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A COMMERCIAL MICROCOMPUTER
DECISION SUPPORT SYSTEM FOR THE AIR FORCE
RESEARCH AND DEVELOPMENT PROJECT MANAGER

THESIS

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Captain, USAF

AFIT/GSM/LSY/86S-18

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AFIT/GSM/LSY/86S-18

A COMMERCIAL MICROCOMPUTER DECISION SUPPORT SYSTEM

FOR THE AIR FORCE

RESEARCH AND DEVELOPMENT PROJECT MANAGER

THESIS

Presented to the Facility of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial fulfillment of the

Requirements for the Degree of

Master of Science in Systems Management

Phillip A. Thomas, B.S.E.E.

Captain, USAF

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Preface

This project was conceived as a result of the growing realization that the Air Force project manager has very few computerized tools with which to help him or her determine which alternative projects under consideration for further development should be pursued; it is difficult at best to explain why you choose a certain route, or alternative, when your knowledge and experience tell you it "feels" best. A computerized decision aid that helps the project manager identify, and justify, the "best" alternative could save many of the dollars and careers lost in the past due to incorrect decisions.

In addition, my personal experience has been that all too often we in the Air Force speed millions of dollars on software development when a commercial product could solve the problem just as effectively.

Thus, with an distinct application in mind, and with the objective to locate commercial software that supports that application, this project took shape: To locate, acquire and test a commercial microcomputer decision aid for the project manager. The real test of any system is how well it performs the intended job in actual operation, not test or simulated operation. The test data is a integral, and invaluable, part of this project.

This research could not have been performed without the work of Captain Thomas Triscari and Dr. William Henghold, both in collecting the data and guiding me through the pitfalls of academic research; my thanks to both. But the most appreciation goes to my loving wife Margaret for cheerfully enduring and supporting this task, and my children Phillip II and Dawn; they must now stop calling me "Uncle Daddy". I owe my family a debt of time and attention that I am looking forward to paying.

ii

Table of Contents

List of Figures

List of Tables

Abstract

The purpose of this investigation was to locate, acquire, and test realistically a commercial microcomputer decision support system (DSS) for the Air Force project manager. Only commercial microcomputer DSSs were considered in a effort to demonstrate the cost savings that could be possible by using off-the-shelf software for a dedicated application instead of engaging in an expensive software development project.

A realistic test was achieved with actual project data collected specifically for a detailed project selection decision, which provided a specific utility assessment, and by managerial use of the DSS which provided a general utility assessment.

The specific utility assessment identified some limitations with this system. The general utility assessment suggests this system provides useful managerial decision aid in many decision situations involving predetermined alternatives.

A COMMERCIAL MICROCOMPUTER DECISION SUPPORT SYSTEM FOR THE AIR FORCE RESEARCH AND DEVELOPMENT PROJECT MANAGER

I. Introduction

Background and General Issue

The microcomputer has had an impact on the business world that could not have been predicted ten years ago. The microcomputer allows accountants to keep better records, managers to more effectively manage budgets and schedules, and company executives to better gauge successes and failures. Secretaries, as well as managers, use it as a word processor and designers use it as a drafting tool. Product advertisements and reviews in the popular computing literature indicate that businessmen are using the microcomputer along with decision-assist software as a decision aid, but military, and specifically Air Force research and development (R&D) managers are not mentioned in these journals. However, some of the commercial software may be as applicable to military applications as it is to civilian applications.

Commercial Software. In addition to the billions of dollars spent on various projects and project management, millions of dollars are spent each year by the Air Force on software development. This often involves the contracting of a civilian company to write a specialized program for a single Air Force application, which is a very expensive process. Some of this development money could be saved if off-the-shelf commercially available programs were used for the Air Force application rather than engaging in expensive software development contracts. Commercial

1

software that aids the program manager's project selection decision process could provide a savings in both the development of the software and in an enhanced selection process for future projects.

