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THE USE OF COMPUTER-AIDED DECISION SUPPORT SYSTEMS FOR COMPLEX SOURCE SELCTION DECISIONS

THESIS

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Abstract

In the critical arena of source selections, the decision-maker is often overwhelmed by the complex hierarchy of intertwining factors and multitude of conflicting tasks required to successfully purchase an effective weapons system. At this time, there is no available tool with which to assimilate contributing criteria into an organized framework to aid in the decision making process. A decision support system (DSS) acts as the framework upon which the complex elements may be organized. The purpose of this research is to test the use of a computer-aided decision support system in the source selection environment. Through a controlled experiment, the use of a DSS was tested for the following variables.

1. Effectiveness. This was defined as the number of "correct" decisions made.

2. Consistency. This was defined as how many of the same decisions were made.

3. Speed. Did the use of the DSS speed the process?

4. Difficulty. How easy was it to make the decision?

5. Confidence. How confident was the decision-maker that his decision was correct?

6. Understanding. How well did the subject understand the process by which the decision was made?

The results of the experiment indicated little effect of the DSS on effectiveness and consistency. A negative correlation was discovered between the use of the DSS and the time required to reach a decision. A positive correlation was discovered between DSS and the variables ease, confidence and understanding.

These results suggest further research into the applications of decision support systems. In the Air Force environment where any decision must pass multiple approval "tests," the perceived increase in confidence and understanding would certainly be an advantage for the decision maker. The increased simplicity of the process speaks for itself.

THE USE OF COMPUTER-AIDED DECISION SUPPORT SYSTEMS FOR COMPLEX SOURCE SELECTION DECISIONS

I. Introduction

One of the most complex decisions made in the government is that of the source selection decision. The acquisition of Department of Defense (DOD) weapons systems is made up of many complex tasks (Thybony, 1988:8). It is the large scope of necessary activities and the intricate interrelationships of the factors involved to ultimately achieve a source selection decision that warrant the investigation into an effective computer-aided decision support system.

The multiple tasks involved are divided among a variety of specialists in their various functions, but are under the overall control of the program manager and the contracting officer. While the program manager has the responsibility to achieve overall program success (FAR: 1.6, 2.1, 15.604), the contracting officer has the authority to legally bind the government in a contractual document.

Although these two individuals carry the brunt of the load, it is the Source Selection Authority (SSA) who must make the final decision as to which contractor will receive the final award (Cibinic et. al., 1988:I-1). This decision must be a compilation of the efforts of the functional specialists towards the accomplishment of a lofty goal: to acquire a timely system that is responsive to the needs of the user, and to acquire it at a reasonable price.

The contracting officer and the program manager must make award decisions based on a complex hierarchy of intertwined factors on a daily basis. Faced with these intricate relationships and the multitude of conflicting tasks , the contracting officer and the program manager could easily be overwhelmed.

The ultimate decision involves not only multiple criteria, but it also involves many alternative approaches to the problem at hand to choose from. In such a situation, the decision-making process can easily become confused. With dozens of competing criteria and sub-criteria, decisions may not take into account all relevant factors. More likely, the SSA will make a decision without fully understanding the relative importance of the interaction of these criteria.

If the decisions do not reflect the interaction of the competing factors, a real threat is posed to the entire decision-making process. Systems that do not perform up to expectations, or are unreasonably costly may be purchased. The results of such purchases could prematurely make obsolete the system being procured, with the worst case being that the defense of the nation is adversely affected. The search for an effective aid to the decision-making process is warranted for all of these reasons.

The complex environment of source selections requires a new way to cope with the multitude of factors that affect the decisions that are made. Because the system proposed must be understandable to those who will employ it, yet not be so simplistic as to be useless, the new decision-making process must be logical, simple and should just plain appeal to "good sense."

This research proposes a decision support system based on the Analytical Hierarchy Process to aid the program manager, the contracting officer and the SSA in identifying and evaluating all the relevant criteria and alternatives in making the final source selection decision. The issue to be addressed by this research is not whether the decisions currently being made are right or wrong, but whether they can be improved.

In order for a computer-aided support system to be effective in source selections, the individual activities leading to the decision must be reviewed. Early in the source selection process a Source Selection Plan is formulated in order to delineate the areas that will be important to award. These areas are split into factors and subsequently, the factors into items. Each of the items, factors, and areas relate to each other in a different fashion and have different relative weights (Cibinic et. al., 1988:V-12). The ability to assimilate this information into an understandable decision is paramount to the process and can only be worsened by ever present time constraints. Thus an organized framework is needed to keep up with the interaction of the criteria contributing to the decision.

This research addresses the problem that at this time there is no tool to aid the program managers and contracting officers in their assimilation of the criteria as they make these complex decisions on a daily basis. To further complicate the matter, the final decision is made by the SSA who is not directly involved in the evaluation of the competing proposals; thus, any mistakes made by the contracting officer or the program manager are magnified in the final decision.

A less than desirable decision in the Department of Defense can have far-reaching repercussions; a system may not be fielded in a timely manner; it may not address the threat that it was designed to counter; it may be too costly to be an effective system. Clearly, these consequences constitute a danger that the best possible decisions are not being made by the government in the source selection process. This danger may be lessened by the development of a decision support system (DSS) to aid in the process.

For all of the aforementioned reasons, the search for an effective aid to the decision-making process is both timely and necessary. It is the search for an effective aid to the decision-making process on which this research is focused.

Specific Problem

Given the limited capability of the human mind to process large amounts of information in complex situations, there is a high probability that the best decisions are not being made in the DOD acquisition process. Many authors have questioned the ability of humans as information processors. Most notably, Miller proposes a theory based on the "magic number seven, plus or minus two." The theory is described by Davis and Olson: the human mind is only capable of tracking seven (plus or minus two) pieces of information at one time (Davis and Olson, 1985:245).

The purpose of this research is to search for an effective aid in the decision-making process. The obvious problem with the outcome is encouraging the use of the system. There is a fear among existing workers that the computer is making the decisions. The adoption of a DSS may be viewed as allowing a computer to make the most important decision in the acquisition process. However, a DSS is only a tool; it does not make a decision, it merely aids in the organization and the assimilation of the multiple factors that go into the decision-making process.

The acquisition field is ripe for the introduction of some decision-making aid. With billions of dollars at stake, the decision-maker should have any advantage that he can get in order to make his final choice. Given the limited capability of the human mind to understand and assimilate the large amounts of information involved in the acquisition process, there is a high probability that the quality of the decisions being made can be improved upon.

II. Literature Review

This chapter is divided into three sections, 1) Decision-Making, 2) The Analytical Hierarchy Process, and 3) The Expert Choice Software. The section on decision-making will address classical decision theory and the theory of Decision Support Systems (DSS). The second section will be devoted to Thomas Saaty and his Analytical Hierarchy Process. Finally, the Expert Choice DSS will be briefly described.

Decision-Making

Decision-making is loosely defined as choosing between alternatives; thus the primary role of managers today is to make decisions. Through the proper decisions, organizations are either successful or unsuccessful in achieving their goals; therefor, decision-making is of paramount importance to any organization. Not surprisingly a large body of literature has been devoted to decisions and decision-making theory; the most well-known and accepted of the theorists is Herbert A. Simon.

Simon warns against the simplified definition of decision-making presented above when he describes a "lengthy, complex process of alerting, exploring and analyzing that precede that final moment" of choice (Simon, 1977:40). In his book, The New Science of Management Decision, Simon examines the decision-maker in all the phases of the decision-making process when he describes his classic model: 1) Intelligence, 2) Design, 3) Choice, and 4) Review (Simon, 1977:40). The model suggests that there is a natural progression from one phase to the next, allowing for the return to any previous phase if the situation warrants (Simon, 1977:43).

Intelligence. During this phase the decision-maker identifies a problem, defines and refines the problem and decides if action is necessary. Intelligence activities are how the decision-maker recognizes dissatisfaction with the current state of affairs.

Design. The design phase consists of searching for, creating, and analyzing alternative courses of action. This process includes testing for the feasibility of any possible solutions.

Choice. This is the time when a choice among alternatives is made. Simon claims that most definitions of decision-making concentrate on only this phase of the process and ignore the other phases of decision-making.

Review. The decision is implemented and reviewed at this stage (Simon, 1977:40-42).

Simon's model asserts that although all decisions are made through a process similar to the one described above, the process is affected by the type of decision to be made. Simon separates decisions into two categories: programed and nonprogrammed (Simon, 1977:45). Simon states:

> Decisions are programed to the extent that they are repetitive and routine, to the extent that a definite procedure has been worked out for handling them so that they don't have to be treated de novo each time they occur (Simon, 1977:46).

Simon goes on to differentiate these from nonprogrammed decisions.

> Decisions are nonprogrammed to the extent that they are novel, unstructured and usually consequential. There is no cut-and-dried method for handling the problem because it hasn't arisen before, or because its precise nature and structure are elusive or complex, or because it is so important that it deserves a custom-tailored treatment (Simon,1977:46).

This separation into programed and nonprogrammed decisions is supported by Lohaus who describes "programmed" and "custom" decisions. Lohaus' programmed decisions are those that are recurring and based on established policies or routines (Lohaus, 1985:3.17.7). Custom decisions are those that require the personal attention of the professional manager because the decision must be customized to fit the specific situation (Lohaus,1985:3.17.7).

Further support is lended by Gorry and Scott Morton who describe "structured" and "unstructured" decisions.

Integral to their position is the thought that the unstructured decision requires the human decision-maker to make subjective judgments, whereas structured decisions do not (Gorry and Scott Morton, 1971:60).

Key to all of these positions is that the "nonprogrammed" decision is not repetitive or recurring like the "programmed" decision. Simon suggests that if a problem occurs often enough, a routine will be developed to address it, thus making the problem "programed" (Simon, 1977:46).

Similarly, Sprague and Carlson suggest that decisions are "unstructured" due to uncertainty (Sprague and Carlson, 1982:94). In either event, while the very nature of the "nonprogrammed" decision requires special attention, the recurring aspect of the "structured" problem suggests that routines can be developed to make the decision.

As the review above indicates, decisions fall into one of two categories: programmed or nonprogrammed. Simon uses this distinction to support that different processes are used to make different types of decisions. Simon writes:

> The main reason for distinguishing between programed and nonprogrammed decisions is that different techniques are used for handling these two aspects of our decision making. The distinction, then, will be a convenient one for classifying these techniques. I shall use it for that purpose, hoping that the reader will remind himself from time to time that the world is mostly gray with only a few patches of pure black or white (Simon, 1977:47).

Cook summarizes the review quite well when he writes:

> . . . decision types can be classified into two general categories:
>
> 1. Programmed: Structured, routine, repetitive, governed by procedure, operational, non-complex, etc.
>
> 2. Nonprogrammed: Unstructured, underspecified, unique, novel, creative, strategic, complex, etc.
>
> While a given decision may fall into the "gray area" between the two general types, the preponderance of writing in this field and the variety of nomenclature used by different authors to refer to essentially the same decision types permits use of the two categories as a reasonable basis for analysis (Cook, 1987:21).

The types of decisions have been categorized; the processes through which decisions are made must also be examined categorically. While not always referred to by the same nomenclature, two major processes reveal themselves in the literature; optimizing, and satisficing are the decision-making processes under which virtually all decisions can be categorized.

Optimizing. To optimize is to make the best possible decision under the circumstances at hand. Simon's process for finding the "optimal" solution is that of a rational man making his decision based on perfect knowledge of all alternatives; alternatives that are then subjected to an economic cost-benefit analysis (Simon, 1976:xxviii).

Lohaus describes optimizing in a similar fashion; the decision-maker considers all possible solutions by weighing the alternatives against each other until the best or optimal solution is found (Lohaus, 1985:3.17.8).

Kepner and Tregoe assert a theory similar to that of Simon, defining an optimizing decision analysis as a system through which the decision-maker comes to the optimal decision. The decision-maker considers the "musts" and the "wants" in the context of the possible alternatives. By performing analysis on these competing alternatives, the decision is made (Kepner and Tregoe, 1981:86-88).

Optimizing is indeed a lofty goal. In fact, Simon is skeptical that it can be achieved by the unaided human mind. Many theorists have discussed the limitations inherent to the human mind. These limitations will be discussed later in the context of optimizing and satisficing.

<u>Satisficing.</u> Satisficing is the act of finding the solution that is "good enough." Lohaus describes satisficing as identifying a solution, testing the solution, and securing the acceptance of the players that are involved (Lohaus,1985:3.17.8). Because every possible solution cannot be enumerated and subjected to cost-benefit analysis, the decision-maker settles for an "acceptable" solution. Thus, satisficing is how the human mind copes with its own limitations.

Simon further describes satisficing by listing habit, clerical routine and organizational structure as being prevalent decision-making aids (Simon, 1977:48). These methods all exhibit the characteristics of satisficing as they are based on established routines coming to a satisfactory solution. An obvious danger to these methods, is that the established routines may lag behind the dynamic environment of the decision-maker and become obsolete. If this is the case then not only is the optimal solution not achieved, but a satisfactory solution is not achieved.

Many authors have described the human decision process as some form of satisficing. By describing an "administrative" man who looks for a solution that is satisfactory, Simon introduces his theory of "bounded rationality" in order to explain how the decision-maker coped with overwhelming complexity. (Simon, 1976:xxix).

Likewise, Lindblom describes his "science of muddling through" as a method that managers turn to because it is impossible to optimize. Citing time pressures, budget constraints and the ability to process information as the factors that force the decision-maker to "muddle through," Lindblom asserts that the decision maker turns to satisficing (Lindblom, 1959:80).

In the same vein as Simon and Lindblom, Soelberg presents his "implicit favorite" model to describe the decision-making process. This model suggests that decision-makers are forced to simplify the process because of complexity. Suggesting that the model suggests that the decision-maker does not enter into the "choice" phase of Simon's model until an "implicit favorite" is identified, Soelberg maintains that the rest of the decision-making process is devoted to justifying the implicit favorite (Soelberg, 1967:19-29).

Clearly, decision-making processes can be categorized as either "optimizing" or "satisficing." It can also be seen that given the choice, the optimal decision is preferable to the satisfactory decision. The review above supports that few managers optimize. Cook found that only 45.5% of managers optimize (Cook, 1987:155). Janis and Mann summarize the obstacles to optimizing into two categories:

1. Limitations of the human mind.
2. Bureaucratic obstacles (Janis and Mann, 1977:41).

This research attempts to address the first of the two obstacles through the use of decision-support systems.

Decision support systems (DSS) are computer programs designed to aid in the decision-making process and have been described as "another powerful weapon in the information technology arsenal, aimed at improving the effectiveness of managers in organizations" (Fick and Sprague, 1980:7). The emphasis should be that the DSS is a tool rather than the decision-maker (Alter, 1980:1). By allowing the computer to do what the human mind cannot, the process is improved.

As the role of the computer is integral to the theory of DSS's, certain assumptions are made about that role:

1. The computer must only support the decision-making process. It cannot make the decision itself.

2. DSS's lend themselves best to "semi-structured" problems where the computer can augment the decision-maker's own judgments about the problem.

3. The decision-maker and the DSS must be in an interactive mode to gain the full advantage of the DSS (Keen, 1976).

All of these assumptions show that the decision itself is made by the manager. The DSS only provides support for the manager.

Alter describes seven classes of DSS's:

1. "File Drawer Systems." These are basically online filing systems or databases.

2. "Data Analysis Systems." These allow simple analysis to be performed on data. Automated budget systems fall into this category.

3. "Analysis Information Systems." These add a limited modelling capability to data analysis systems.

4. "Accounting Models." These actually calculate the consequences of financial decisions for comparison purposes.

5. "Representational Models." This is the class of simulation models. These models are used to predict outcomes in uncertain environments.

6. "Optimization Models." These models generate the "best solution" based on a series of constraints.

7. "Suggestion Models." These models provide decisions to repetitive (structured/programmed) situations (Alter, 1980:90-91).

While all of the above DSS's are available to the manager, it is the optimization model that this research is concerned with. These models allow the decision-maker to input his own judgments and the computer can optimize the solution.

The Analytical Hierarchy Process

As seen in the review above, a number of authors are skeptical about the ability of the human mind to "optimize." Saaty has proposed a method of optimization that will enable the decision-maker to avoid many of the short-comings that hinder the optimization process.

According to Saaty, a complex decision is one where there are a number of alternatives which are supported by multiple decision criteria and other factors. These other factors may be tangible or intangible in nature, but they interact to support the overall decision (Saaty, 1982:27).

To make the optimal decision, all possible alternatives must be identified and considered, and all relevant criteria that support the alternatives must be examined. In order to make sense of all this information, some support framework must be employed. The Analytical Hierarchy Process provides just such a framework:

> Basically AHP is a method of breaking down a complex, unstructured situation into its component parts; assigning these parts, or variables, into a hierarchic order; assigning numerical values to subjective judgments on the relative importance of each variable; and synthesizing the judgments to determine which variables have the highest priority and should be acted upon to influence the outcome of the situation. (Saaty, 1882:5)

Saaty claims that the AHP represents the natural decision-making process of the human mind and allows for the expansion of the boundaries of the mind when dealing with large amounts of information. The process mandates a "rational" framework when dealing with multiple conflicting alternatives and criteria. The AHP allows for the structuring of the decision into hierarchies, thus lending a structure to an otherwise unstructured problem and giving the decision-maker a new perspective on the problem. By conceiving of the problem as a "whole" made up of smaller parts, the interaction among criteria and alternatives can be considered simultaneously and the optimal decision can be made (Saaty, 1982:24).

