of changing the priorities of the criteria on the final outcome.

3.2. The Research

The objective of this study was to select the best lime supplier for AKG Construction Inc., a company in Turkey. AKG primarily sells bag products, concrete blocks, glass blocks, and limestone-building products. As one of the construction materials it sold, the company in 1999 started producing 285 thousand cubic meters of autoclaved aerated concrete (AAC) a year. AAC is a structural, insulating building material made of a combination of cement, lime, gypsum, water, and expansion agent. The company has two plants: One in İzmir and one in Kırıkkale. Annual production of AAC at the İzmir plant, which has 45,000 m^2 open-air and 15,000 m^2 enclosed facilities, is 275,000 m^3, while at the Kırıkkale plant, where these areas are 100,000 m^2 and 20,000 m^2, respectively, the capacity is 550,000 m^3, yielding a total capacity of 825,000 m^3. AAC is used in a wide range of building construction with residential, commercial and industrial buildings being the most common. AAC is economical, easy to use, environmentally friendly, energy efficient, cellular, and lightweight. It consists of basic materials that are widely available. One of those raw materials is lime. The company currently purchases lime from three suppliers. Since managing multiple relationships within a supply chain is a challenging task, the selection of the supplier for the lime became a very important issue for AKG Inc. They wanted to select the best lime suppliers and place orders for lime among them considering various criteria. We used AHP to study the problem because supplier selection problems deal with a relatively large number of attributes and the hierarchical framework of the AHP makes it possible to cope with this. We met with the managers of the company for several hours. The team of AKG decision-makers was comprised of a quality control manager, a production manager, an operations manager, a purchasing manager, a sales manager, a plant manager, and a marketing manager. First, the AHP methodology was presented to the decision-making team since they were not familiar with the idea. Initially 89 criteria were identified. However, the decision-making team went through some initial evaluation of the factors and eliminated ones that were felt to be insignificant in selecting a lime supplier, ending up with 64 factors. Three lime suppliers were identified as the decision alternatives: Akyuz, Bastas, and Kirsehir. Finally, we constructed a six-level hierarchy with the following criteria:

-Logistical Performance: The decision-making team identified three main

criteria. Great importance is given to the supplier's *logistical performance*, as supplier delivery performance is crucial. The decision-making team categorized *logistical performance* into two subcriteria: *delivery performance* and *cost analysis*. Since orders or material releases sent to a supplier have a quantity and due date to receive the material, the supplier's performance in both lead-time requirements for on-time delivery and the ability to deliver the quantity requested have an important role. Therefore, *delivery performance* was further decomposed into two sub-subcriteria: *delivery quantity* and *lead-time requirements*. Besides the delivery performance, the decision makers thought cost was important. Hence price, terms of payments and credit, and supplier's willingness to help the company find ways to reduce purchase cost are subcriteria under the *cost analysis* category.

-***Commercial Structure***: The decision makers considered the infrastructure of the supplier, the commercial structure, to be one of the main criteria. *Commercial structure* is divided into six categories: *communication systems*, *technical capability*, *personnel capabilities*, *cost structure*, *organizational structure*, and *performance history*. *Communications systems* encompass all the ways the supplier manages the relationship with the buyer. The willingness of the supplier's employees to contribute to supply chain objectives (*willingness of employees*) and ease of contact with the supplier (*ease of contact*) helps to maintain a positive relationship with the supplier. The decision making team decided that supplier's technical capability must also be evaluated. The ability of the vendor to provide technical support (*technical support*) and responsiveness of the vendor to changes in purchase quantities and due dates (*responsiveness*) are secondary sub-criteria under *technical capability*. The decision-making team believed that the supplier evaluation process also required an assessment of personnel capabilities. The second category labeled *personnel capabilities* includes three criteria: The overall skills and abilities of the workforce especially with regard to the level of education and training received (*overall skills*), the degree to which employees support the company's continuous improvement (*support*), and the experience of employees (*experience*) are key factors. Evaluating a supplier's *market viability* involves detailed cost data provided by the supplier (*providing cost detail*), an assessment of the supplier's financial condition and stability (*financial capability*), and the market share of the supplier (*market share*). *Organizational culture* is another critical factor in selecting the best lime supplier and it is divided into three criteria: *long-term relationship*, the supplier's willingness to develop longer-term relationships; *reliability/trust* refers to acting responsibly and meeting performance expectations reliably. Developing a trusting relationship with the suppliers is one of the critical elements that will result in important benefits for both firms. The third criterion, *management capability*, includes management's commitment, overall professional ability, and willingness to develop a closer working relationship with the buyer. The decision-making team found *performance history*, relating to the supplier's reputation for performance, to be important. Past experience with the supplier (*past performance*) and

business references provided by the supplier (*business references*) are the criteria that comprise performance history.