Project Selection and Decision Support Systems (DSS). The Air Force directs and manages R&D projects that involve many new and different technologies. Each R&D project manager, working with limited resources, must use his or her own methods to choose the most promising prospects among the relevant technologies. Some projects are significantly promising and lead directly to a clear choice among many possibilities. Other projects, however, require an additional and more in-depth evaluation, or trade-off, based on some criteria for developing a most appropriate investment strategy. This decision process can be described as "semi-structured" since it often requires the manager to make an intuitive decision about what technology or research effort to pursue. Donnelly et al point out that "resources (financial and nonfinancial) are becoming more and more scarce. In such a situation, choices must be made, and some method is necessary to help management make the choices" (7:140). The realities of normal budget constraints faced by every manager plus the additional constraints forced on the military manager due to such things as Gramm-Rudman impacts, make each decision, or lack thereof, even more critical. A decision aid for the military project manager could help to avoid mistakes and add structure to the semi-structured decision process. A computer-based decision aid, or DSS, could further assist the project manager by providing a structured decision format which aids the transition from a semi-structured to a structured decision process. In addition, a computer-based DSS could provide results, such as graphical outputs, not

2

readily available with pencil and paper analysis.

Microcomputer DSSs. While DSSs can be quite complex in terms of hardware and software, there are three primary reasons that only microcomputer DSSs are considered for this project. The first reason for this is that time, money, equipment, and manpower are limited; the resources are not available for a long-term, expensive search-purchase-evaluation project. Second, a microcomputer DSS can provide a personal, dedicated, and often private environment for managerial decision making. This includes the fact that microcomputer programs are transportable and therefore provide the greatest potential for use at any office or laboratory in the Air Force. A terminal-modem-mainframe computer link could provide personal DSS service but this would rarely be dedicated (the manager could wait for computer time or be "bumped off" during use) and, despite security precautions, would never be completely private from other computer users. Therefore, the same microcomputer DSS could provide a familiar and dedicated decision aid at almost any permanent, or temporary, duty location. And third, the specific microcomputer used for this research, an Apple Macintosh*, best satisfies one of the primary system requirements (discussed in Chapter III): A managerial DSS must provide an exceptional ease of use for infrequent, non-technical, users of the system. This is accomplished with a graphic display/mouse input that provides a less intimidating user interface which may encourage more frequent managerial use.

As noted above, DSSs can be quite complex. However, simple rank ordering of numeric project data can be accomplished with a spreadsheet

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3

type of program. A DSS can take this process a step closer to facilitating semi-structured decision making by supporting visual decision model building (graphically depicting the decision model), allowing normally non-quantifiable inputs in the decision model (inputs within a semi-structured range such as good to bad or like to dislike) and by providing a graphic output. DSS capabilities are discussed in Chapter III.

One final, noteworthy, benefit of using a DSS is that it can provide a computer printout which is a permanent record of the decision process. The printout can be included in reports as a justification and explanation and as an after the fact audit trail if a question is later raised about the decision.

Specific Problem

The general issue discussed above leads directly to the following research question: What is the feasibility of structuring and aiding the semi-structured, or intuitive, R&D project selection decision process using a commercial microcomputer decision support system? The process of structuring and aiding a semi-structured R&D decision using a commercial microcomputer DSS involves two specific problems:

1. How are semi-structured R&D project decisions made now? What intuitive decision processes do project managers use in conjunction with structured decision processes to assign program priorities and identify the most promising technologies ? This can be answered from past research and is discussed in Chapter III.

2. How can a commercial microcomputer DSS add structure to and aid the semi-structured decision process ?

4

Investigative Questions

The discussion of the general issue resulted in two specific problems; two investigative questions must be answered to resolve the two specific problems:

1. What are the semi-structured decision processes that Air Force R&D project managers use now when assigning program priorities?

2. What commercial microcomputer decision aid best fits the specific DSS criteria and will aid this R&D semi-structured project selection decision process?

Research Objective

This research is focused on a distinct objective: To locate, acquire, demonstrate realistically, and assess a commercial microcomputer DSS that supports and aids the R&D project manager's semi-structured project selection decision process. The DSS location and assessment criteria and the DSS selection process are in Chapter III.

Project Data. The best method to realistically demonstrate the operation of a DSS intended to support the project selection decision process is to perform project selections with data derived from actual projects that will proceeding in the near future. Therefore, the data used for this test are from the Research Planning Workshop for Artificial Intelligence in Manufacturing conducted 31 July 1985 to 1 August 1985 (12). The workshop data are described in Chapter III and the utility analysis of the DSS/data combination is in Chapter IV.

Managerial Feedback. The primary assessment of this DSS is a result of exercising the system with the data and is in Chapter IV, Utility Analysis.