By claiming that this process is innate to the human mind, Saaty asserts that when faced with a complex decision, the individual constructs a hierarchy of criteria and alternatives building up to the decision. By assigning values of importance to the factors and making mental judgments about the criteria, the decision-making matrix is established. The decision-maker then performs a mental synthesis on the hierarchy and selects the alternative that is the "best" per his own judgments. The AHP allows the decision-maker to look at only parts of the decision at one time while keeping perspective as to the whole.

In order to illustrate the AHP, Saaty uses the example of the possible urbanization of a river region in Pennsylvania. The most important issue to the decision-maker was the environmental quality, thus the protection of the environmental quality becomes the top level of the hierarchy (see figure 1). Saaty goes on to describe the example:

> The highest level was the overall objective of protecting environmental quality. The lowest included the final actions, or alternative plans, that would contribute positively or negatively to the main objective through their impact on the intermediate criteria. The alternatives were (A) to leave the area nonurbanized, (B) to allow partial urbanizations, and (C) to allow total urbanization. The intermediate levels of the hierarchy comprised the two basic criteria for

evaluating environmental quality: (1) esthetic criteria, which were further structured into properties of vividness, intactness, and no noise or disturbances; and (2) hydrologic criteria, subdivided into no flooding, water quality, and channel naturalness. This hierarchy graphically depicts the interdependence of elements in the problem; it both isolates the relevant factors and displays them in the larger context of their relationship to each other and to the system as a whole (Saaty, 1982:15-16).

The overall hierarchy of the decision is shown in figure 1.

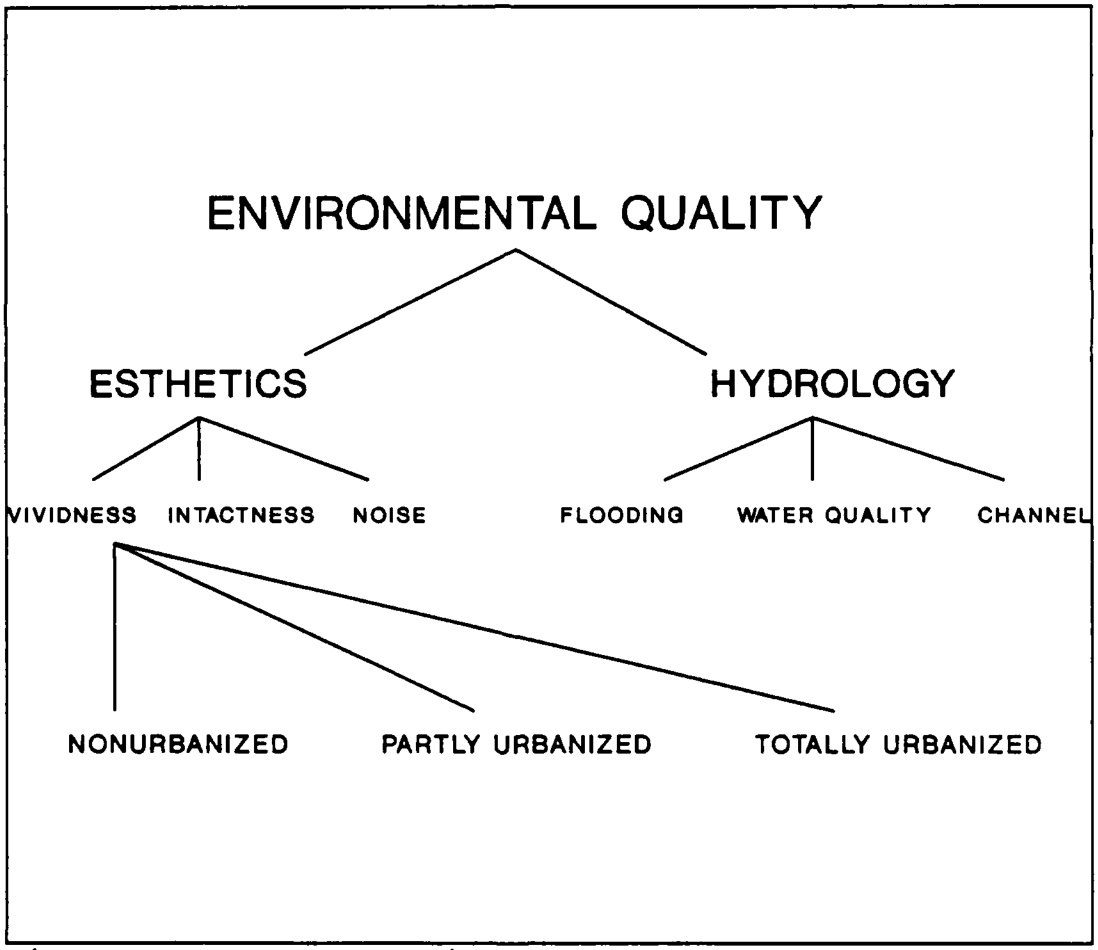


Figure 1 Adapted from Figure 2-1 (Saaty, 1982:15)

After constructing the hierarchy, it is incumbent upon the decision-maker to assign relative importance to each of the factors within the hierarchy. In the AHP, these judgments are quantified in order to compare them. As Saaty states, "Often words alone or logical argument cannot express the subtleties of deeply felt differences" (Saaty, 1982:16).

The next step in the process is to make judgments on the different merits of the alternatives. These judgments are made at the lowest level of the hierarchy thus allowing for the most simple judgement to be made by the decision-maker. The AHP simplifies this process by structuring the problem into sections that the decision-maker can handle. While the entire problem at once may be overwhelming, humans . . .

> have the ability to perceive relationships among the things they observe, to compare pairs of similar things against certain criteria, and to discriminate between both members of a pair by judging the intensity of their preference for one over the other. Then they synthesize their judgments -- through imagination or, with the AHP, through a new logical process -- and gain a better understanding of the whole system (Saaty, 1982:17).

The next issue at hand is that of consistency. If the judgments are not consistent, then the decision is flawed and the judgments should be reconsidered, thus the AHP tests for consistency of judgments. (Saaty, 1982:16). As Saaty states:

> The consistency is perfect if all the judgments relate to each other in a perfect way. If you say that you prefer spring to summer three times more and that you prefer summer to winter twice more, then when you give the judgement comparing your preference of spring to winter it should be 6 and not anything else. The greater your deviation from 6, the greater your inconsistency. This observation applies to relations among all the judgments given. We would have perfect consistency, then, if all the relations checked out correctly (Saaty, 1982:16).

The validity of the Analytical Hierarchy Process is defended by Harker and Vargas in their paper "The Theory of Ratio Scale Estimation: Saaty's Analytical Hierarchy Process" when they state, "AHP is based on a firm theoretical foundation and, as examples in the literature . . . illustrate, the AHP is a viable, usable decision-making tool" (Harker and Vargas, 1985:50).

This research proposes to employ the AHP in the decision-making process through the use of a DSS. Expert Choice, developed by Decision Support Software will be used by the author to construct and test a model that will aid in the source selection process.

The Expert Choice Software

Expert Choice is a decision support program that is based on Saaty's AHP. The system allows the user to graphically portray a complex decision analysis problem with multiple conflicting criteria and alternatives in much the same fashion as in figure 1. Once the attributes are modeled, the decision-maker can make both objective and subjective judgments about the factors and criteria, through which alternatives are ranked by the program in a manner which is consistent with these judgments.

The judgments are entered in one of two ways: objectively or subjectively. In the objective fashion, the user can enter numerical scores for the different factors. Subjectively, the user is presented with the criteria as a series of pairs and then asked to make subjective statements about the pairs. These statements are of the nature of whether or not one alternative is better than another with respect to this criteria. The user can make judgments ranging from "they are equal" up through "alternative one is extremely preferable to alternative two" and so on. A typical model, as created by the members of the experimental group can be found in Appendix B.

The program then synthesizes the information that is input in a consistent manner and provides a rank-ordered list of alternatives, given that information furnished by the user. The decision-maker can then perform sensitivity analysis on the decision and the criteria in order to fully understand the decision-making process. Expert Choice also reports on the logical consistency of the decision maker in the judgments that have been made and allows for corrections in this area.

Expert Choice is an excellent adaptation of the AHP for the computer. It was chosen for this research because of its theoretical foundation in AHP and its ease of use.

III. Methodology

"Research Design," "Discussion of Variables," and "Discussion of Hypothesis" entail the three major areas of methodology covered in this chapter. "Research Design," details the experimental design that will test the null and research hypotheses. "Discussion of Variables," outlines the major constructs, the pertinent variables and the null and research hypotheses of this study. This section concludes with a discussion of the operationalization of the variables. "Discussion of Hypotheses," lists the null and research hypotheses to be tested by the research.

Research Design

A post-test-only control group design was used to test the hypotheses of the study. The method employs one experimental group and one control group as diagrammed below where X_1 is the experimental treatment and O_1/O_2 are post-test observations.

$$\begin{array}{lll} (R) & X_1 & O_1 \\ (R) & & O_2 \end{array}$$

Arguably, the more common research design might have been the pre-test-post-test control group experimental design as diagrammed below:

$$\begin{array}{llll} (R) & O_1 & X_1 & O_3 \\ (R) & O_2 & & O_4 \end{array}$$

The pretest notion is used primarily to ensure the equality of the two groups (Campbell and Stanley, 1963, p.25). Also, the pre-test can introduce a bias into the control group that may invalidate the experimental results (Campbell and Stanley, 1963, p.14).

The validity of the post-test-only experimental design is defended by Campbell and Stanley when they write:

> While the pretest is a concept deeply embedded in the thinking of research workers in education and psychology, it is not actually essential to true experimental designs. For psychological reasons it is difficult to give up "knowing for sure" that the experimental and control groups were "equal" before the differential experimental treatment. Nonetheless, the most adequate all-purpose assurance of lack of initial biases between groups is randomization. Within the limits of confidence stated by the tests of significance, randomization can suffice without the pretest (Campbell and Stanley, 1963, p.25).

Thus, for the above reasons, the post-test-only control group experimental design was chosen for this research.

The experimental treatment in this research is the introduction of the decision support system using Expert Choice software. The control group was asked to make a decision by any means that they were most comfortable with. As indicated by the design, the assignment to the groups was random to control for all variables except in the independent variable of interest.

The two groups were given a briefing on the decision scenario with multiple competing criteria and choices. The experimental group then received the treatment. An explanation of the Analytical Hierarchy Process and Expert Choice was given to the individuals. The post-test consisted of a complex decision scenario. The experimental group used the DSS, each subject was given an identical computer on which the Expert Choice software was loaded. They created their own models and used the DSS to aid in the process. The control group used whatever decision-making method that they usually employ.

After completing the scenario, each subject filled out a questionnaire designed to test the variables described below in the section entitled "Discussion of the Variables and Major Hypotheses." Univariate and bivariate analyses were performed on the data to draw conclusions and recommendations from the research.

This experimental design controls the threats to internal validity quite well (Emory, 1985:121). If there is a problem with internal validity it is in separating the effects of the AHP and the DSS. However since the DSS is largely based on the AHP this may not be necessary. The goal of this research is, after all, to search for an effective decision-making aid. If the combined effects of the AHP and the DSS are positive then the individual roles of each are inconsequential. The individual roles of each may be the subject of further research.

The post-test-only control group experimental design is not as strong in the field of external validity. There is the possibility that subjects were affected by the act of being tested; however, this is more of a problem in studies in which the pretest introduces unusual activities (Emory, 1985:121). Since the pre-test has been eliminated and the experiment was conducted with AFIT students familiar with the acquisition process, this may not be a problem.

A second problem with external validity is whether or not the findings are generalizable to the PCOs, PMs, and SSAs of the acquisition community; 45 AFIT students may not be a representative sample. A subjective case may be made, however, that these subjects were relatively typical if program managers, contracting officers and source selection authorities. This generalization is based on the similar education, training and career paths of the population studied, compared with that which apparently exists in the acquisition community.

Discussion of Variables

Major Constructs. The following constructs are contained in the research design and warrant definition:

1. Decision: A solution that ends uncertainty or dispute.

2. Decision-Making Process: The method by which the decision maker chooses among competing alternatives to achieve the preferred state and end the uncertainty or dispute.

3. The Analytical Hierarchy Process: A process through which a complex situation is broken down into its components. These components are arranged into a hierarchic order according to importance. Subjective judgments are assigned numerical values according to their relative importance. Finally, the judgments are synthesized to determine which components should hold priority in the overall situation.

Variables. The variables used in this design were derived from the literature review and the author's judgement of the factors important to test the hypotheses. Demographic variables were included to aid in describing the population and the sample used to test the hypotheses. The demographic variables were also used to explain the relationships between the sample and the results achieved in the testing of the dependent variables. Finally, the demographic variables were used to verify the lack of bias in the two groups.

Independent Variable. X_1--The use of the Expert Choice Software model based on the Analytical Hierarchy Process. The subjects were given an introduction to Expert Choice and its modeling capabilities. Included in this introduction was a description of the Analytical Hierarchy Process. Subjects were then given a complex decision scenario and asked to make the best possible decision using the DSS. Each subject was assigned to an identical computer onto which Expert Choice had been loaded.

Dependent Variables. The following are the dependent variables used to test the hypotheses.

1. Effectiveness. This is a measurement of the subjects ability to make the "best" decision. This "best" decision was determined by a "panel of experts" who were given the decision scenario generated by the author in advance of the experiment. The panel used the guidance available and any method that they wished to employ to solve the problem. The subjects' decisions were then compared to

the decision of the panel. If they agreed, then the subject made an "effective" decision.

2. Consistency. Consistency was measured by the number of the individuals in the control group and the experimental group who chose the same outcome. This variable is important to avoid the appearance that the decision-making process is arbitrary.

3. Speed. The actual amount of time taken to make the decision. All subjects were timed during their decision-making process.

4. Difficulty. Ease of the process. This was measured by a post-test survey and based on the feelings of the subjects.

5. Understanding. How well does one comprehend the process used to make the decision? This was measured by administering a post-test survey and examining the answers of the subjects.

6. Confidence. A measure of the decision-maker's feeling that the alternative chosen was correct.

Demographic Variables. The following demographic variables served as control variables to analyze their relationship to the dependent variable and to analyze their effect on the relationship between the dependent and the independent variables.

1. Education. This variable records the highest level of education achieved by the subject. The scale ranges from "High School" through "Post-Graduate or Professional Degree."

2. Major Field of Study. If the subject has completed sufficient education to have a concentration, this variable records that area.

3. Formal acquisition related courses. This variable records the familiarity with the acquisition process by the measure of formal education in the field.

4. Courses in field of expertise. This variable measures the formal education received in the subjects' specific field of expertise in the work place.

5. Experience. Subjects were asked for the number of years of specific experience they have had in their field of expertise.

6. Certification. Subjects were asked if they have been certified in their field by a professional organization to further measure familiarity in the field.

<u>Other Variables of Interest.</u> The following questions were asked to examine the subjects' feelings about the decision-making process and the specific scenario at hand.

1. If you had more time, could you have made a better decision? Did the subjects feel hurried?

2. Would you classify this decision as structured (programmed) or unstructured (non-programmed)? Because the use of a Decision Support System lends itself more readily to a less structured problem, this question measured the subject's view of the problem at hand. If the acquisition process upon which the experiment is based is a highly structured process, then one would expect little difference between the groups on the dependent variables.

3. How did you feel about this process? The subjects were given a scale ranging from "Frustrated" to "Joy" in order to get a feel for their comfort in the situation.

Operationalization of the Variables.

Operationalization of the variables was accomplished by a written questionnaire that was administered after the experiment. To briefly recapitulate, the independent variables were: effectiveness, consistency, speed, difficulty, understanding, and confidence. The first three (effectiveness, consistency, and speed) lend themselves well to an objective measurement. While the last three (difficulty, understanding, and confidence) required the subjects to respond to statements relating the extent to which they agreed or disagreed with statements about the process.

An objective measure can be used to measure effectiveness, speed, and consistency. Effectiveness was defined above as the number of "correct" answers. This was measured counting the number of answers that corresponded to the answer provided by the "panel of experts." Consistency is the frequency of the same answer. This, again was measured objectively. Finally speed was simply measured by the elapsed time required to make the decision.

The last three dependent variables were measured by asking the subjects to express agreement or disagreement with statements relating to the variables. The Likert-type scale below was used to prompt the subject responses.

STRONGLY	MILDLY	3 NEUTRAL	MILDLY	STRONGLY
1 AGREE	2 AGREE		4 DISAGREE	5 DISAGREE

The Likert-type scale is frequently used because of its advantages for statistical uses. These scales are more suited to statistical analysis than free-form questions. The Likert-type scale is verified by Kidder as being the most frequently used scale to analyze attitudes (Kidder, 1981, p.215). The answers provided by the subjects are represented by numerical scores in this system and can be subjected to numerical analysis.