-***Production***: The production capacity of the supplier (*production*) is one of the three main criteria. *Production* is divided into seven subcriteria: p*roduct specifications*, *material specifications*, *inventory policy*, *equipment*, *production capacity, process capability*, and *quality management systems*. The *product specifications* criterion is broken down into the *physical* and *chemical* characteristics. *Physical characteristics* is further categorized into three sub-criteria: storage requirements of the product provided by the supplier (*storage*), pH level of the product (*pH level*), and particle size of the product (*particle size*). *Chemical characteristics* are subdivided into hydration level of lime (*hydration*), degree of burn (*degree of burn*), processibility of the lime (*processibility*) and the proportion of calcium oxide (proportion of *CaO*). Specifications of the raw materials used by the supplier in lime production involved three criteria: The purity of calcareous rock (*purity of calcareous*), magnitude of the calcareous rock reservoir (*magnitude of the reservoir*), and quality of coal used in the lime production (*quality of coal*). The size of the supplier's available warehouse facility (*size of available facility*), availability of exclusive warehousing (*exclusive warehousing*), and the humidity level of the supplier's warehousing (*humidity level*) were the sub-criteria for the *inventory policy* criterion. The equipment used by the supplier is also considered when evaluating a lime supplier. The *Quality of equipment* used to manufacture the product and *production technology* being used by supplier are comprise the *equipment* sub-criterion. The decision-making team decided that the supplier's process capability was another concern that must be considered. The sixth category, labeled *process capability*, includes three criteria: the ability to develop process technology (*process technology*), the supplier's future process capability (*future*) and the ability to meet current and expected future production requirements (*continuity* in production). *Quality management systems* is mentioned as important in the supplier selection. Quality certifications the supplier has received (*certification*), the overall skills and experience of quality control personnel (*personnel*), the quality control tools being used by the supplier (*quality tools*), the defect rates of the supplier (*defect rate*), and quality control inspection methods (*inspection*) used by the supplier are included under quality management systems.

4. Applying the AHP in Supplier Selection

4.1. Structuring the Hierarchy

Figure 1 shows the hierarchy for the lime supplier decision model.

4.2. Performing Pairwise Comparisons

After constructing the hierarchy, pairwise comparisons were performed systematically throughout the structure. Prior to our study, we hoped that we would be able to go through the pairwise comparisons together with the decision making team. It was not possible due to differences among the schedule of the managers. Hence, 191 questions questionnaires including all possible pairwise comparison combinations were distributed to the decision-making team.

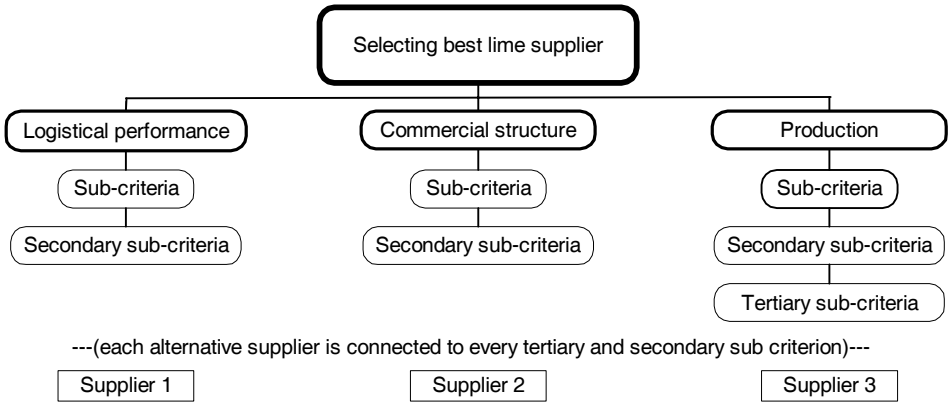

Figure 1 A hierarchical representation of the AHP model

	Logistical Performance	Commercial Structure	Production
Logistical Performance		4.718	0.620
Commercial structure			0.153