However, the intended users are managers and their perceptions of this system are paramount. Therefore, managerial assessment of this DSS is provided through feedback, written and verbal, from managers that participated in a "hands-on" demonstration of the DSS. This consisted of a brief demonstration of the DSS followed by the opportunity for each manager to manipulate the DSS as if he or she were performing the project selection. Each manager-participant filled out a questionnaire at the end of the session indicating their perceptions of the DSS. The questionnaire is developed in Chapter III and the results are discussed in Chapter V.

II. Methodology

Introduction

This chapter discusses the research methodology necessary to locate, acquire, realistically demonstrate, and assess this microcomputer DSS. First, the scope and limitations of the research are discussed to set the stage for the steps that follow. Then the specific steps required for this research are discussed in the section titled Particular Method. The research flow is illustrated in Figure 1.
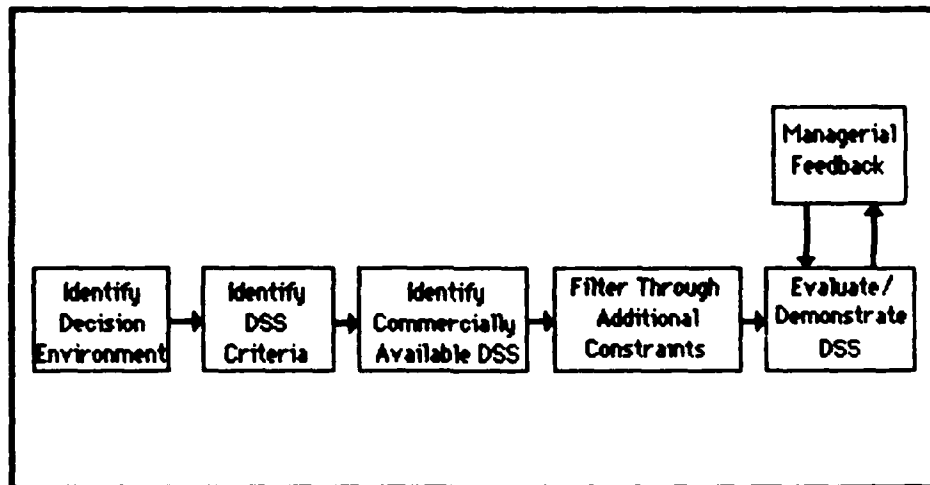
Figure 1. DSS Research Methodology/DSS Choice Flow Chart

The steps (indicated in Figure 1) follow a sequential flow; the type of decision to be supported is identified first, then the applicability of DSSs to that decision type (in general) is determined, then the availability/applicability of commercial microcomputer DSSs, which are further limited by additional constraints, is determined, and finally the actual utility analysis and managerial assessment of the DSS is

accomplished.

Scope

The research objective is to locate, acquire, realistically demonstrate, and assess a commercial microcomputer DSS that supports and aids the Air Force R&D project manager's semi-structured decision process. Thus, the scope of this research is limited to (1) identifying a semi-structured decision process used by Air Force R&D laboratory managers in R&D project evaluation, termed the decision environment, through a literature review, (2) Identifying commercial microcomputer DSSs through computer literature and product advertisements that support this R&D decision environment, (3) Acquiring the one DSS that best fits developed criteria, (4) Building decision models with the DSS and performing a decision analysis with actual data, (5) Presenting the DSS to a sample of project managers for their assessment, and (6) Analysis and discussion of the utility analysis, the results, and the impressions that the DSS made on the managers.

Limitations. As discussed later in the section called Additional Constraints, the constraints of limited time, limited money, and of using a Macintosh microcomputer for full-time DSS research limit the scope of this research project. These constraints limit the number of DSSs available for this research and possibly decrease the utility of the DSS as a decision aid. The utility of the DSS is discussed in Chapter V, after the utility analysis is performed in Chapter IV.

This research is not directed toward development of a DSS of such broad utility that it supports every "what if" situation or every conceivable report and data format. For example, a decision aid that handles a "what if" analysis involving 10 or 20 alternatives with 40 or 50 factors each, may not

8

be affordable and/or may not provide an acceptable graphics capability or a user friendly input/output format; a DSS that performs evaluations of only five alternatives with six to ten factors each may be more affordable, provide a better graphics capability, and a better user interface. Similarly, all microcomputer DSSs may not support ad hoc report requests such as for "A List of every alternative with a Criteria 3 rank above 5". In either case, for some decisions, it may be necessary to invest a considerable amount of time in data preparation and/or data entry into the DSS which would result in more difficult DSS preparation for use. Thus the data interface could require the DSS to be prepared for use by someone familiar with it prior to turning it over to the manager who would then manipulate it for the decision results.