Where indicated by initial investigation, a correlational analysis was performed on the variables of interest. Because the data was condensed into an ordinal form, Gamma was used as a correlation coefficient. Gamma, as with most correlational coefficients, ranges from -1.0 to +1.0. Meier and Brudney describe Gamma as follows:

> What gamma (and many other ordinal measures of association) does is take the difference between the number of concordant or consistently ordered pairs and the number of discordant or inconsistently ordered pairs in the cross-tabulation. This difference indicates the relative support in the contingency table for a positive as opposed to a negative relationship between the two variables. If the number of concordant pairs exceeds the number of discordant pairs, then on balance, there is greater support for a positive relationship in the table. In that case the difference between them will be positive, and the gamma statistic will have this sign. On the other hand, if the number of concordant pairs is less than the number of discordant pairs, there is greater support for a negative relationship. The difference between them will be negative, and this will be reflected in the (negative) sign of gamma. Regardless of the direction of the relationship, the larger the difference between the number of concordant and the number of discordant pairs, the greater is the association between the two variables, and the greater is the magnitude of gamma (Meier and Brudney, 1981:232).

The calculation for gamma is shown below.

$$\text{Gamma} = \frac{\text{\# of concordant pairs} - \text{\# of discordant pairs}}{\text{\# of concordant pairs} + \text{\# of discordant pairs}}$$

Operationalization of the demographic variables and the variables termed "other variables of interest" was achieved by using open-ended questions. The different demographic variables were measured with responses to alternatives. Wherever possible, the response of "other" was provided with the prompt to provide the information free-form. The variables described as "other variables of interest" were open ended questions that allowed the subject to respond free-form. These were analyzed for recurring trends.

For specifics on the questionnaire, see the copy found in the appendix.

Discussion of the Hypotheses

In chapters one and two, the nature and complexity of the defense acquisition process were discussed. Given the human inclination to satisfice, the author suspected that the best possible decisions were not being made by the parties in the process. As discussed in chapter two (Simon, Lindblom, and others), the limited capability of the human mind is a major circumstance that excludes optimizing in complex decision scenarios.

Saaty (also discussed in chapter two) proposes the Analytical Hierarchy Process as a method to increase the ability to optimize. The use of the AHP, coupled with the aid of computer aided decision support systems should aid in the decision-making process. From this the author suspects that the process can be improved through the use of these tools.

In this research, variables have been tested to measure the degree to which the decision-making process is improved by the use of a computer aided decision support system, specifically Expert Choice. The objective of the research is to identify the variables, if any, that are affected by the DSS.

To accomplish this objective the following null and research hypotheses were formulated:

Null Hypotheses. The following is a discussion of the null hypotheses.

H_{01}: The use of a DSS will have no effect on the effectiveness of the decision-making process.

H_{02}: The use of a DSS will have no effect on the consistency of the decision-making process.

H_{03}: The use of a DSS will have no effect on the speed of the decision-making process.

H_{04}: The use of a DSS will have no effect on the difficulty of the decision-making process.

H_{05}: The use of a DSS will have no effect on the understanding of the decision-making process for the participants.

H_{06}: The use of a DSS will have no effect on the decision maker's confidence in his decision.

Research Hypotheses. The following is a discussion of the research hypotheses.

H_1: The use of a DSS will increase the effectiveness of the decision-making process.

H_2: The use of a DSS will increase the consistency of the decision-making process.

H_3: The use of a DSS will increase the speed of the decision-making process.

H_4: The use of a DSS will make the decision-making process less difficult.

H_5: The use of a DSS will increase the understanding of the decision-making process for the participants.

H_6: The use of a DSS will increase the decision maker's confidence in his decision.

IV. Analysis

This chapter will focus primarily on: 1) Demographics, 2) Findings, 3) Hypotheses, and 4) Free-Form Data. In the section entitled demographics, the general make-up of the control and experimental group will be discussed. The section on findings will address the validity of the null and research hypotheses proposed in the previous chapter. The section on hypotheses will address the implications of the findings on the research hypotheses proposed in the section entitled "Methodology." Finally, the section on free-form data will discuss the feelings of the subjects based on open ended questions in the questionnaire.

Demographics

Demographic information was gathered through a series of questions on the questionnaire. This section will address each question and participant responses. For details on the questionnaire, see the copy found in the appendix. The statistics are reported in percentages.

The following five questions were used to verify the level of expertise of the subjects and to ensure that there was no bias due to a difference in expertise between the experimental and control groups.

Question 1: What is the highest level of education that you have completed?

The following results are summarized in figure 2.

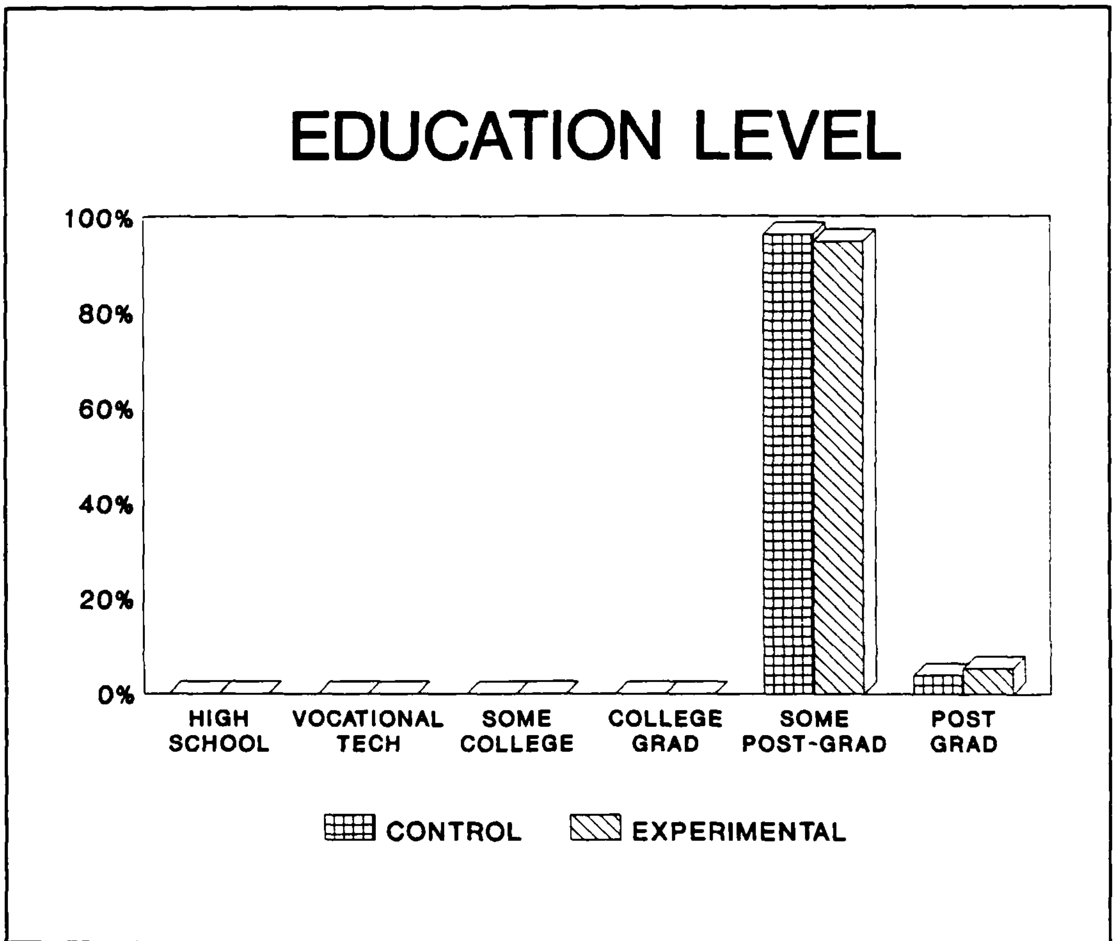


Figure 2 Distribution of Educational Level

Control Group: Of the control group 96% reported some graduate level education with 4% reported already having achieved a graduate level degree.

Experimental group: Some graduate level education was reported by 95%, while the remaining 5% reported a graduate degree.

No essential difference exists between the groups. The high level of education achieved by the groups is not surprising since the experiment was conducted on graduate students at the Air Force Institute of Technology.

Question 2: What was your major field or area of study?

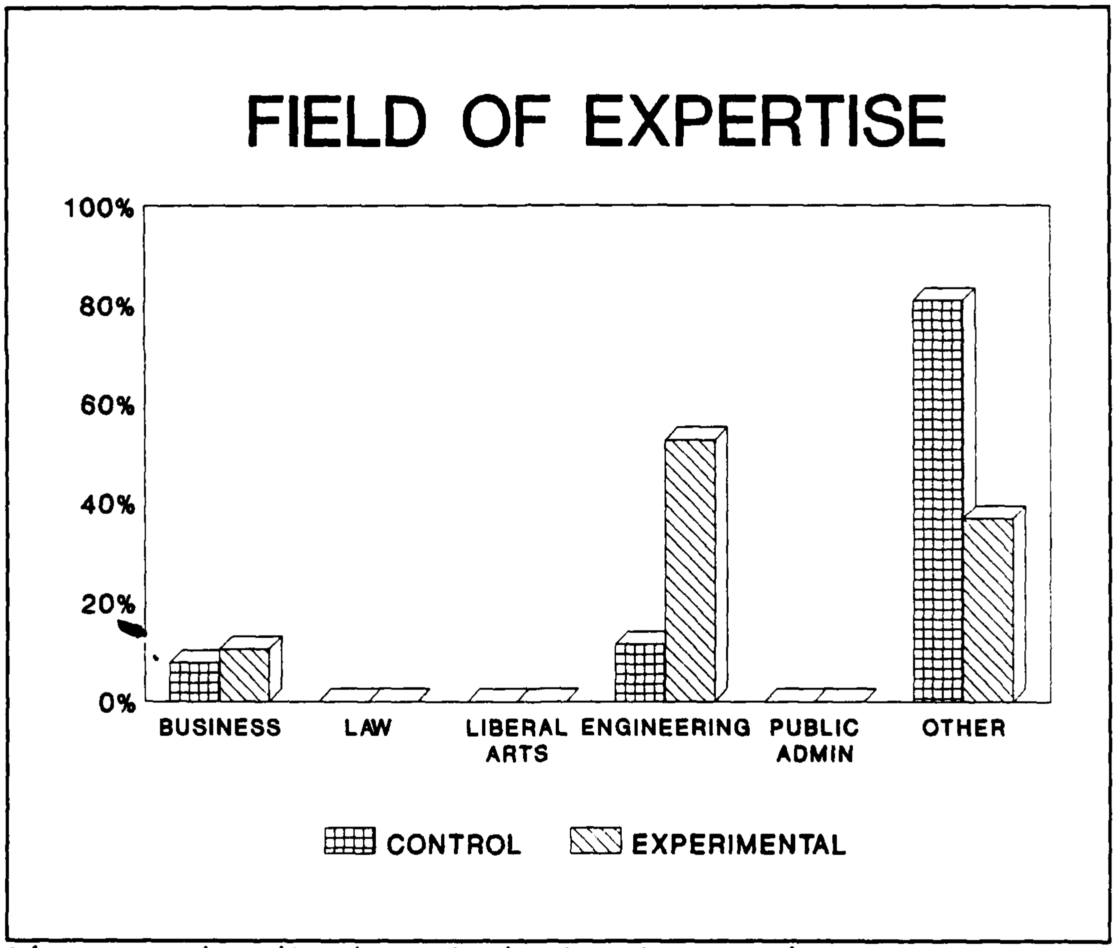


Figure 3 Distribution of Fields of Expertise

Control group: "Business" was reported by 19% as their major field of study while 12% reported engineering, but the clear majority reported some form of systems management.

Experimental group: Of this group, 11% reported "Business," 53% "Engineering" and 37% reported some form of systems management. The results of the experimental group indicate that although the entire group is currently studying systems management at AFIT, group members identify more readily with engineering. While there appears to be a difference here, the free form questions indicated that there is almost no difference in the major field between the two groups.

Question 3: How many acquisition related courses have you taken?

Control group: Figure 4 shows that 19% reported having taken no courses, 54% had taken one to three, 23% four to six, 4% seven to ten, while no individuals reported more than ten.

Experimental group: In this group, 11% reported no courses taken, 37% reported having taken one to three, 47% four to six, and 5% seven to ten. Again, no subjects reported more than ten courses. These results indicate a good solid level of training in the acquisition field. Both groups were centered around the "one to three" area and the "four to six" area. If there is any difference, the experimental group seems to have had somewhat more training in the acquisition field. This difference could suggest an area for further research; however, later results will indicate that there was virtually no difference between groups on the choice of contractor. This lack of difference would indicate that this difference in training had little or no effect on the outcome of the experiment.

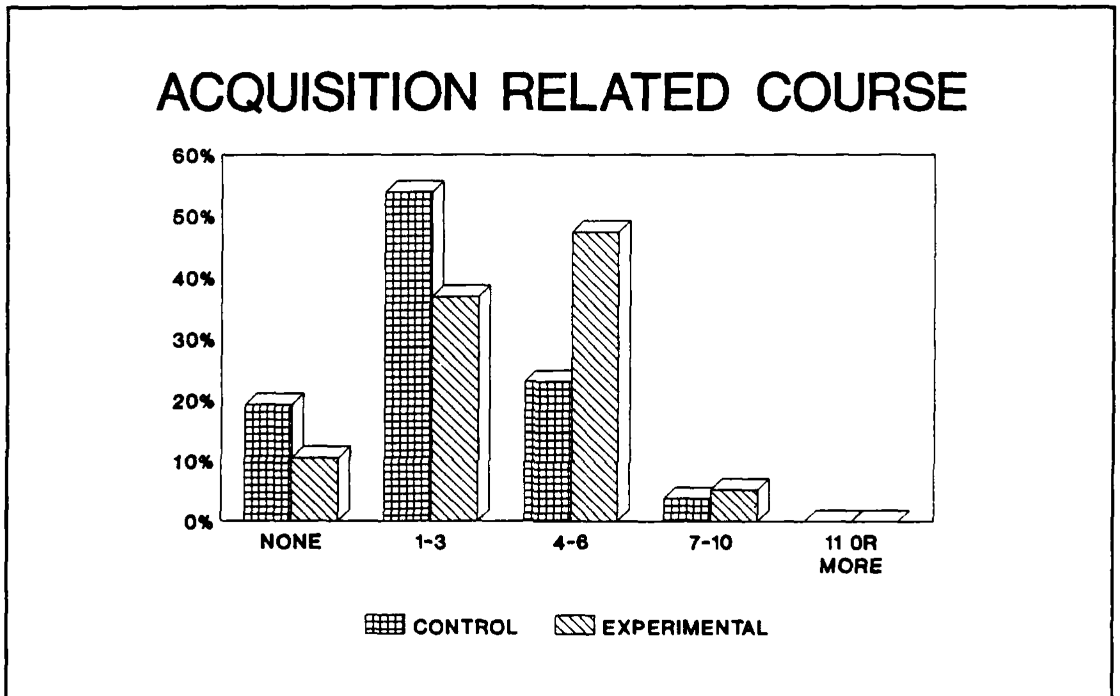


Figure 4 Distribution of the Number of Courses Taken

Question 4: How many courses have you taken in your field of expertise?

Control group: Here, 19% reported no formal courses in their field of expertise, 50% reported between one and four courses. The remaining 31% reported five or more.

Experimental group: Only 5% reported having taken no courses, but 53% reported between one and four; 42% reported over five courses completed in their field of expertise.

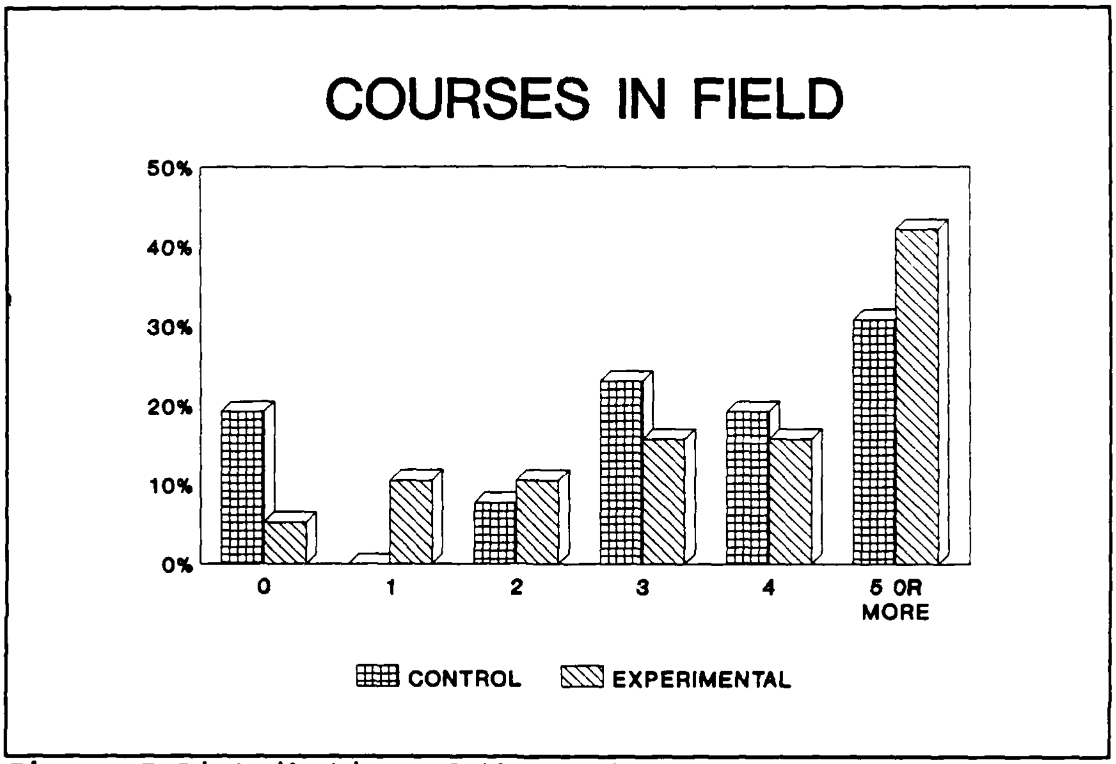


Figure 5 Distribution of the Number of Courses Taken

Again, there is a slight difference in the educational level in field towards the experimental group, however, the difference is so small as to be inconsequential. The same argument applies here as above due to the lack of difference in the choice of the contractors. This small difference in education could have little effect on the outcome of the experiment.