Figure 2 Comparing major criteria –judgments and resulting weights of major criteria

	Delivery	Cost analysis	Priorities
Delivery Performance		0.190	0.159
Cost analysis			0.841

Figure 3 Comparing criteria for logistical performance

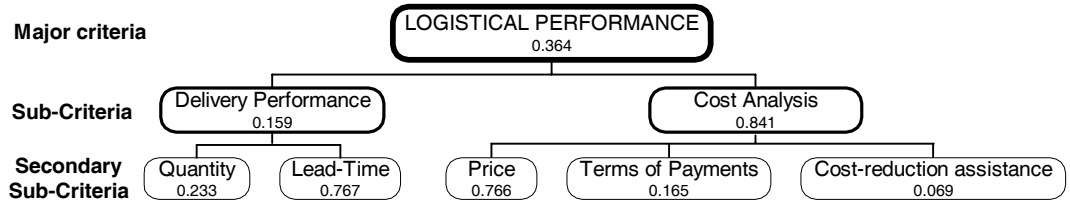

Figure 4 Priorities of logistical performance criteria

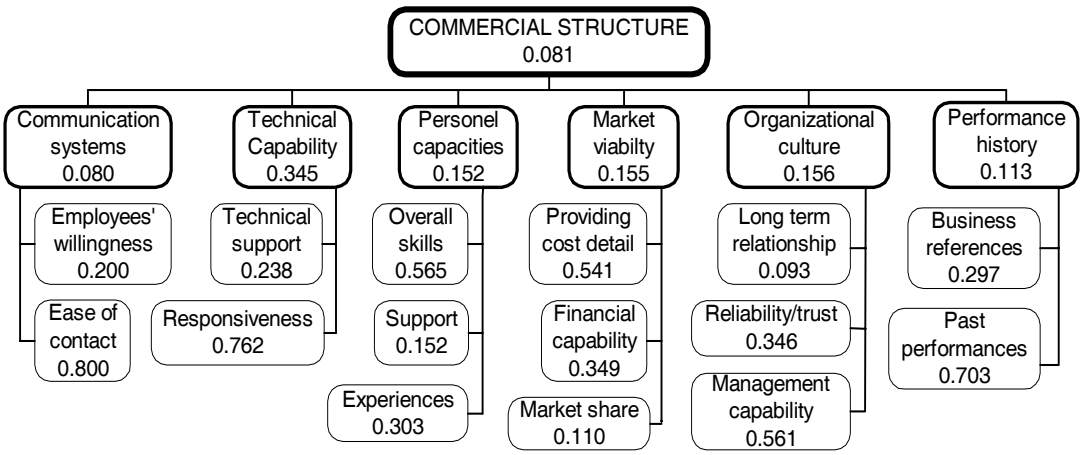

Figure 5 Priorities of commercial structure criteria

Each respondent first made all the pairwise comparisons using semantic terms from the fundamental scale and then translated them to the corresponding numbers, separately. After performing all pairwise comparisons by the decision-makers, we aggregated individual judgments using the geometric mean as Saaty suggested (Saaty, 1990). The judgments were based upon the information gathered through the questionnaires.

We entered the combined judgments provided through the questionnaires in the pairwise comparison judgments matrix for the three major criteria with respect to the goal. Production is the most important factor of selecting the best lime supplier with a priority of 0.555. Logistical Performance is also a major factor with an importance priority of 0.364. Figure 2 shows the resulting priorities. As shown in Figure 3, for the subcriteria of Logistical Performance, cost analysis received the highest priority, 0.841. Under cost analysis, not surprisingly, price received the highest priority, 0.766 (Figure 4). And under the delivery performance subcriterion, lead-time turned out to be the most important one, 0.767.