Particular Method

The Decision Environment. Past research on decision methods and R&D project selection methods provides the starting point for this research. The research by Lee (11) and Prince (15) was specifically aimed at identification of semi-structured project selection decision processes and is used to develop the framework of a representative semi-structured decision process for the Air Force R&D laboratory management environment. This framework establishes the decision environment and is used along with the DSS criteria to judge the appropriateness of the DSSs that are located. The decision environment is discussed in Chapter III.

DSS Identification. Next, a "system" is discussed and some of the ideal DSS criteria are identified from the literature reviewed. The ideal DSS criteria are further broken down into specific criteria. Then, for the DSS

9

selection process, some microcomputer DSSs are located through product reviews, advertisements, and product information from the manufacturers. The number of applicable microcomputer DSSs is first reduced by limiting them to only those that fit the project selection decision environment as opposed to those DSSs oriented toward alternative generation, personnel evaluation or product-sales decisions. The refined DSS criteria are used in conjunction with the additional constraints discussed below for the selection of one of the remaining commercial microcomputer DSSs. The DSS review and comparison is reported in Chapter III.

Additional Constraints. Not only must the DSS chosen for this project meet the requirements discussed above and detailed in Chapter III, it must also meet some strict research constraints. These constraints and their reasons are:

1. The DSS must be obtained and useable before 31 April 1986 so that AFIT deadlines for this research can be met.

2. The DSS must be bought for under $100 since there is no research money available and personal money must be used if purchase becomes necessary.

3. The DSS will operate on an Apple Macintosh computer since it is the only microcomputer available for full-time DSS research, and it fits many of the system requirements discussed in Chapter III.

Realistic DSS Demonstration. The last steps in this project are a realistic demonstration, or utility analysis, and a managerial assessment of the DSS. The DSS is used to build a specific decision model called the decision environment model (DEM). The utility analysis of this DSS involves building a DEM for each of the three groups of projects generated by the

10

Research Planning Workshop for Artificial Intelligence (AI) in Manufacturing. The AI project data is discussed in Chapter III and the project models are built and exercised with the data in Chapter IV. After the models are built, the scoring data entered and the top five projects in each group indicated by the DSS, the weight (or priority) of a criterion is shifted to see what change in project selection occurs due to the shift, or "what if" the weight is different. Therefore, the the majority of the assessment of how well this DSS fits the specific decision situation is as a result of exercising the system (including initial training, model building, data preparation and entry, and sensitivity analysis) for this research project instead of from the short time that managers use the system and provide subsequent feedback. But after the utility analysis is the managerial assessment of this DSS.

Managerial Assessment. The managerial assessment is considered "hands-on" because first the DSS is demonstrated and then each manager is allowed to operate the DSS in an actual decision situation. Since managers participate in a decision (or managerial utility) analysis this will give a test of ease of use for the managers since they are not involved in building the DEMs or entering the project data. Also, this may give an indication of the training required for managers that may use the DSS infrequently. The assessment of the DSS is provided by managerial feedback.

The managerial feedback is achieved through a short questionnaire that was completed by each manager that participated in the DSS hands-on demonstration. In addition, some of the verbal comments from the demonstrations are included in the results and discussed. The questionnaire is developed in Chapter III and the results are discussed in Chapter V.

11

III. Literature Review and Preliminary Research

Introduction

This literature review begins with a short discussion of decision processes. The discussion then progresses to previous research performed about the R&D project selection decision process in general and specifically that process used at the Air Force Wright Aeronautical Laboratories, which establishes the decision environment. Then the composition of a system is discussed and the broad area of decision support systems is reviewed. This includes how some DSSs work and the continuing controversy over the user interface. Next, a brief survey of some operational DSSs is conducted and the field of DSS software is narrowed down to that now commercially available for microcomputers. The DSS criteria for this research are then derived from the literature and the additional constraints discussed in Chapter II. These criteria/restraints are refined into a software selection matrix which is used for selection of the Macintosh DSS software that best supports the decision environment and meets the additional constraints. Next is a section discussing the project data with which this DSS is tested. Last is a section on the development of the Management Questionnaire which is the instrument used for the managerial assessment of this DSS.