Question 5: How many years of experience do you have in your field of expertise?

Control group: Figure 6 shows that 35% reported having less than 1 year of experience in their current field, 30% reported between one and four years while the remaining 35% reported five or more years of experience.

Experimental group: Here, 26% reported having no experience in their current field, 58% reported between one and four years of experience while only 16% reported five or more years.

The control group holds the edge in the years of practical experience with 35% reporting five or more years.

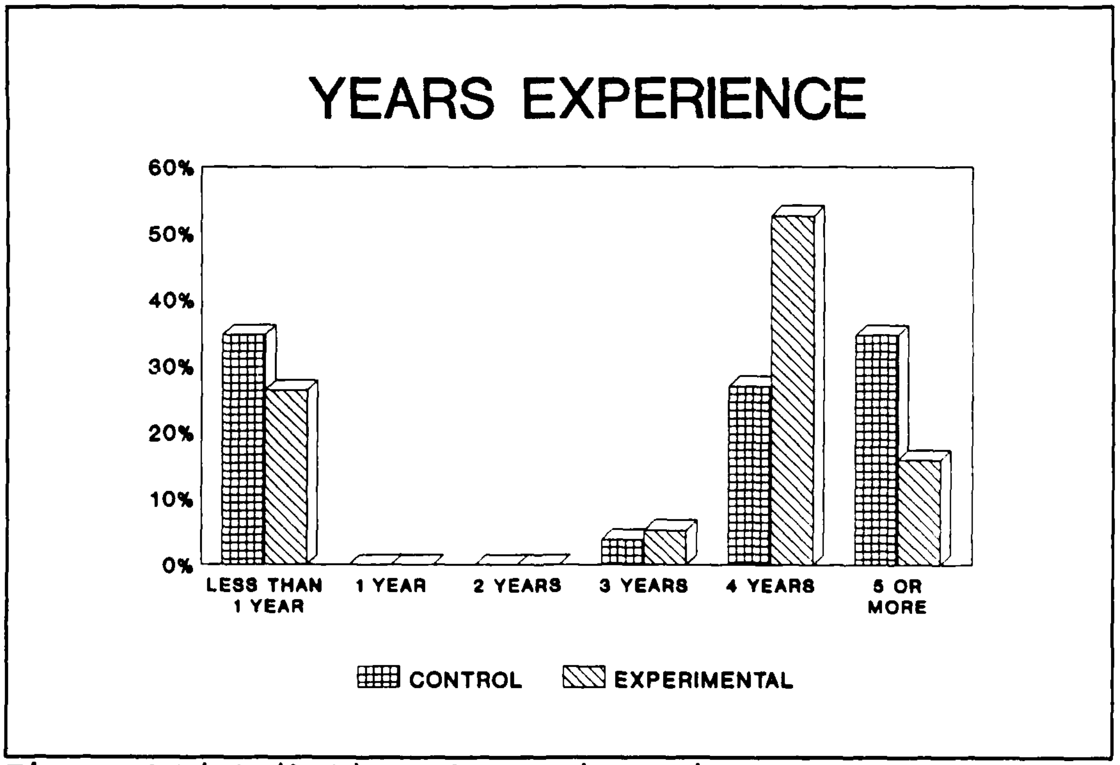


Figure 6 Distribution of Experience in Years

Question 6: Are you certified in your field?

Control group: Only 8% reported certification as some level of program manager. All other responses indicated no certification.

Experimental group: Certification of program manager was reported by 11%. Again, all other responses were "not certified."

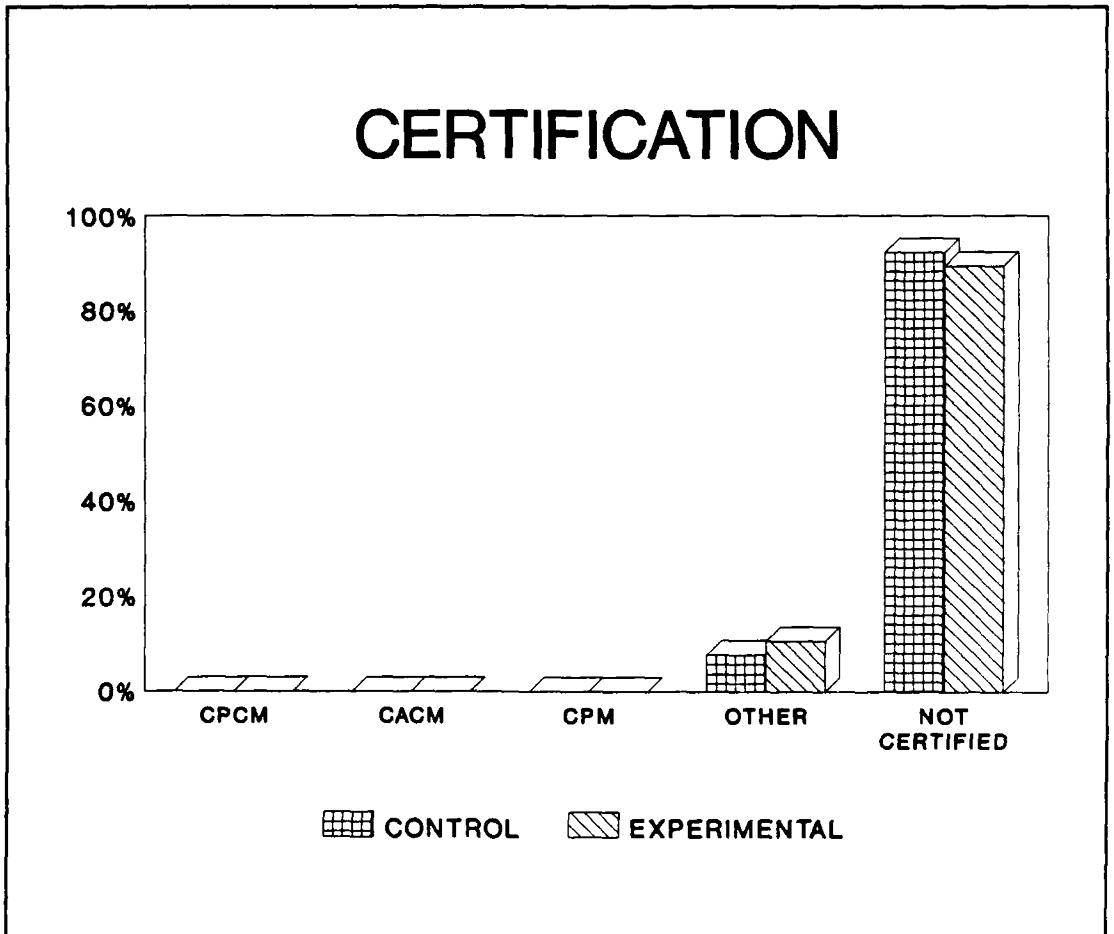


Figure 7 Distribution of Certified Subjects

The data from this question does not indicate any concern of differences, nor is it surprising due to the level of the subjects in their career field. As figure 7 indicates, the results on this question are almost identical.

When using a post-test only control group experimental design, a major concern is that of bias in the groups (Campbell and Stanley, 1963, p.25). However, the results of the demographic questions indicate that randomization has achieved its purpose. As Campbell and Stanley state, "the most adequate all-purpose assurance of lack of initial bias is randomization" (Campbell and Stanley, 1963, p.25). The above analysis clearly indicates that the two groups do not contain any significant biases that would invalidate the results of the experiment.

Findings

These findings were based on the research questions found in the questionnaire. As discussed in the chapter entitled "Methodology," the variables "effectiveness," "consistency," "speed," "difficulty," "understanding," and "confidence" were used to test the research hypotheses.

Each question was examined individually and the results were summarized. Overall conclusions indicated by the results are reserved for the final chapter entitled "Recommendations and Conclusions."

Effectiveness. This variable was measured objectively by comparing the number of "correct" answers in the groups. In each group 85% of the subjects chose the "correct" answer-- Magnetic Technologies Inc. Only 8% of the control group chose Fusetech, 4% chose Smith and Jones, and 4% chose Techco. The experimental group had remarkably similar results. Here 10% chose Fusetech 5% chose Techco. Figure 8 shown below indicates very little difference between the groups.

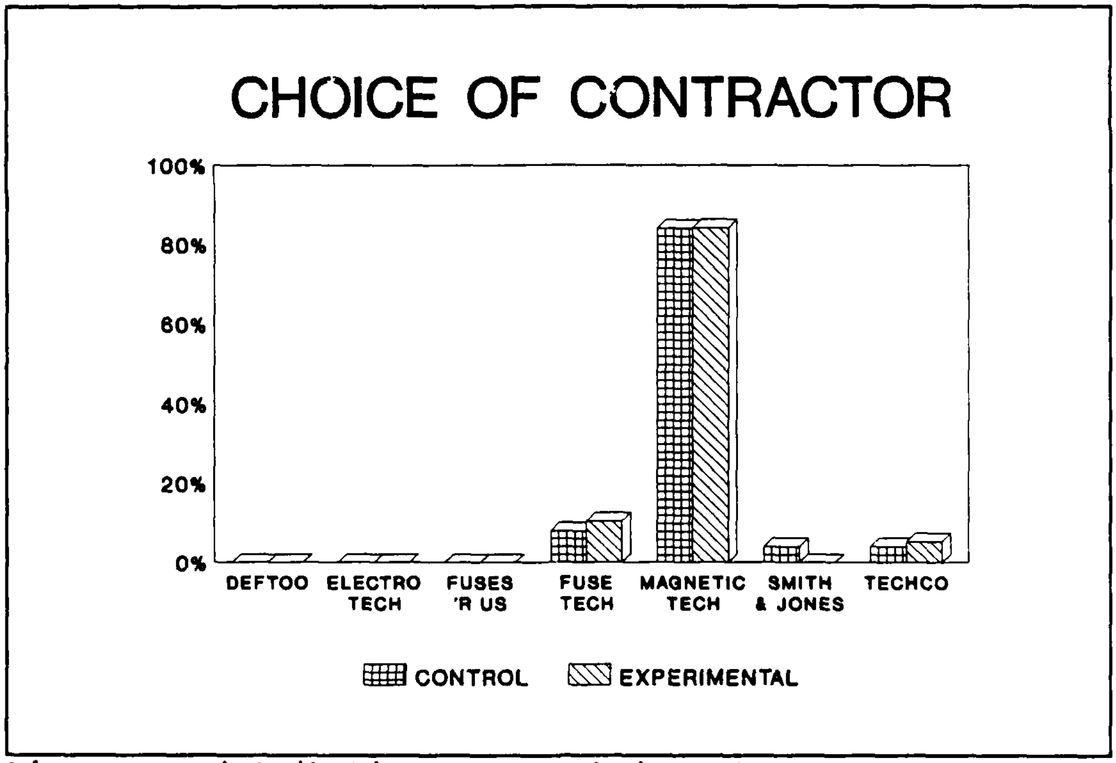


Figure 8 Distribution of the Choice of Contractor

<u>Consistency.</u> This variable was also measured objectively by comparing the distribution of the answers. Figure 8, again, shows that the two groups chose the same alternative with consistency.

<u>Speed.</u> By timing the decision-making process, an objective measure of speed was obtained.

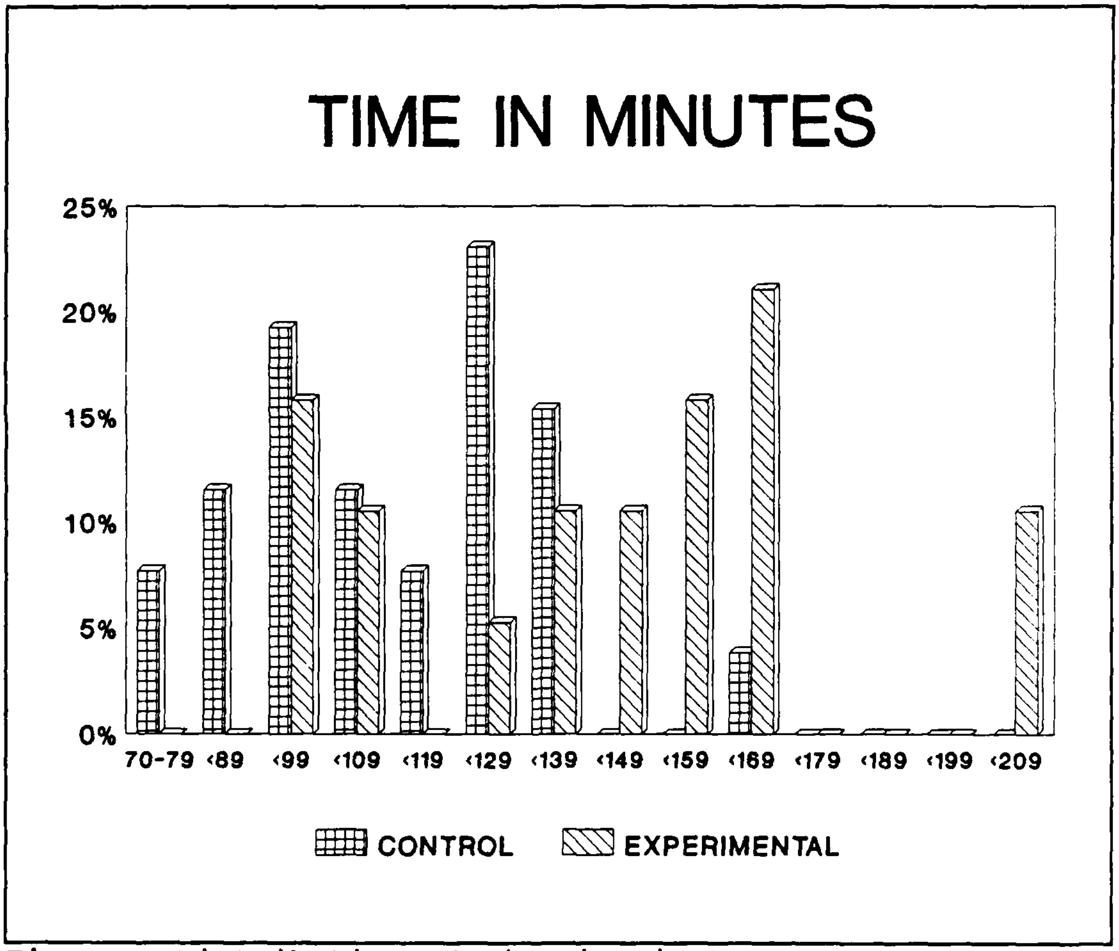


Figure 9 Distribution of Time in Minutes

Figure 10 shows that the control group tended to make quicker decisions than the experimental group. This was, at first, a great surprise to the author; however, some of the answers to the free-form questions yielded an indication that the control group may have satisficed. These free-form questions are discussed later.

Difficulty. The statement "I found the decision-making process easy" was presented to the subjects.