When we evaluated the commercial structure branch, technical capability turned out to be the most important one with the priority of 0.345 and the second highest priority, for organizational culture, is 0.156 (Figure 5). For the production criterion product specifications turned out to be the most important of the seven sub-criteria with a priority score of 0.317. The priorities in the production branch are shown in Figure 6.

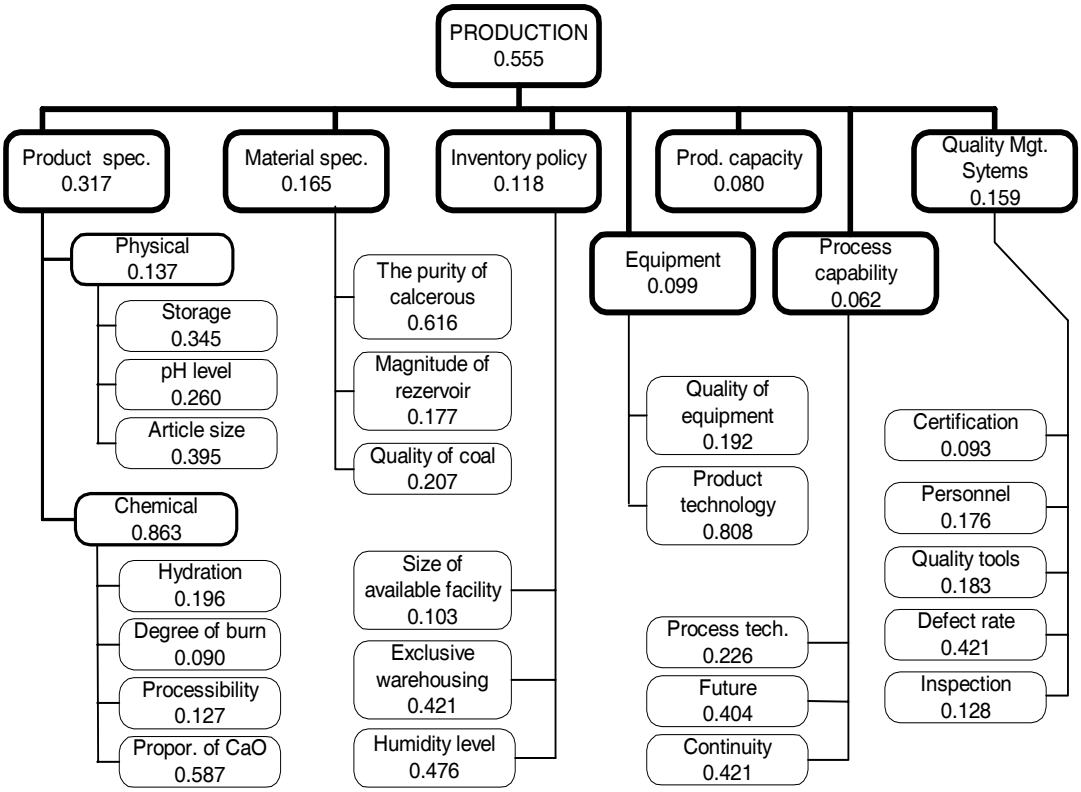

Figure 6 Priorities of production criterion

DELIVERY QUANTITY	Akyuz	Bastas	Kirsehir
Akyuz		6.804	4.708
Bastas			0.195

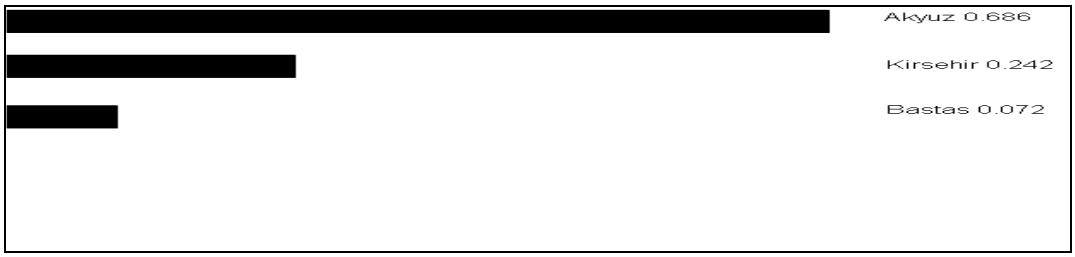

Figure 7 Comparing alternatives based on delivery quantity

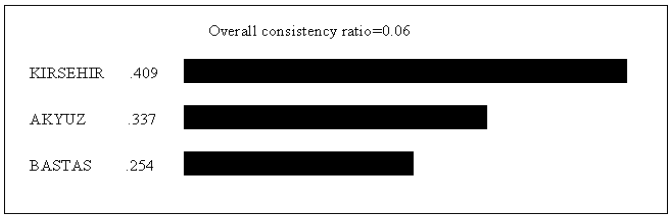

Figure 8 Overall results

Finally we compared each pair of alternatives with respect to each criterion. For example, for the sub criterion delivery quantity (located on the left-most branch under delivery performance), we obtained a matrix of paired comparisons (Figure 7) in which supplier 1 (Akyuz) is preferred over supplier 2 (Bastas) and supplier 3 (Kirsehir) by 6.804 and 4.708, respectively and supplier 2 is preferred by 0.195 over supplier 3. Akyuz appears superior to the other two alternatives with respect to delivery quantity. The resulting priorities show Akyuz as the top choice with a preference rating of 0.686, followed by Kirsehir.

4.3. Synthesizing the Results