Although many of the sections introduced above are not part of the literature, they are necessary for completion of this research and they evolve from the literature in a natural sequence. Therefore, those sections that comprise part of this research process are included with the literature to preserve the flow of thought and for clarity.

The Decision Process

Almost any textbook on management describes the most recognized

decision processes. Keen and Morton identify five views on decisionmaking:

1. *The economic rational concept*: This is the classical
normative theory of decisionmaking, in which
decisionmakers are all-knowing and able to evaluate all
alternatives. They are dissatisfied with any solution but
the best.

2. *The satisficing, process-oriented view*: this
considers the decisionmakers to be intendedly rational
although cognitive limits lead to a bounded rationality;
thus the goal of any decisionmaker is to get a good
enough answer, not the best possible one. This point of
view stresses the *process* of decisionmaking and not
just its outputs; it emphasizes the relatively limited
analysis and search most managers will make and their
reliance on heuristics.

3. *The organizational procedures view*: this focuses on
the interrelations among components of the organization.
It highlights organizational structure, mechanisms for
communication and coordination, and the standard
operating procedures by which decisionmaking is
systematized and often simplified.

4. *The political view*: this regards the participants in
the decision process as actors with parts to play. They
have strong individual preferences and vested interests
and form coalitions of organizational subgroups.
Decisions are frequently dominated by bargaining and
conflict, with the result that only small deviations from
the status quo are normally possible. Major innovations
are (quite reasonably) resisted by those whose position,
interests, or simply job satisfaction will be affected.

5. *The individual differences approach*: this view argues
that an individual's personality and style strongly
determine his or her choices and behavior. Personal
"rationality" is subjective and behavior is very much
determined by the manner in which an individual
processes information. [9:80]

These decision methods or schools of thought were developed through

research on civilian management. The methods used by Air Force R&D

managers appear to be different but in fact fit into one or more of the categories listed above.

The Project Selection Decision Process

Dr. David Lee conducted research for development of a decision aid for the MANTECH project selection process. He found that "MANTECH project selection and resource allocation decisions are complex mental processes involving numerous considerations. Without a systematic evaluation methodology, some considerations can be overlooked, while others may be overemphasized" (11:13). His response was to propose project score and summary sheets to add consistency to the project selection process (11:13). These score and summary sheets are, in fact, one form of a DSS; any plan that aids the decision process could be called a DSS. It is not necessary for the plan to operate on a computer to qualify as a DSS, but, as discussed previously, a computer-based decision aid could provide many benefits not readily available through other analysis techniques.

Captain Jeremy Prince performed research into the methods used for R&D project selection at the Wright Aeronautical Labs. He found that the three main factors used are Air Force need, technical merit, and resource availability (15:37). In addition, Captain Prince found that no formal decision method was used; decisions were made "via a group consensus of researchers or by a management committee", but that the most used formal decision techniques were checklist and profile charts, scoring models, decision trees, and goal programming (15:38). This would indicate a satisficing approach to Air Force R&D project decisionmaking, and it is often influenced by political and organizational pressures. Prince

14

recommends further research into the "impact a decision support system may have on research project selection" (15:42). Therefore, a DSS that aids the project selection decision process should provide, or in some way support, one of those techniques Prince found used most often: Checklists and profile charts, scoring models, decision trees, and/or goal programming. However, "The impact of the DSS is often qualitative; it does not necessarily reduce costs or directly increase profits but "improves" the decision process" (9:99). Thus, one method for improving the Air Force R&D project selection decision process would be to assist the project manager with one of the techniques identified by Prince.

The Decision Environment. The decision environment includes the decision maker's organization, the decision maker, and the type of decision as illustrated in Figure 2 from Adelman (1:335). The interfaces are depicted by the sets of arrows and the Decision Making Organization interface refers "to what extent the DSS facilitates the decisionmaking process of the organization" (1:335). The interface between the user and the DSS indicates not only that the DSS should be userfriendly, providing information in and out in a format that the decision maker finds useful, but that the DSS should support the type of decision that the decision maker faces. In addition, the DSS should support a recognizable (by the decision maker) decision process. Therefore, a DSS designed to aid an R&D project manager should work within his or her decision environment. In other words, does the DSS support only business related topics such as sales, marketing and personnel or will it support the Air Force R&D project manager's decision environment which involves semi-structured decisions concerning new technologies and project alternatives?