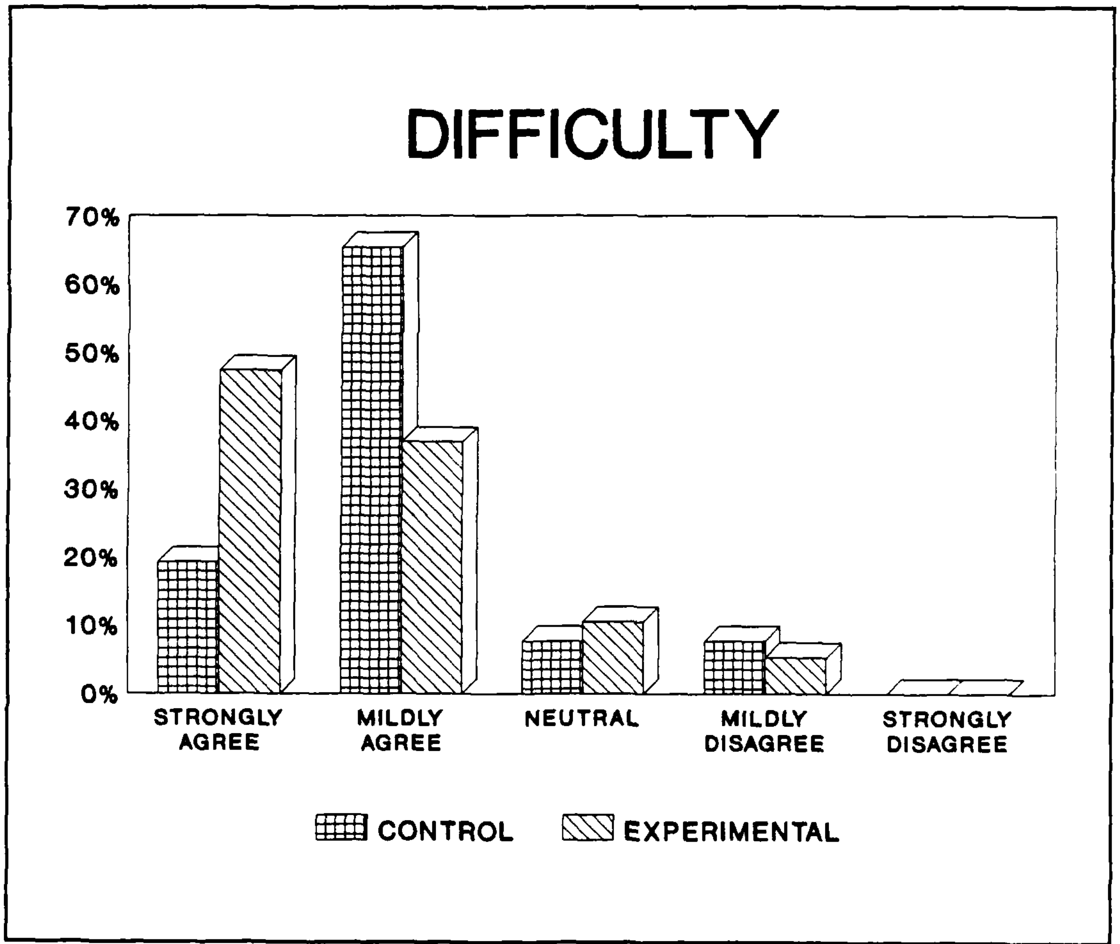


Figure 10 Distribution of the Level of Difficulty

Figure 10 above indicates a difference between the groups. While only 8% of the control group and 5% of the experimental group indicated any disagreement with the statement at all, experimental group members were much stronger in their feelings. This degree of feeling was indicated by the number of "strongly agree" answers. The section below entitled "Hypotheses" contains a correlational analysis investigating this difference. While it was not surprising that the experimental group found the process to be easy, it was surprising that the control group found it so. Again, this may indicate that the control group employed some form of satisficing. This postulate was supported by the free-form questions and will be discussed later.

Understanding. Figure 11 represents understanding.

This variable was measured through the use of a Likert-type scale attached to the following statement "I understood the process by which the contractor was chosen." The majority of the respondents in both groups were bunched at the responses labeled "Strongly Agree" and "Mildly Agree" as seen above in figure 12. There were significantly more "Strongly Agree" answers in the experimental group which indicated an area for further study. A correlational analysis was performed and the results are reported below in

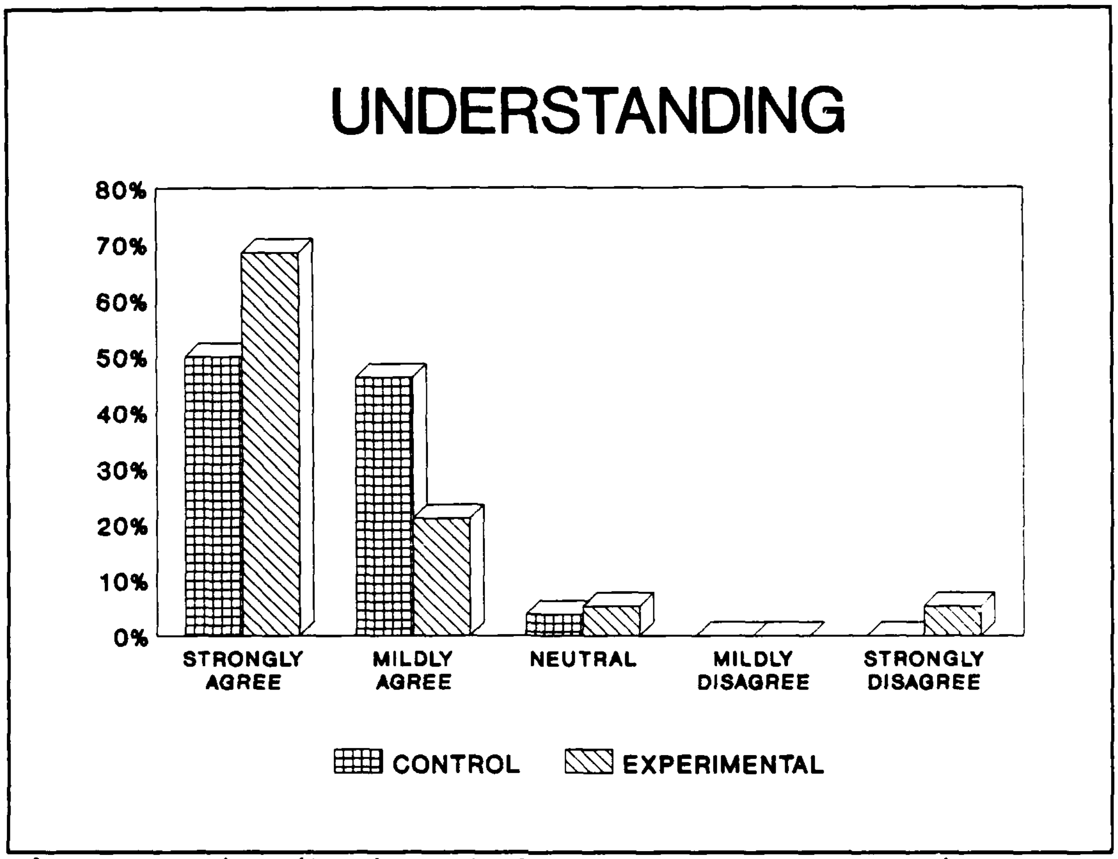


Figure 11 Distribution of the Level of Understanding

the section entitled "Hypotheses." There was one "Strongly Disagree" in the experimental group, but this seemed to be the result of not understanding the computer.

<u>Confidence.</u> This variable was also measured by a Likert-type scale. The statement examined was "I am confident that I made the right decision." As seen in figure 12, there may be a slight difference in the groups indicating a small increase in confidence for the experimental group. This finding was supported by a correlational analysis shown in a later section.

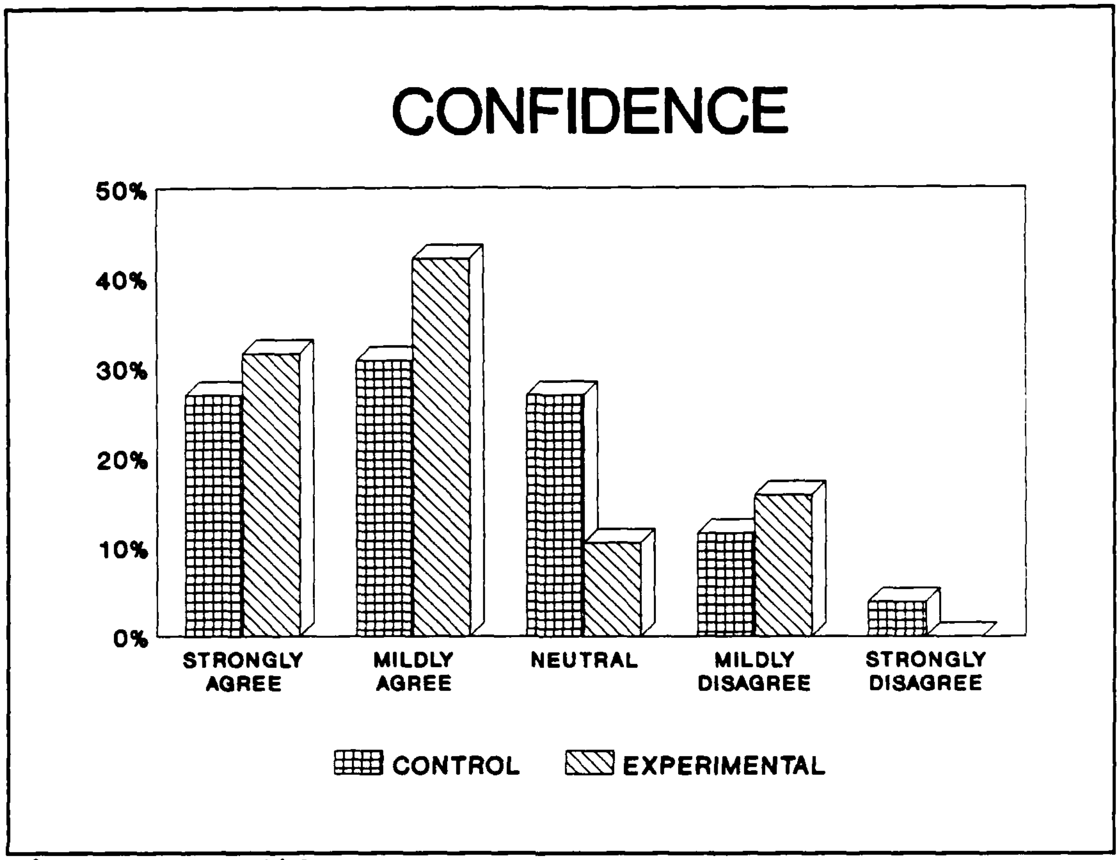


Figure 12 Confidence

There was one interesting finding in this area discovered in the free-form answers. A single respondent from the experimental group reported the computer indicating the correct decision, yet the subject refused to trust the model. The subject changed his decision to an incorrect answer based on a lack of confidence in the model.

Hypotheses

The following are of the implications of the above findings as they relate to the null and research hypotheses proposed in the methodology section. Each hypothesis will be discussed individually. An overall discussion of the findings can be found in the final chapter.

H_{01}: The use of a DSS will have no effect on the effectiveness of the decision-making process.

This null hypothesis cannot be rejected. An examination of the results to the effectiveness measure reveals that there is little or no evidence to support that the experimental group experienced any increase in effectiveness due to the DSS. The percentage of correct answers between the two groups was identical.

H_1: The use of a DSS will increase the effectiveness of the decision-making process.

This research hypothesis must be rejected. There was no difference between the groups.

H_{02}: The use of a DSS will have no effect on the consistency of the decision-making process.

Again, there is no evidence to reject this null hypothesis. The two groups showed an almost identical distribution for consistency purposes. The only inconsistency was that the control group had one individual choose Smith & Jones.

H_2: The use of a DSS will increase the effectiveness of the decision-making process.

Again, this research hypothesis cannot be supported by the results obtained. There was no difference between the two groups in consistency.

H_{03}: The use of a DSS will have no effect on the speed of the decision-making process.

The results of the experiment in figure 9 seem to justify the opposite of what was expected. Certainly, this null hypothesis must be rejected. The control group worked much faster than the experimental group. Some of this discrepancy can be explained because the experimental group was relatively unfamiliar with the software, having received a one-hour indoctrination prior to the experiment. Most of the subjects indicated that if they had been more familiar with the software, they would have worked more quickly. This factor alone may be insufficient to explain the large difference between groups.

H_3: The use of a DSS will increase the speed of the decision-making process.

This research hypothesis was completely negated by the findings. The experimental group, as seen in figure 9, was clearly less speedy than the control group.

H_{04}: The use of a DSS will have no effect on the level of difficulty of the decision-making process.

The results indicate that the experimental group felt more strongly about the ease of the process as indicated by the high percentage of "strongly agree" responses to the "difficulty" question. The null hypothesis is therefor rejected. A correlational analysis was performed on the variable "difficulty" and the use of the DSS. Figure 13 summarizes the results.

COUNT COLUMN %	AGREE	DISAGREE	ROW TOTAL
CONTROL	5 35.7	21 67.7	26 57.8
DSS	9 64.3	10 32.3	19 42.2
COLUMN TOTAL	14 31.1	31 68.9	45 100

GAMMA = -.58

Figure 13 Cross-Tabulation of DSS and Difficulty

As seen, the Gamma value of -.58 indicates moderate to strong correlation between the use of the DSS and how difficult a subject found the process to be. The cross-tabulation shows that of those people responding who agreed that the process was easy, 64.3% were in the experimental group. Only 32.3% of the subjects who disagreed were in the experimental group, for a difference of 32.1%. Clearly, the null hypothesis must be rejected-- a large difference exists between the two groups. This becomes important in light of the evidence that the decisions were accurate with or without the DSS. Certainly, H_{04} is suspect for rejection.

H_4: The use of the DSS will make the decision-making process less difficult.

As discussed above, there is clear evidence to accept this hypothesis. The analysis shows that the experimental group found the process to be less difficult.

H_{05}: The use of a DSS will have no effect on the level of understanding of the decision-making process for the participants.

Nearly all of the respondents in both the control group and the experimental group reported a level of understanding the process; however, the experimental group indicated a stronger feeling. A correlational analysis was performed to investigate this phenomenon.

COUNT COLUMN %	AGREE	DISAGREE	ROW TOTAL
CONTROL	13 52.0	13 65.0	26 57.8
DSS	12 48.0	7 35.0	19 42.2
COLUMN TOTAL	25 55.6	20 44.4	45 100

GAMMA = -.28

Figure 14 Cross-Tabulation of DSS and Understanding

Although Gamma is only -.28, this still indicates a weak to moderate correlation between the use of the DSS and the level of understanding of the subject. However, there is still a clear difference between the groups. When asked whether they understood the process, 65% of the subjects who reported a low understanding were in the control group. Only 35% were in the experimental group.

A single respondent from the experimental group reported "strong disagreement" to the understanding prompt.

That respondent went on to report that the lack of understanding was related to the software, not the decision-making process.

H_5: The use of a DSS will increase the understanding of the decision-making process for the participants.

The difference between the two groups, although less pronounced, is still not to be ignored. These results indicate that the use of the DSS did increase the understanding for the participants.

H_{06}: The use of a DSS will have no effect on decision maker's confidence in his decision.

This is also an area in which tangible differences can be asserted. The experimental group showed more confidence in their decisions than did the control group. 31% of the control group reported "mild agreement" to the confidence measure, but only 27% were willing to report strong agreement. Only 58% report some confidence. In contrast, 32% of the experimental group reported "strong agreement" and 74% reported some form of agreement.

Figure 15 shows the results of a correlational analysis performed on this variable.

Figure 15 indicates that those using the DSS were more confident in their decisions than were the subjects not using the DSS. H_{06} must be rejected.

COUNT COLUMN %	AGREE	DISAGREE	ROW TOTAL
CONTROL	16 53.3	10 66.7	26 57.8
DSS	14 46.7	5 33.3	19 42.2
COLUMN TOTAL	30 66.7	15 33.3	45 100

GAMMA = -.28

Figure 15 Cross-Tabulation of DSS and Confidence

H_6: The use of a DSS will increase the decision-maker's confidence in his decision.

This hypothesis supported by the data. The the experimental group was more confident in its decisions.

Free-Form Data

The following free-form questions were asked of the subjects to gain further insight into the process.

1. If you had had more time could you have made a "better" decision?

There were only two 2 of 26 subjects in the control group who felt that they needed more time. This is not surprising given the speed with which the control group completed the exercise. The experimental group yielded some surprising results. Although the majority of subjects made the correct decision, six out of 19 felt that with more time they could have made a better decision.

2. Would you classify this decision as structured (programmed) or unstructured (non-programmed)?

Over 90% of each group felt that the problem presented was structured. One respondent in each group felt that it was both structured and unstructured and the remaining found it to be unstructured. This finding could explain the lack of difference in the effectiveness between groups. The review of the literature reveals that Decision Support Systems are most suited to semi-structured to unstructured problems. Since the subjects found this to be a highly structured problem, one would expect less of an effect by the DSS in the area of effectiveness. The chapter entitled "Recommendations and Conclusions" examines this thought further.

3. How did you feel about this process?

The distribution below describes the responses to this question. A majority of each group reported either a "relaxed" feeling or a response of "other" that indicated a similar feeling. One subject on the experimental group quit the entire process early indicating extreme frustration with both computers in general and the software package. On the whole, any findings will not be biased by feelings of anxiety within the two groups.

4. Why did you choose this contractor?

In this section, the subjects were given the opportunity to describe the process by which they made the decision. The experimental group all referenced the software package. An examination of the models constructed by the group indicates that the processes were almost all identical. The control group subjects employed some form of satisficing in order to simplify the problem at hand.