Expert Choice provides two ways of synthesizing the local priorities of the alternatives using the global priorities of their parent criteria: the distributive mode and the ideal model (Saaty, 2001). In our case, the ideal mode would be the way to synthesize the results since we are interested in selecting the best vendor rather than distributing the purchases of lime among all the vendors based on their priority scores. In any case the distributive mode results were not much different than the ideal mode results. After deriving the local priorities for the criteria and the alternatives through pairwise comparisons, the priorities of the criteria are synthesized to calculate the overall priorities for the decision alternatives. As shown in figure 8, *Kirsehir* turns out to be the most preferable supplier among the three alternatives, with an overall priority score of 0.409. The suppliers ranked according to their overall priorities were: Kirsehir, Akyuz, and Bastas, which indicates that Kirsehir is the best lime supplier.

5. Sensitivity Analysis

A series of sensitivity analyses were conducted to investigate the impact of changing the priority of the criteria on the suppliers' ranking. First, Dynamic Sensitivity was performed using Expert Choice©. We investigated the impact of changing the priorities of the three main criteria on the suppliers' rankings. The suppliers' rankings were relatively insensitive to changes in the importance of the commercial structure, production and logistical performance criteria. The importance of logistical performance has to be is increased all the way from 0.364 to 0.650 as shown in Figure 9, for Akyuz to become the best supplier. We investigated a second scenario where the relative importance of commercial structure was increased from 0.081 to 0.460. Even with this large change, the same overall rank as in the final outcome was preserved (Figure 10).