15

DECISION MAKING
ORGANIZATION

USER

DECISION
SUPPORT
SYSTEM

ENVIRONMENT
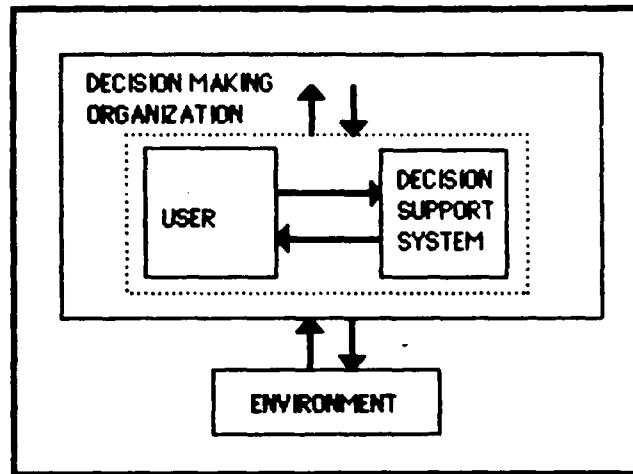
Figure 2. Pictorial framework for considering issues relevant to the design and evaluation of Decision Support Systems [1: 335]

Decision Support Systems

<u>Systems.</u> Before a DSS can be assembled to support a specific application, the general concept of a "system" must be explored. Donnelly et al. say that "A system is a collection of objects united by some form of regular interaction and interdependence" (7:544). "Each system is composed of subsystems which in turn are made up of other subsystems" (4:271). Subsystems, then, would be the objects united but some subsystems may only be comprised of individual components. In either case, "The interconnections and interactions between the subsystems are termed interfaces" (4:271).

<u>Subsystems.</u> The components of the system, the subsystems, will determine the system. For a DSS, the system may only be comprised of the hardware subsystem and software subsystem. The hardware could be as

16

large as a mainframe computer or as small as a microcomputer, and in some cases may only be a coin to flip. However, a DSS in the context of this research effort involves a computer system. A computer system requires both an operation software subsystem and an application software subsystem, at a minimum, to perform a useful function. The operation software subsystem runs the computer and provides the user interface, in conjunction with the particular type of computer, while the application software subsystem is what performs the work, in this case the "decision support" in DSS. The DSS for this research will be composed of a microcomputer subsystem and a software subsystem, but it must interface with the user and the data. The user interface and the data will be discussed more later.

Training. Implied in the use of a system is the training required for the user to effectively use it. Since this DSS project is focused on a userfriendly managerial system, training should be kept to a minimum. The result of providing minimum training to the manager/user becomes evident through their subsequent use and assessment of the system and is discussed in Chapter V.

DSS. Thousands of computer programs have been written to ease the burden of almost every repetitive or complex task. But only within the past two or three years have microcomputers become powerful enough to run programs to help make decisions. "DSSs ... are designed specifically to support particular decision processes rather than to expedite and/or automate transaction processing, record keeping, and normal business reporting" (10:17). Davis identifies three characteristics that a DSS should have to be effective. These are:

17

1. The computer must support the manager but not replace his or her judgment. It should therefore neither try to provide the "answers" nor impose a predefined sequence of analysis.

2. The main payoff of computer support is for semistructured problems, where parts of the analysis can be systematized for the computer, but where the decision maker's insight and judgment are needed to control the process.

3. Effective problem solving is interactive and is enhanced by a dialogue between the user and the system. The user explores the problem situation using the analytic and information-providing capabilities of the system as well as human experience and insights. [4:368-369]

Davis' three characteristics establish a broad framework within which a DSS should operate. For a DSS to exhibit the characteristics that Davis identifies, it should perform some specific functions that in combination form the characteristics of the DSS. Kosy and Dahr derive some suggested DSS functions in the following way:

Staff activities can be supported in many ways and the types of functions served by DSS cover a wide spectrum. They range from those that are very data-oriented to those that are very model-oriented. The following points on this spectrum may be identified:

- Retrieve data items, consolidate, and prepare prescribed reports (e.g., roll up a resource plan)

- Provide tools for ad hoc data analysis (e.g., time-series extrapolation)

- Calculate consequences of alternative decisions (e.g. simulation)

- Generate and suggest good or optimal decisions in specialized domains (e.g., inventory optimization) [10:17]