The most surprising finding in this area was that all of the control group reported using some variation of Saaty's Analytical Hierarchy Process. While the subjects were unaware of the AHP by name, all reported having split the decision into manageable parts and forming some form of hierarchy. While unexpected, this finding lends great credence to Saaty's claim that the AHP is a good model of the human decision-making process. However, Saaty would undoubtedly argue that the AHP is not a satisficing approach! This will be discussed in more detail later.

V. Conclusions and Recommendations

In the conclusion, a brief recapitulation of the findings detailed in chapter IV will be presented; also conclusions will be drawn as to the import of those findings. Finally, brief suggestions will be made as to areas for further research that were suggested by the findings of this thesis.

Conclusions

The results of the experiment conducted in this research were at first surprising to the author. There was no increase in the effectiveness or consistency of the decision-makers of the group that used the DSS. Theory suggests that the human inclination to satisfice would decrease the effectiveness of those decision-makers not using the DSS. An examination of the data suggests that the control group decision-makers did satisfice in some way while simultaneously employing some form of AHP. The implications of these results could suggest that either 1) perhaps it was too simple to make the "correct" decision (the problem was actually more structured--programmed--than it first appeared), 2) filtering the information before employing optimization techniques is a very effective, albeit satisficing, strategy, or 3) the use of a DSS will not lead to "better" decisions.

The possibility that the experiment was too simple may not be solvable at this level of research. The mere act of writing the case study lended a structure to the problem that may not be there in the real world. Theory suggests that structure simplifies the decision-making process.

If filtering information before using optimization techniques is a very effective strategy, then that is an important finding in and of itself and therefor warrants further investigation.

The possibility that the use of a DSS may not lead to "better" decisions was examined by Todd and Adams in a paper presented to the Ninth International Conference on Decision Support Systems. They challenge the notion that the use of a DSS will lead to more effective decision-making. In their paper, they discuss the Prospect Theory (Kahneman and Tversky) and the Cost-Benefit theory.

The Prospect Theory suggests that the decision-making process does not stay constant across subjects thus suggesting little or no control by the decision-maker. The Prospect Theory is described as:

> an example of a perceptual model of decision behavior. It argues that, in situations that involve making risky decisions, people use strategies that are inconsistent with normative models. Specifically, Kahneman and Tversky identify two classes of aberrations termed the

certainty effect and the isolation effect. The certainty effect results in decision makers underweighting outcomes that are simply probable when compared to those that are certain. The certainty effect causes problems that are framed as gains to be approached in a risk averse fashion, while those that are framed as losses are viewed in a risk seeking mode. The isolation effect causes common characteristics of problem solutions to be discarded before a selection is made. Both of these effects lead decision makers to different solutions based upon the framing of a particular problem (Todd and Adams, 1989:208).

Todd and Adams go on to conclude:

> The implication of the Prospect Theory is that very little progress is likely to be made in terms of aiding and assisting decision making. If individuals do not have conscious control over the mechanisms which they use during problem solving, then no amount of training or assistance will facilitate the improvement of decision making. Decision behavior may be manipulated in this case by a conscious framing of the problem to invoke certain processes from the decision maker, but after that point, support tools may be of little use (Todd and Adams, 1989:209).

Both the AHP of Saaty and DSS theory support this idea; a conscious framing of the problem will lead to benefits.

The Cost-Benefit Theory suggests that the decision-maker weighs the relative effort required to implement decisions and then chooses an acceptable route with the least expenditure of resources. Todd and Adams describe the theory:

> Decision makers presumably contrast the amount of cognitive effort required to implement a particular strategy with the expected benefits associated with the particular strategy. The benefits of the various approaches are typically measured as the likelihood of that approach

> leading to a good decision or an accurate response (Payne 1982). Given values for cognitive effort and decision accuracy, a trade-off is made. The assumption is that, ideally, decision makers would like to maximize the quality of their decisions while at the same time minimizing cognitive effort. However, to the extent that these two objectives are typically conflicting, some form of compromise is required (Johnson and Payne 1985). In terms of DSS research, the key message of Cost-Benefit Theory is that decision maker behavior cannot simply be viewed as being quality oriented. Thinking is hard and as a result effort may be an important determinant of DSS use (Todd and Adams, 1989:209.

From this Todd and Adams suggest:

> If a decision aid were to automate a series of strategies, reducing the cognitive effort for each but maintaining their relative degree of difficulty or strain, we would anticipate that the decision maker would continue to utilize the same strategy as used in the unaided environment. For a decision aid to induce change in this case, it must alter the effort rankings or relationship between various strategies. Consequently, in a decision aided environment, which equally supports all strategies and not changing the effort relationships between them, there would be no strategy shift (Todd and Adams, 1989:211).

Todd and Adams conclude by suggesting that the thrust of DSS research should be directed towards the relationships between various strategies rather than decision quality (Todd and Adams, 1989:212). The results of this research seem to support the theories of Todd and Adams: there was no increase in the quality (in terms of effectiveness and consistency) of the decisions due to the DSS.

A second important finding of this research was that the use of the DSS took more time than unaided decision-making. This suggests that in the absence of any positive effects, the use of a DSS would be a waste of resources. However, the response to some questions revealed that the increased time may be attributable to learning the system. Also, the initial investment of time required to learn the DSS is analogous to the "gear up" time in implementing any new and automated system. Todd and Adams (as seen above) postulate that the decision maker must see a noticeable difference in the effort expended in order to make this commitment. However, after an initial loss of resources, the benefits should be reaped.

Summarizing the positive effects of the DSS indicated by the research, there was a positive correlation between the use of the DSS and how "easy" the decision-maker found the process. A positive correlation was also observed for the confidence of the decision-maker in his own decision and with his understanding of the decision making process when the DSS was used. All of these results suggest areas for further development of the DSS concept. In the Air Force environment where the decision-maker is constantly required to explain and "sell" his decision to superiors, the increase in confidence and understanding of the process could be invaluable assets.

A final intriguing finding of this research is that all of the control group appeared to use the Analytical Hierarchy Process in some form or another. This would, at first glance, seem to support Saaty's contention that the AHP is innate to humans in the decision-making arena. However, further examination of the data yielded that the control group used the AHP to satisfice! All of the subjects used some method to reduce or discount the extraneous information. The AHP was designed as a method to induce optimization when making complex, unstructured decisions. As suggested by the review of the literature, there is a "bounded rationality" exercised by the human mind (Simon and Others). Perhaps the AHP is the innate model used by the human mind to exercise bounded rationality when presented with overly complex scenarios. Further, in less complex situations, the "right" answer can apparently be derived without the use of computer-assisted DSS, even though AHP is being employed.

Recommendations

Further research is certainly warranted in the area of decision-making aids. Some recommendations for further study are as follows:

-- Conduct similar research allowing for the time required to learn the DSS.

-- Conduct similar research with a more complex scenario.

-- Conduct field (action) research with a real-world organization dealing with nonprogrammed decisions.

-- Conduct research designed to examine the greater confidence and understanding of those subjects who used the DSS. If this confidence and understanding can be passed on to higher levels of review, then the use of the DSS would have an overall positive effect on the source selection process as well as on further complex decisions.

-- Conduct research into the AHP and its possible uses as a satisficing or bounded rationality strategy.

-- Conduct research aimed at affecting the effort relationships among strategies (rather than decision quality) as suggested by Todd and Adams.

This research revealed positive effects associated with using computer-aided decision support systems. It also revealed a lack of effect on decision quality when facing a semi-structured problem. Clearly, more research is needed into this vital area of emerging technology.

Appendix A: Case Study and Survey

The following is a case study designed to test your ability to make decisions. The decision at hand is that of a government source selection. You will be presented with the situation, the government technical evaluation, the government cost evaluation, the government management evaluation and a list of the issues that the government feels are important to the decision. You will then be asked to make a decision as to which of the involved contractors "best" meet the criteria that the government has deemed important in this situation.

Please do not discuss this decision with anyone else in your group. Also, do not discuss the method by which you intend to make your decision with anyone else.

There is a short survey that you are asked to complete at the end of the exercise. Please be as honest as you can in the completion of the survey. ALTHOUGH THERE IS A "SCHOOL" ANSWER, THIS IS NOT A "GRADED" EXERCISE.

You must complete the questionnaire in its entirety before you leave the exercise. You will not be allowed to leave until that time.

GOOD LUCK!

NAME: ____________________________

On May 23 198X, the lab at Anywhere AFB released a request for proposals for their magnetic fuse program. Response to the RFP was encouraging. The following contractors submitted proposals (in alphabetical order):

a. Deftoo Ltd.

b. Electro Tech

c. Fuses 'R Us

d. Fusetech Inc.

e. Magnetic Technologies Inc.

f. Smith & Jones Co.

g. TECHCO

An initial evaluation was performed and all offerors were considered to have a reasonable chance to receive the award. You are provided in the following:

a. a list of the evaluation criteria and their relative importance.

b. the government technical evaluation

c. the government management evaluation

d. the government cost evaluation

With this information the final decision must be made as to who will build the Magnetic Fuse for Anywhere AFB. Keep in mind that the evaluation criteria that you have are those that were published in the RFP and must be adhered to. A decision not based on these criteria will most likely be protested resulting in unacceptable lost time and money for the government.

You as the decision-maker must choose amongst the competing contractors. . .

1. EVALUATION CRITERIA

a. General Considerations

Proposals will be evaluated on a subjective basis for their conformance with the terms and conditions of the solicitation.

b. General Basis for Contract Award

(1) The Government contemplates awarding one (1) contract to the offeror whom the Government determines can accomplish the requirements set forth in this RFP in a manner most advantageous to the Government. The Government reserves the right to make no awards at all. The Government also reserves the right to award a contract at other than the lowest price after consideration of all factors.

(2) This is a technical competition with cost and management considered subordinate. Offerors are encouraged, however, to perform technical-cost tradeoffs to achieve a balance where the proposed cost must be entirely compatible with the technical and management proposals. No advantage will accrue to an offeror who submits an unrealistically low cost proposal. Accordingly, the offeror's proposal may be penalized during the evaluation to the degree that the estimated cost is unrealistically low.

(3) An alternate proposal will be evaluated in the same manner as a proposal that meets the stated basic proposal requirements or the stated evaluation criteria herein and in accordance with the Section L provision entitled, "Alternate Proposals."

c. Specific Areas of Evaluation

(1) The specific areas of evaluation shown in descending order of importance are as follows:

(a) Technical - is considered one and one half times as important as management or cost/price.

(b) Management - is considered equal to cost/price.

(c) Cost/Price - is considered equal to management.

(2) Technical Area: The items and factors to be evaluated in this area are listed below. The items listed

below are of equal importance. The order of importance of the factors within each item is addressed at the item level.

(a) <u>Soundness of Approach:</u> The Offeror's proposal shall include an outline of the main problem areas and the general approach used to solve these problems. An evaluation of the various methods considered should be presented including specific experience in using these methods and justifications of the method selected. The evaluation factors are listed below and are equally weighted.

<u>1.</u> Approach to defining target signatures.

<u>2.</u> Approach to enhancement of signal-to-noise ratio.

<u>3.</u> Approach to signal processing.

(b) <u>Understanding the Problem:</u> The proposal must clearly show that the offeror recognizes all the technical requirements, scope, and unique problems associated with this program. Unclear, inconsistent,, and incomplete technical information will be interpreted as a lack of understanding on the proposer's part. The following evaluation factors are weighted equally.

<u>1.</u> Plating and coating of fibers and/or magnetostrictive fibers.

<u>2.</u> Mine applications

(c) <u>Compliance with Requirements:</u> A response to each specific requirement in the statement of work will be evaluated. Any interpretations, deviations, and exceptions shall be clearly stated. The offeror should describe how he proposes to comply wit requirements. The evaluation factors listed below are equally weighted:

<u>1.</u> Schedule

<u>2.</u> Laboratory tests

<u>3.</u> Field test support

(d) Special Technical Factors: The offeror's proposal should be responsive to the factors listed below. They are equally weighted.

1. Growth options

2. Specific experience

(3) Management Area: The items to be evaluated in this area are listed in descending order of importance. The order of importance of the factors, if any, within each item is addressed at the item level.

(a) The management proposal for the program must be complete and describe procedures for identification, documentation, and control during design, programming, test and validation phases of the program.

(b) The program's master planning schedule must be complete, reasonable, identify each task and clearly integrate all facets of the proposed program.

(c) The organization structure should show lines of authority/responsibility and communication within the company. The program manager's position in the organization must be clearly established and indicate he has the authority and responsibility to successfully accomplish the project. All subcontractors must be identified and the scope of their responsibility defined.

(4) Cost Area: The offeror's cost proposal will not be rated or scored, but will be reviewed for reasonableness, realism, completeness, and continuity. Direct material and direct labor hours are of equal importance, and are considered twice as important as travel and other direct costs.

(a) Direct Material: The contractor's proposal will be reviewed to determine the reasonableness of the bill of materials. The completeness and detail of the list will be examined.

(b) Direct Labor Hours and Labor Mix: The total hours proposed and the mix of skilled labor will be examined in detail. Salaries will be verified through audits.

(c) Travel: Travel, if any, will be reviewed for the necessity of the trips and the costs involved.

(d) Other Direct Costs: It is conceivable that the contractor will require ODCs. The nature and explanation of these costs will be reviewed for appropriateness.

Results of Technical Proposal Evaluation, Magnetic Fuse

1. The technical proposals received on the subject RFP have been evaluated.

2. The following firms submitted proposals that are acceptable on a technical basis and are recommended for consideration.

3. Discussion of proposals which are acceptable.

a. Deftoo Ltd.

(1) Soundness of Approach. Deftoo Ltd.'s approach is based on requirements and preliminary design resulting from previous programs as well as a consideration of trade-offs. They realize the Mach-Zehnder configuration as being well suited for high sensitivity field sensing. Refer to Target Activated Munitions Sensors programs and reports for high signature analysis expertise. Various techniques for maximizing the signal-to-noise ratio are discussed with an active interferometer scheme being chosen. All approaches examined are considered to exceed government standards. For this purpose, Deftoo Ltd. proposes to experiment with various signal processing and analysis techniques during laboratory and field tests.

(2) Understanding the Problem. The proposal shows a very god understanding of the performance and design requirements for the overall MF. Their continuous fiber plating technology is optimized. Deftoo Ltd. indicates current work in various fiber optic sensor developments. The proposal shows a full understanding of the issues for mine applications.

(3) Compliance with Requirements. The contractor shows an acceptable program schedule. Laboratory and field tests are not specifically defined, but parameters to be characterized and general vehicle types are not noted. This is considered a weakness.

(4) Special Technical Factors. While their fiber plating technology and magnetic knowledge allows for practical, easy-to-fabricate, magnetic fuse design, growth potential is limited. The contractor has a production plating systems which provides continuous automated processes for making the sensor. This indicates an adequate experience level.

b. Electro Tech

(1) Soundness of Approach. Electro Tech proposes to develop a magnetometer based on the standard Mach-Zehnder technique outlined in the many trade journals. This fiber optic interferometer technique is based on the demonstrated principle that if one branch of a two branch fiber bundle is coated with magnetostriction material or glued to a bulk material such as metglas, then a magnetic disturbance will result in an optical fringe pattern which is readily detected. Electro Tech proposes to glue the fiber to metglas. This technique does not appear to offer advantages of the other techniques due to stability problems and the potentiality of high background noise; however, since the optical wavelength is very small (.8 - .9 micron) and the fibers can be made very long in terms of wavelength, the device can be extremely sensitive. Also, the "cook book" approach prepared by Electro Tech does not reflect any innovative ideas as to improvements in the selections of fiber/coatings, signal processing techniques, or signal-to-noise ratio enhancements.

(2) Understanding the Problem. Electro Tech demonstrated an understanding of the problem by presenting a straight forward approach. Questionably, Electro Tech avoided the issue of fiber plating by proposing to glue sensor fibers directly to metglas. The sensitivity of this technique may be less than plating fibers with a magnetostriction material such as nickel. Electro Tech's proposal did not indicate the in-house fabrication of a breadboard which would have provided data as to the sensitivity of Electro Tech's Metglas concept. It appears that Electro Tech's approach explored the use of acceptable optical sensor technology. No reference to mine applications was made.

(3) Compliance With Requirements. The proposal indicated compliance with requirements except for the requirement that the sensor have a frequency response from DC to 5000 Hz. The contractor states that the lowest frequency of sensor operation is fixed by the relative velocity of the target and does not necessarily extend down to DC in an absolute sense. The contractor seemed to be hedging on meeting this requirement. This indicates a weak preliminary laboratory test schedule. No field tests were indicated.

(4) Special Technical Factors. The contractor is weakest in the growth options and specific experience factors. Although the SOW does not require that the sensor determine range and angle to target, Electro Tech appeared to unnecessarily exclude considerations of the sensor's long term ability to measure target range and bearing. The sensor may, therefore, not have as high a potential for growth. The proposal did not reflect any specific experience in the fabrication and testing of magnetic fuses.

c. Fuses 'R Us

(1) Soundness of Approach. Fuses 'R Us proposes to use their Mach-Zehnder interferometer. One leg of the interferometer is a reference path and the other is immersed in a ferrofluid bath. By choosing a ferrofluidic bath as the sensing medium, the long term stability, and therefore, successful implementation of the sensor in the field is questionable. With this approach signal processing and target signature definition is hampered.