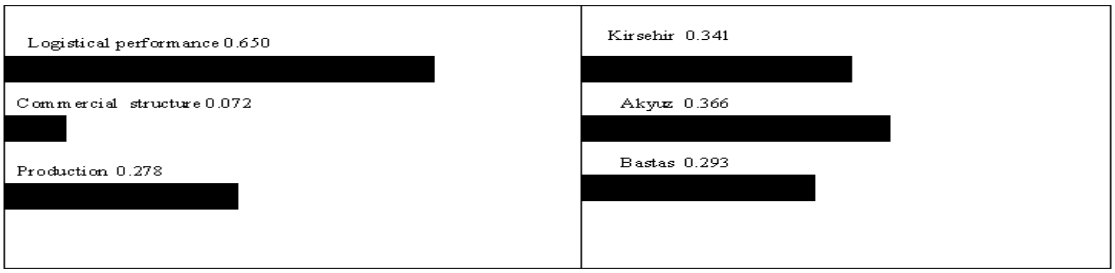

Figure 9 The first scenario

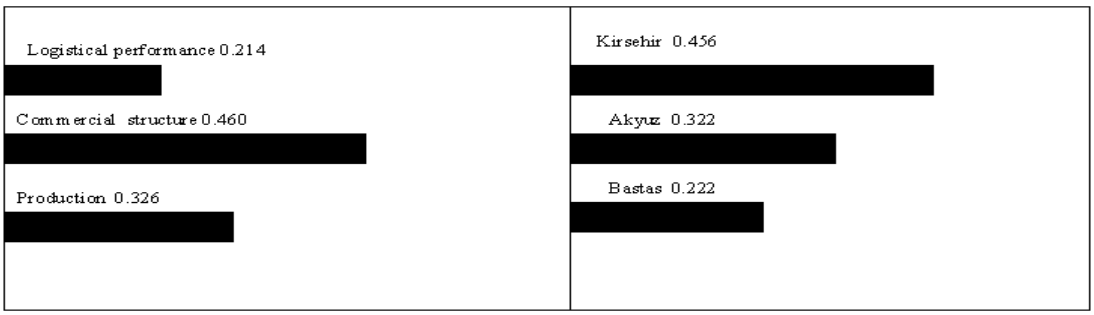

Figure 10 The second scenario

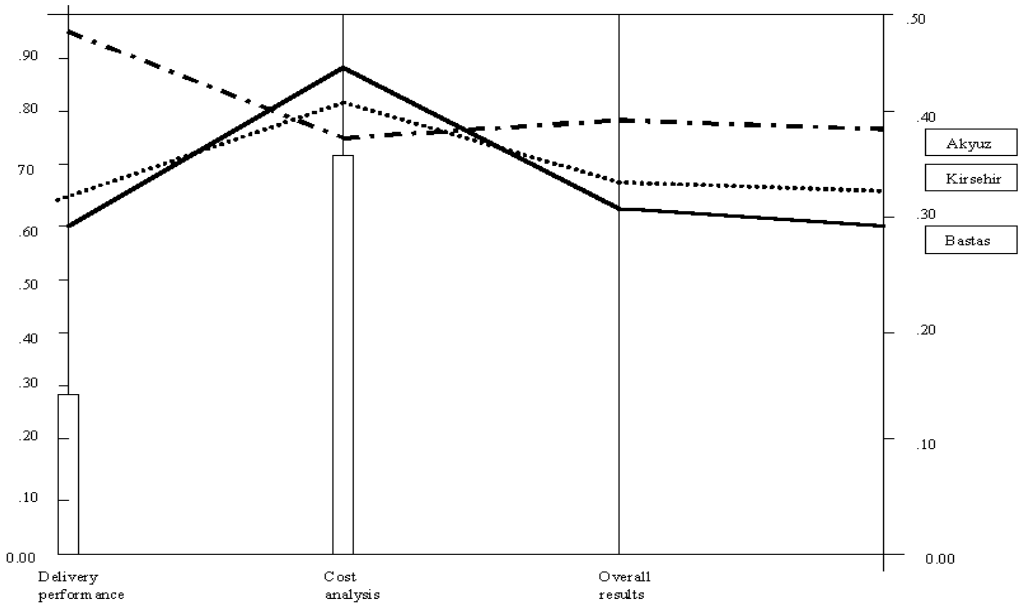

Figure 11 Sensitivity analysis for logistical performance sub-criteria

In the third scenario, when the importance of production is decreased from 0.555 to 0.072, the suppliers' rankings do not change although the priority of the best alternative is reduced from 0.409 to 0.346. We can conclude that the results are not sensitive because even in the case of logistical performance such a large change in importance is quite unlikely.

The second type of sensitivity analysis was performed using the Performance Sensitivity analysis of *Expert Choice*©. We investigated what would happened if we changed the importance of the sub-criteria under two main criteria, *commercial structure* and *production*, and found that the suppliers' ranking does not change regardless of the assumed priorities. Kirsehir is superior to the other two suppliers on the *commercial structure* criterion whereas Akyuz is superior to Bastas. When we decreased or increased the importance of either of these criteria, Kirsehir remained the best alternative in all cases. For example, when the importance of *technical capability* was increased up to 0.700, all three suppliers maintained their rank. When the importance of *cost structure* was increased from 0.155 to 0.750, the suppliers' ranking did not change. In terms of the *production* criterion Kirsehir is superior to the other two suppliers whereas Akyuz is superior to Bastas. Even making extreme assumptions did not change the final outcome. As an example, we increased the importance of *quality management systems* up to 0.65; *process capability* up to 0.78; *equipment* up to 0.62; *material specifications* up to 0.72. In all these cases the suppliers maintained their rank. We did not include a figure showing this analysis.

In Figure 11 we show the performance sensitivity graph for the *logistical performance* subcriteria. In some cases changing the priorities reverses the ranks of the alternatives. When we increased the importance of *delivery performance* up to 0.296, Akyuz became the best alternative, with an overall priority score of 0.384 while the overall priority of Kirsehir is decreased from 0.409 to 0.320. Bastas is still preserved as the third alternative, even when its preference rating is increased up to 0.254 as shown in Figure 11.

The results of the various what-if scenarios were that the outcome of our analysis is very robust and Kirsehir is nearly always the best supplier for AKG Inc under any hypothetical change in the priorities of the criteria and subcriteria.

6. Conclusion

In this study we proposed a comprehensive AHP model to select the best lime supplier for a construction company in Turkey. AHP enabled us to incorporate 64 factors that were both qualitative and quantitative for assessing the vendors. Although the final decision indicates that Kirsehir dominates the other suppliers rather decisively based on these many factors, in the end the managers decided to allocate the order quantities between the two top suppliers, most likely to have some redundancy. The study showed us that the number of criteria included in the supplier selection process is quite important. Although we initially considered 89 criteria, we went through an initial trimming process and eliminated 15 of them. The choice and number of factors to be included in the supplier selection process must be conservatively selected since the decision-making process is complex and

time consuming for the managers.

The current vendor selection decision is a group decision involving both quantitative and qualitative criteria and illustrates how AHP can be used in group decision-making. The managers determine the priorities through their judgments and the software supports obtaining final priorities even in cases where there is no consensus.

As Handfield *et al.* (2002) pointed out one major weakness of the application-oriented AHP literature is that it tends to focus on the mechanics of the AHP, instead of the practical implications of implementing the methodology. Though it is one of the most extensively used Multiple Criteria Decision Analysis Methodology, our literature search indicated that most studies stopped with finding the best solution and ignored the analysis of sensitivity. Sensitivity analysis is very important for practical decision making, sometimes even as important as finding the best solution. In this case it gave us (and the managers) great confidence that the results of the model were correct and should be implemented.

The process of conducting sensitivity analysis helped the decision-making team be far more confidant with their decision since they could see in a visual display that even if the importance of certain criteria were to change, the overall ranking would not change though the degree of preference rating might be somewhat strengthened or weakened.

Bounded rationality and limited cognitive processes make it really impossible for the decision maker to adequately consider all of the factors involved in a complex screening decision without the aid of a decision support methodology like the AHP. Managers would likely base their decision on only a subset of important criteria while not understanding their relative importance and the interactions.

We are well aware of some of the discussions about theoretical soundness of the methodology, especially the issue of whether or not the AHP is unaffected by the addition of new alternatives. One school of thought argues that rank reversals upon the addition of new alternatives do occur in practice and any theory or model should reflect this fact whereas the other argues that rank reversal should be prevented. And a third school contends that the AHP should support two different computational modes: one which allows rank reversal and one which prevents it (Saaty, 2001), and that the decision as to whether or not to allow rank reversal lies with the decision-makers. In our application we used the ideal mode which prevents rank reversals even if new vendors are added to the system.

There are some limitations to the approach. AHP assumes independence among the criteria and the alternatives. If there is dependence among the criteria, the Analytic Network Process (ANP) (Saaty, 2005) is more appropriate; yet ANP requires far more comparisons which may be formidable in a practical decision environment. This is a new area of research to explore.

We needed a methodology that was well supported with a well developed software conducive to making a real life application that would be easily understood by the managers. When there are many criteria involved, AHP is among the very few multiple criteria approaches capable of handling them, especially if some of the criteria are qualitative. The *Expert Choice*

software enables sensitivity analysis of the results which is very important in any really practical decision-making process. We were able to obtain the cooperation of the decision-making team to structure the model and to get them to make the necessary judgments to solve it. We attribute our success mainly to the ease of use of AHP and the existence of easy-to-use commercial software. In this study the AHP model was used for a strategic supplier selection process, but in addition to effective supplier selection purchasing managers can also use this model for supplier benchmarking, supplier development initiatives, and evaluating supplier performance.

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