(2) Understanding the Problem. Fuses 'R Us demonstrated an understanding of the problem by recognizing several potential techniques for a demodulation scheme. They proposed a detailed investigation of the approaches as part of the program. For mine applications, Fuses'R Us will use a battery that is adequate for a 30-day remote operation in the pulsed mode. The action of coating the reference fiber with nickel is questionable. It may invalidate the sensor since both the "reference" and sensing fibers would then react to magnetic field fluctuation.

(3) Compliance with Requirements. The contractor proposes to meet all requirements set forth in the RFP without exception. Fuses 'R Us expects to complete the program in 20 months. Special test equipment may need to be purchased to conduct such tests as immunity of RFI and EMI interference. These are necessary to complete both lab and field tests.

(4) Special Technical Factors. The contractor did not evidence any specific experience with magnetic sensors other than an interferometer. Also, this type of sensing scheme appears to limit the growth options of the sensor. Fuses'R Us proposal contains an innovative approach. However, because of the unknowns stated above which appear inherent in this approach, we feel that unless they can be satisfactorily resolved prior to award, the risk to pursue this approach would be unacceptably high.

d. Fusetech Inc.

(1) Soundness of Approach. Fusetech Inc. has proposed an outstanding approach to solving the problems of the magnetic fuse. The resultant design provides for operation at the point of maximum sensitivity, permits the use of a permanent magnet bias, and is extremely rugged. It proposes maximizing the signal-to-noise ratio by use of a very unique low noise interferometer developed at Fusetech Inc. by using divided Fabry-Perot fiber optic cells, common-mode rejection, matched path lengths and a multimode laser source. To define target signatures Fusetech Inc. proposes to perform a comprehensive search of classified target characteristic literature. This is considered an excellent approach. This approach will lead to highly efficient signal processing.

(2) Understanding the Problem. The contractor shows an excellent understanding of the desired performance and requirements of Magnetic Fuse (MF). For example, they recognize that phase modulation represents the most sensitive approach to plating and coating. In mine applications, they propose to use the MF to isolate nearby targets and determine the point of nearest approach in order to detonate the mine at the optimum point.

(3) Compliance with Requirements. The contractor proposes to comply with all requirements of the RFP. The proposal includes an excellent breakdown of what will be done on the various levels of testing to verify compliance with requirements. Results of the preliminary experiments, to insure proper selection of the fiber coating alloy material, will be thoroughly reviewed with sponsor before selection is made. Additional experiments will then be conducted as they become appropriate. Fusetech Inc. has their own staff of experienced laboratory and field test personnel. This experienced laboratory and field test capability will significantly reduce program risk by early discovery of potential design deficiencies.

(4) Special Technical Factors. The contractor states that the sensor has considerable growth potential in that with only sensor modification, the sensor cold be used in a multi-influence sensor. Active homodyning detection will be employed in order to provide the maximum dynamic range. Exclusive of the power source, the proposed sensor is compatible with the volume requirement. The contractor has exceptional experience in optical research with Navy and Health Institute applications.

e. Magnetic Technologies Inc.

(1) Soundness of Approach. Magnetic Technologies Inc. proposes a fiber optic magnetic sensor utilizing a stabilized laser diode source, a Mach-Zehnder interferometer, and single mode, polarity preserving optical fibers. Their approach is straight forward and adequately details the necessary tasks needed for defining target signatures and signal processing techniques to enhance the signal-to-noise ratio.

(2) Understanding the Problem. The contractor's approach demonstrated a thorough understanding of the tasks unique to this program. Magnetic Technologies Inc. is competent in the area of coating systems and procedures for sputter and vapor phase deposition. Sputtering generally promotes excellent interfacial cohesion and is often preferred when feasible. Magnetic Technologies Inc. proposes to run sputter depositions of both pure nickel and iron-nickel-cobalt alloys, which may prove to offer advantages over use of pure nickel. Such coatings are generally superior to electroplated films and should provide much better magnetostrictive behavior. Magnetic Technologies Inc. prefers sputtering to electroplating. The prospect of using metglas ribbon was ruled out because it might interfere with transducer design and fabrication. Magnetic Technologies Inc. has prior knowledge and experience with mine applications through endeavors in the Wide Area Side Penetrating (WASPM) off-route mine for target classification from vehicular acoustic emissions. Magnetic Technologies Inc.'s proposal reflects that the company has made substantial efforts to expand their technical capabilities to enable them to completely develop magnetic field sensing mines as well. There are signal processing similarities involved in both tasks in order that target signatures be defined and identified. Furthermore, the design and fabrication of military qualified hardware entails planning, standards, and field testing which will not be new to Magnetic Technologies Inc. Magnetic Technologies Inc. has had a significant amount of experience in the area of fiber optic devices and mine applications.

(3) Compliance with Requirements. The contractor proposes to accomplish all requirements of the RFP. The general design is an magnetic sensor with a stabilized laser diode source, Mach-Zehnder interferometer and detector/signal processor. Magnetic Technologies Inc. have their own highly skilled laboratories, field tests equipment and personnel.

(4) Special Technical Factors. The contractor has proposed an innovative concept for coating and sputtering the fibers in their final configuration which greatly enhances the practicality and affordability of the sensors without degrading the growth potential. The contractor lacks specific experience with fiber optic magnetic sensors, but has the experience with other sensors and signal processing techniques necessary for a successful program.

f. Smith & Jones Co.

(1) Soundness of Approach. This proposal is based on mechanical interfacing of magnetostrictive metal alloys to single mode optical fibers. Optical mixing is accomplished by use of a Mach-Zehnder interferometer in a simple arrangement with a polarimeter. The proposal considers all appropriate types of fiber and coating materials, including high birefringent fibers and metglas nickel or deposited nickel subjected to magnetic field annealing cycle. Target signatures will be defined primarily by doing field tests at Anywhere AFB, but the contractor emphasizes the use of field tests to determine or demonstrate the effective sensing range against the moving targets and not the ability to discriminate between them. Signal-to-noise ratio is maximized through consideration of optimization of total fiber length depending upon shot noise introduced and its effects upon sensitivity for various lengths of fiber. It has been determined that the 0.1 gamma requirement can be achieved given the maximum laser noise which is known and their capabilities to adjust circuit design parameters. Approach to signal processing is still questionable because the proposal doesn't specifically address the means by which identification and definition of various target signatures will be accomplished other than through interaction with Anywhere AFB following preliminary field tests.

(2) Understanding the Problem. The proposal identifies no exception to the SOW requirements. The contractor fully understands the need to optimize process parameters to fabricate sensor fiber sensor fiber which exhibits the desired magnetostrictive behavior. Plating is not addressed; yet vapor deposition, sputtering, and adhesion to metglas are, and these are of primary importance since they facilitate better control magnetostrictive material thickness. The contractor is quite knowledgeable of mine technology capable of integrating sensor technology in general, capable of integrating the various components

including the piezoelectric compensator, beam splitter/polarizer, dither coil and diodes, as well as in the design and fabrication of the magnetostrictive transducer.

(3) <u>Compliance with Requirements.</u> The contractor shows an ambitious compliance with the schedule proposing that the first three tasks be accelerated relative to RFP schedule. This is considered optimal. Judging from the technical content of the proposal, one may conclude that there is a good likelihood of the contractor meeting the schedule provided Anywhere AFB personnel manage to push for timely field testing so that a few design iterations may be facilitated. It is apparent that the preliminary designs will serve a purpose for the first trials; their Mach-Zehnder interferometer meets the standard for comparison. Laboratory testing capabilities appear to be quite adequate and they have the necessary technical expertise to structure an adequate testing program. Breadboard design and fabrication are adequate except that redesign and reconfiguration may have to be performed in order to satisfy the 25 cm^3 maximum volume requirement. Batteries are not self-contained according to the breakdown of all the elements included. Field test support was only weakly defined in the proposal.

(4) <u>Special Technical Factors.</u> This contractor exhibits prior and on going experience with both the Navy and the Army to develop a ruggedized fiber optic magnetometer. The growth potential is limited to the possible incorporation of a miniaturized, multi-sensor array into munitions for identification of specific targets. Practicality of the proposed magnetometer appears to be adequate based upon the technical considerations addressed.

g. TECHCO

(1) <u>Soundness of Approach.</u> The contractor proposed the Mach-Zehnder interferometer approach for MF design. The contractor has done an exceptionally thorough job in comparing fiber coatings and, finally, choosing amorphous metals as the materials of choice for design of MF. To define target signatures, environmental magnetic noise will be studied. Signal processing will be conducted by device signature study to determine the best method for detection and threshold. The data will be correlated using multi-sensor inputs. All of these approaches are soundly based in Magnetic Fuse Theory.

(2) Understanding the Problem. The contractor assumes a simple total field magnetomer is the current desirable configuration, while considering such options as multiaxis sensor and magnetic gradient devices. Mine applications of this approach are extremely limited.

(3) Compliance with Requirements. The proposal presents general considerations and a brief description of each test to be carried out. Scheduling of the tests and program are acceptable.

(4) Special Technical Factors. The approach to place priorities on achievement of reliable magnetic field measurements and data acquisition, rather than on real time signal processing functions, improves the evaluation of magnetic sensor feasibility and allows for feature design evaluation. Growth potential is high. Specific experience needed to carry out this program is adequate. No further test facilities are necessary.

Management Evaluation

a. Deftoo Ltd.

Deftoo Ltd. did not submit a management proposal. They addressed management in their technical discussion, yet only as an after thought. All aspects of their "management" must be considered suspect.

b. Electro Tech

Electro Tech did not address management. This must be considered unacceptable.

c. Fuses 'R Us

The management proposal for Fuses 'R Us must be considered outstanding. It is clear that much thought was given to the organization of the program. The master plan must be given the highest marks.

d. Fusetech Inc.

Fusetech Inc. presents only a rudimentary management proposal. Documentation and control of the program are not addressed. The master planning schedule is good, but incomplete. The organizational structure is well defined.

e. Magnetic Technologies Inc.

Magnetic Technologies Inc. proposed a good, sound procedure to track and document the program. Lines of authority are clearly defined. The master planning schedule was adequate but could be improved.

f. Smith & Jones Co.

An excellent approach to documentation and control was proposed. The master planning schedule was outstanding, however with two lead scientists the organizational structure seems questionable.

g. TECHCO

The management scheme of TECHCO is considered to be optimal. All areas of control and documentation are addressed. The organizational structure is clearly defined. An excellent "road map" of the program is prescribed in the master planning schedule.

Cost Proposal Evaluation

1. The seven cost proposals in response to the subject RFP have been evaluated. The evaluations are given below with discussions.

a. Deftoo Ltd.

(1) Direct Material: The direct materials estimate is very high. Questionable costs are for fibers and for miscellaneous electronics hardware and signal processing electronics.

(2) Direct Labor Hours and Labor Mix: The total hours estimate of 2374 appears to be low. The hourly rates are reasonable. Only four labor categories work on this project with a student aide doing 740 hours of the work and a level II profe sional doing 814 hours. This is approximately 60% of the wo k effort which is not acceptable.

(3) Travel: Deftoo Ltd. proposes money for travel but identifies no details. A minimum of two trips to Anywhere AFB would be required. The dollar amount proposed for these trips is reasonable.

(4) Other Direct Costs: Other costs include sales and technical and defense systems. The contractor did not identify what these are. This amount appears to be excessive.

b. Electro Tech

(1) Direct Material: The list of required materials was not provided. They also show no cost for material. This is unacceptable.

(2) Direct Labor Hours and Labor Mix: The total number of man-hours proposed, 4680, as well as the hour breakout by task and labor category are considered reasonable and acceptable to accomplish the technical tasks proposed.

(3) Travel: The contractor identified four travel requirements but gave no details. The most costly trip is one listed under task six for field test. Though the proposed trip is necessary the cost seems unreasonable.

(4) Other Direct Costs: Other direct costs were not addressed in this proposal. This is unacceptable.

c. Fuses 'R Us

(1) Direct Material: The list of required materials is presented in detail but is considered high. The quantity listed for some items is high. The quantities are considered unacceptable.

(2) Direct Labor Hours and Labor Mix: The proposed 4617 hours of direct labor is considered reasonable. The senior project engineer man-hours represent approximately one-half of the total hours which appear to be a reasonable mix.

(3) Travel: None. This is not acceptable.

(4) Other Direct Costs: Cost of a Burroughs computer rental at $125/hour was noted in the general discussion but not listed on the cost breakout. No other costs were addressed. This was considered reasonable.

d. Fusetech Inc.

(1) Direct Material: The direct material estimate is high. The list of required materials is presented in detail and is considered acceptable.

(2) Direct Labor Hours and Labor Mix: The total hours estimate of 1320 man-days (10,560 hours) proposed is high. The man-day breakout by task and labor category is unreasonable and not acceptable to accomplish the technical tasks. It contains too many hours and too many people allotted to trivial tasks. Salary rates and time for labor categories could be cut from 1/3 to 1/2 with some of the categories, data taker, jr physicist, and order processor, eliminated completely.

(3) Travel: Five trips to Anywhere AFB for sponsor reviews are proposed. Two are considered adequate.

(4) Other Direct Costs: The contractor proposes other direct costs. As there is no back-up for these costs, they must be considered high.

e. Magnetic Technologies Inc.

(1) Direct Material: The direct material costs seems reasonable. The major cost items are for material

(tooling and fixtures, 20), six optical splitters and a transducer.

(2) Direct Labor Hours and Labor Mix: The total hours estimate of 5094 is very reasonable with engineers doing 2752 hours of the total work. The other hours are divided between 16 other categories of work. Descriptions of each category are provided. The burden rate is very reasonable.

(3) Travel: The proposed travel includes two trips to Anywhere AFB. This is considered optimal.

(4) Other Direct Costs: Additional costs were proposed for reproduction and photographs. Excellent rationale is provided.

f. Smith & Jones Co.

(1) Direct Material: The estimate is high. The cost for electrical and mechanical fabrication and packaging alone is unreasonable.

(2) Direct Labor Hours and Labor Mix: The total hours of 5936 is somewhat high for the 7 labor categories provided. Labor categories such as senior scientist I, II, and III seem excessive.

(3) Travel: Smith & Jones Co. proposes nine trips - five to Washington D.C. and four to Anywhere AFB, all for technical discussions. No explanation was given for the trips to Washington D.C. These are unnecessary.

(4) Other Direct Costs: Other costs are high and include money for publication. The other money is included in the task breakout, but is not defined. This appears to be high.

g. TECHCO

(1) Direct Material: The direct materials cost was high with their choice of two laser diodes costing in excess of estimates. There is a list of required materials, and it is considered high.

(2) Direct Labor Hours and Labor Mix: The total hours estimate of 4,432 is reasonable. The total direct labor cost is reasonable. The labor mix is high on unskilled labor.

(3) Travel: Travel costs include seven trips to Anywhere AFB. Reasons supporting the trips were not included. Seven trips to Anywhere AFB seem unreasonable.

(4) Other Direct Costs: Other direct costs are for reprographics. This is reasonable and includes all reports and drawings.

Please answer the following questions:

1. What is the highest level of education that you have completed?

1	HIGH SCHOOL	3	SOME COLLEGE (1-3 YRS)
2	VOCATIONAL/TECHNICAL SCHOOL	4	COLLEGE GRADUATE
5	SOME POST-GRADUATE OR PROFESSIONAL		
6	POST-GRADUATE OR PROFESSIONAL DEGREE		

2. What was your <u>major</u> field/area of study for your <u>highest</u> level of education? (ANSWER EVEN IF YOU DID NOT RECEIVE THE DEGREE OR COMPLETE THE PROGRAM)

1	BUSINESS	4	ENGINEERING
2	LAW	5	PUBLIC ADMINISTRATION
3	LIBERAL ARTS	6	OTHER ________________

3. How many formal acquisition-related training courses have you taken since the beginning of your career? (Circle the number of your answer)

1	NONE	3	4 - 6	5	11 OR MORE
2	1 - 3	4	7 - 10		

4. How many courses have you taken in your expertise or related disciplines?

5. How many years of experience in your present career field do you have?

1	LESS THAN ONE YEAR	4	3 YEARS
2	1 YEAR	5	4 YEARS
3	2 YEARS	6	5 YEARS AND OVER

6. Please indicate whether you have been designated as one or more of the following:

1 CERTIFIED PROFESSIONAL CONTRACTS MANAGER

2 CERTIFIED ASSOCIATE CONTRACTS MANAGER

3 CERTIFIED PURCHASING MANAGER

4 OTHER ___________________________

5 NOT CERTIFIED.

7. Time Finished _______________________.

8. Which Contractor did you choose?

____

9. Why did you choose this contractor? (Please use the back of this page if you require additional space.)

10. If you had had more time, could you have made a "better" decision?

11. Would you classify this decision as structured (programmed) or unstructured (non-programmed)?

____

How strongly do you agree/disagree with the following statements?

12. I understood the process by which the correct contractor was to be chosen.

1		2		3		4		5	
	STRONGLY AGREE		MILDLY AGREE		NEUTRAL		MILDLY DISAGREE		STRONGLY DISAGREE

13. I found the decision-making process easy.

1		2		3		4		5	
	STRONGLY AGREE		MILDLY AGREE		NEUTRAL		MILDLY DISAGREE		STRONGLY DISAGREE

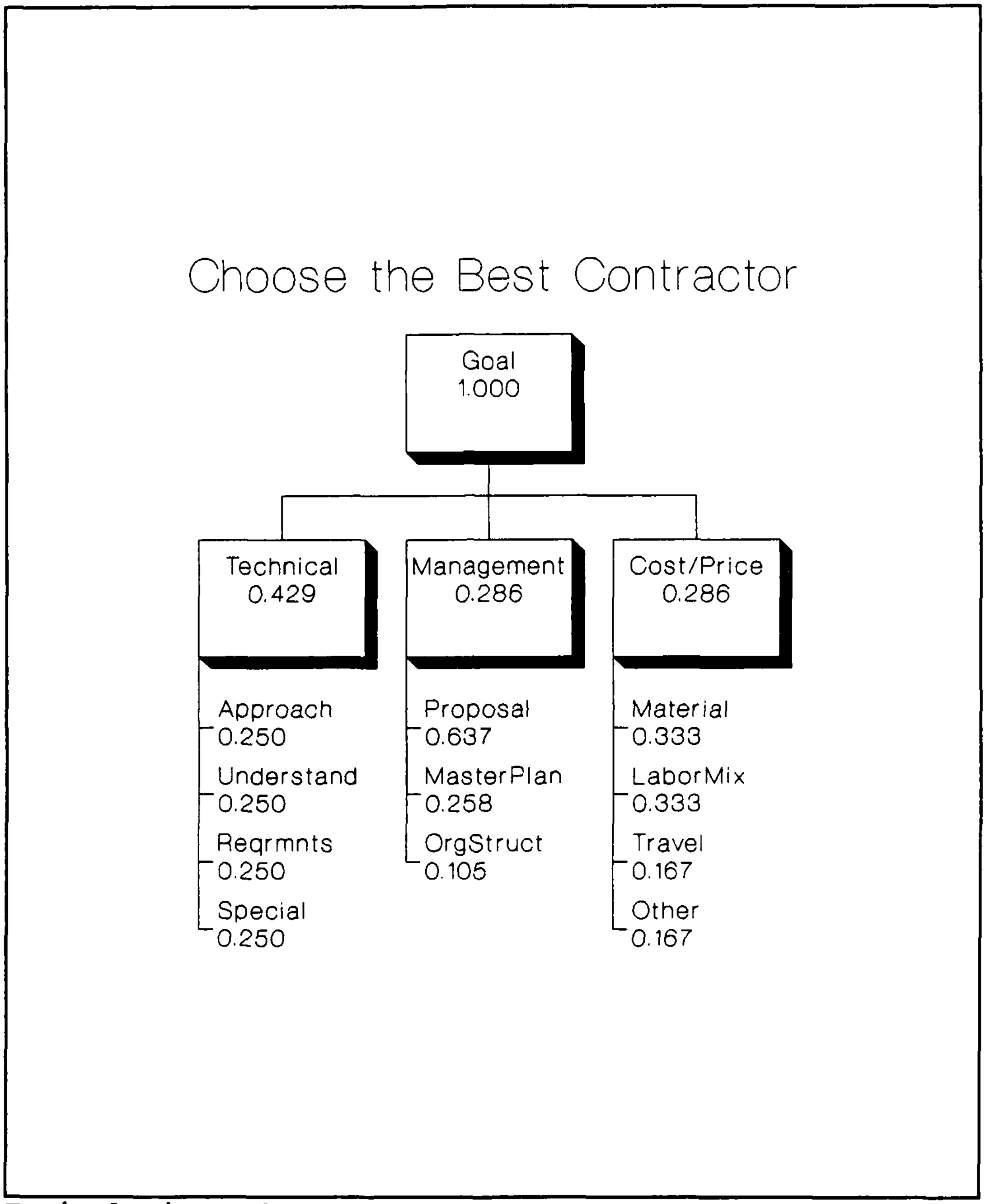
14. I am confident that I made the right decision.

1		2		3		4		5	
	STRONGLY AGREE		MILDLY AGREE		NEUTRAL		MILDLY DISAGREE		STRONGLY DISAGREE

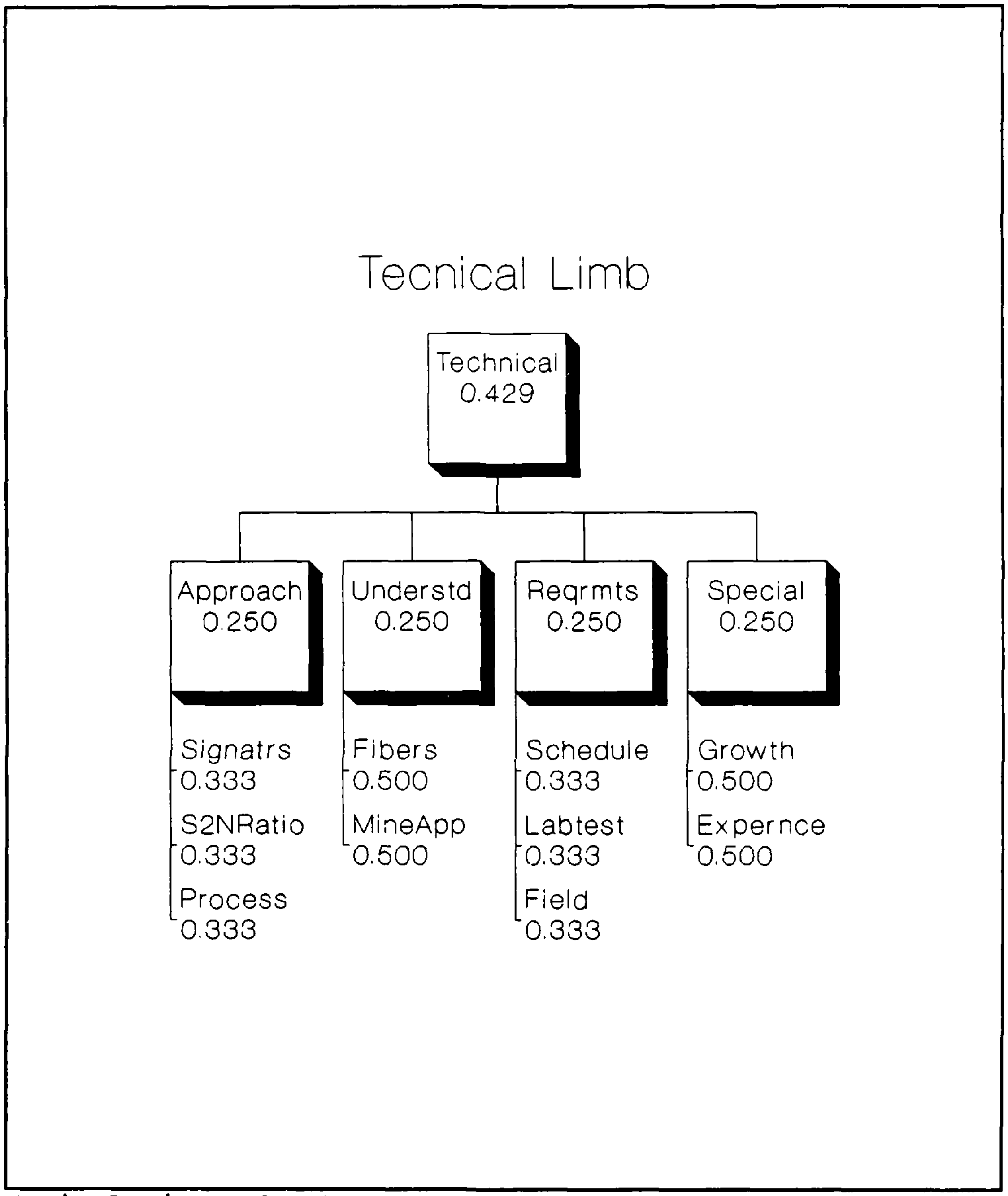
15. How did you feel about this process?

1 FRUSTRATED
2 ANGRY
3 JOY
4 RELAXED
5 APATHY
6 ANXIETY
7 HARRIED
8 OTHER ____________________

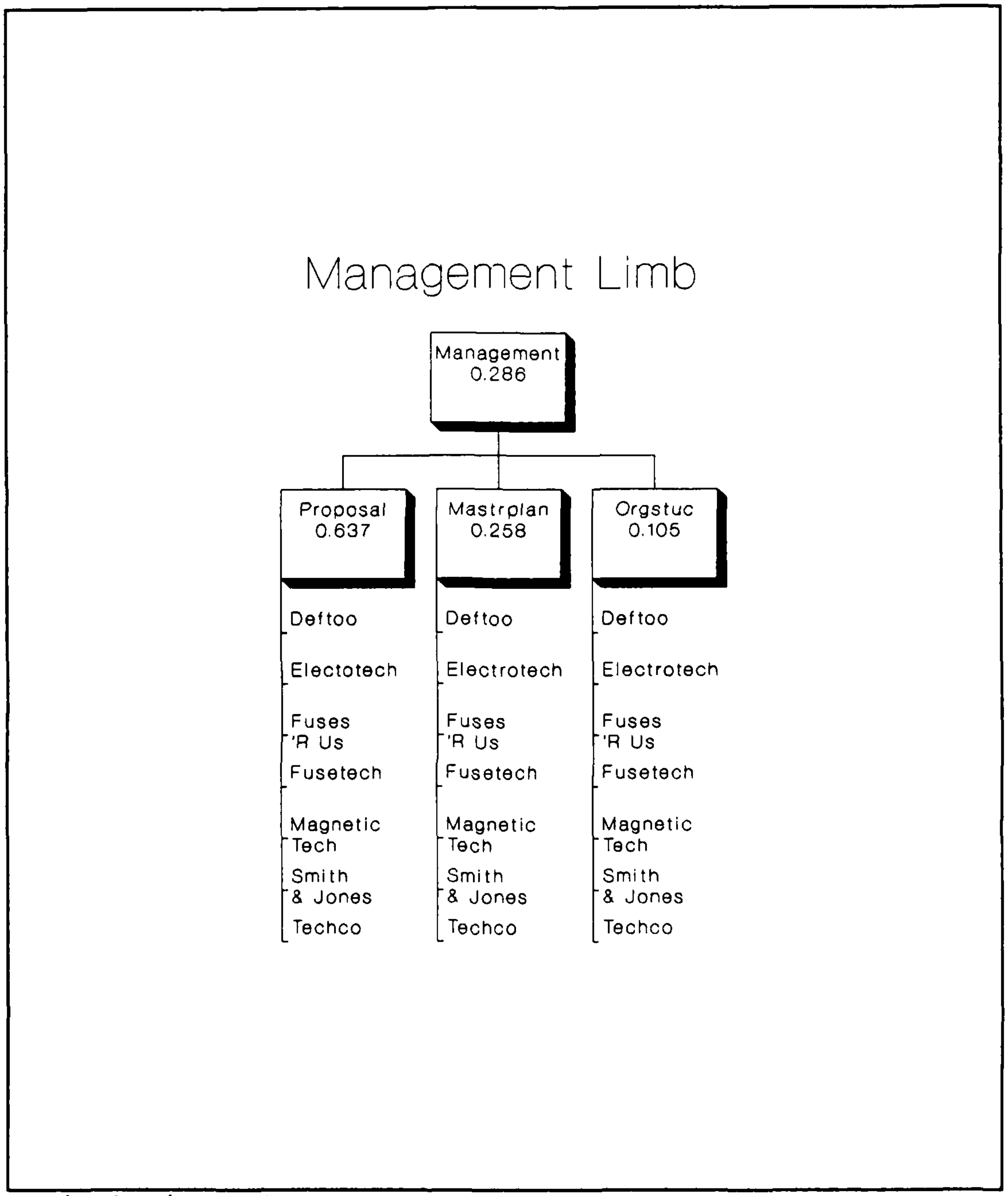
Appendix B: Typical Hierarchy



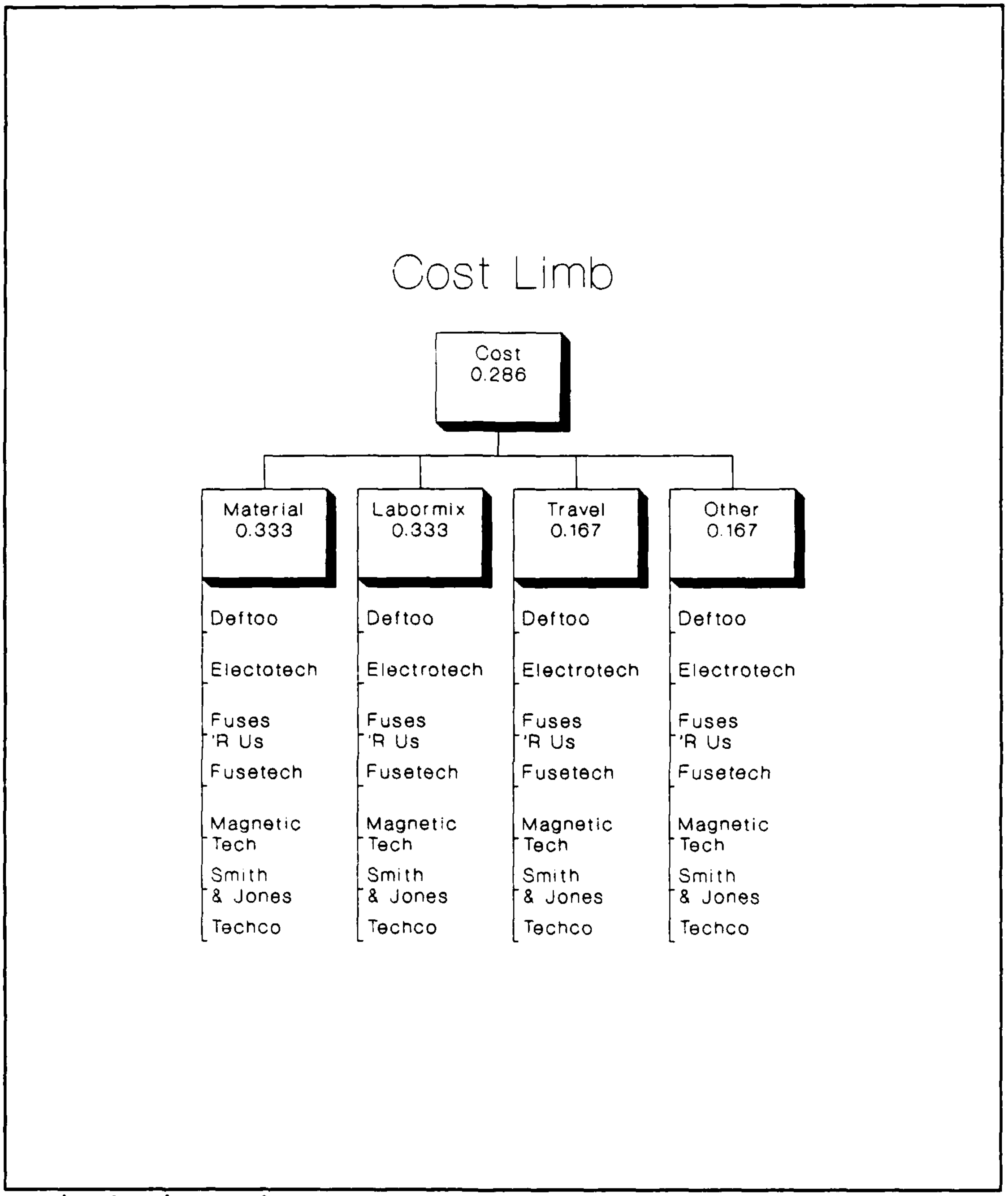
Typical Hierarchy



Typical Hierarchy (cont.)



Typical Hierarchy (cont.)



Typical Hierarchy (cont.)

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Abstract

In the critical arena of source selections, the decision-maker is often overwhelmed by the complex hierarchy of intertwining factors and multitude of conflicting tasks required to successfully purchase an effective weapons system. At this time, there is no available tool with which to assimilate contributing criteria into an organized framework to aid in the decision making process. A decision support system (DSS) acts as the framework upon which the complex elements may be organized. The purpose of this research is to test the use of a computer-aided decision support system in the source selection environment.

Through a controlled experiment, the use of a DSS was tested for the following variables.

1. Effectiveness. This was defined as the number of "correct" decisions made.
2. Consistency. This was defined as how many of the same decisions were made.
3. Speed. Did the use of the DSS speed the process?
4. Difficulty. How easy was it to make the decision?
5. Confidence. How confident was the decision-maker that his decision was correct?
6. Understanding. How well did the subject understand the process by which the decision was made?

The results of the experiment indicated little effect of the DSS on effectiveness and consistency. A negative correlation was discovered between the use of the DSS and the time required to reach a decision. A positive correlation was discovered between DSS and the variables ease, confidence and understanding.

These results suggest further research into the applications of decision support systems. In the Air Force environment where any decision must pass multiple approval "tests," the perceived increase in confidence and understanding would certainly be an advantage for the decision maker. The increased simplicity of the process speaks for itself.