18

However, in addition to, and sometimes instead of, the functions that Kosy and Dahr recommend, some other functions for a DSS to be adequate could be added. "It should provide a framework in which all available information is used to deduce which of the decision alternatives is "best" according to the decision maker's preferences" (13:200). In addition, "features may include curve fitting, Monte Carlo (probabilistic) solutions, and goal seeking" (22:77) which in simpler terms mean fitting a curve to data points to facilitate trend analysis, using simulation techniques to determine the probability of an event occurring, and changing the output to a desired level to evaluate the effect on the input data. A DSS should include "speed of response to maintain the manager's own thought processes; communication with the manager in terms familiar with him; and a structure which is understood by the manager" (22:78). Once a model is built or a scenario established, what-if changes to the model can be tested for their effect on the outcome (22:77). In total, the DSS is a hardware-software combination that will aid the decision maker in the decision process by quickly processing and presenting data using DSS techniques. The techniques for processing and presenting the data are the heart of DSSs.

Some DSS Analysis Techniques. The data processing, or analysis, function of DSS can be performed either by assigning preferences, which is called utility theory (13:201), or by probability theory (13:205). In either case the decision model, a decision tree, is weighted by the preferences or probabilities assigned to each decision branch on the tree. Figure 3 is a simple decision tree which illustrates two possible choices at each branch. A DSS would calculate the probability of A(1) occurring as 0.5 multiplied times 0.7 or 0.35.

19

.7 A(1)

.3

.5

A(2)

A

.5

B(1)

.4

B

.6

B(2)

P [A(1)] = .5 X .7 = .35
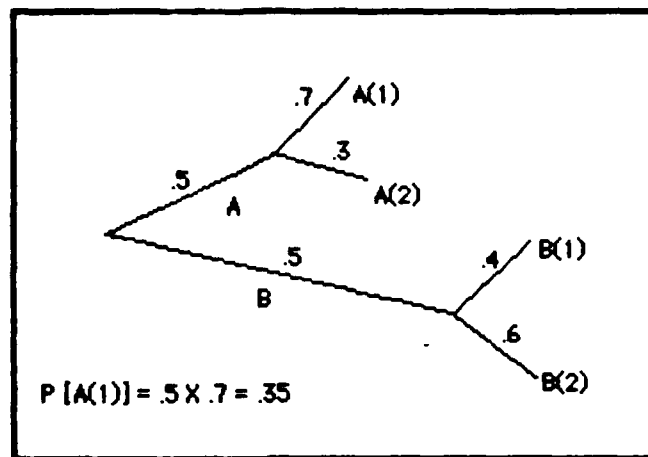
Figure 3. Probability Tree

The tree is much more complicated in practice and in addition, most DSS users have no knowledge of the numbers, where they come from or how the DSS works to provide a result (10:21). Such a lack of knowledge could result in improper DSS operation and therefore erroneous decision results. Some of these deficiencies are overcome by the use of a knowledge-based support system, a concept which comes from research in the field of artificial intelligence and allows the computer "to store, apply, and communicate knowledge" (10:21). The state-of-the-art of microcomputers and their programs has reached the level within the past year to use AI techniques but they are not yet in wide use.

The User Interface. For any managerial computer system to be used, it should be easy to learn and to use. The benefit or service that it provides is almost secondary when weeks or months are spent learning the system and the manager must relearn it each time the system is changed or not used for a few days. "This is the province of the user interface. To eliminate the need for a computer specialist, the interface should be flexible, forgiving,

20

fast, informative, and easy to learn without training" (10:24). Reimann states that "ease of use or "user friendliness" is perhaps the single most vital criterion" (17:23). Userfriendly criteria dictates that "the design of the DSS must be focused on potential users and their decisionmaking needs" (3:457).

An important part of userfriendliness involves the method of communication with the computer. "Explicit communication may involve specific displays and controls, structured dialogues via keyboards or voice, or natural language via keyboards or voice. Implicit communication can be accomplished using unobtrusive but direct observations, indirect measurements, or inference" (19:17).

"From a manager's point of view, the system should appear to be a helpful staff assistant" (10:27). The method of communication between the manager and the computer will determine if the system is a helpful staff assistant or a bothersome tool that is used only as a last resort. There are two popular methods of communication used on the microcomputers currently on the market. IBM*, and IBM compatible, microcomputers provide a keyboard entry, menu driven communication interface which uses structured dialogue. The Apple Macintosh microcomputer provides a mouse entry, icon (pictorial) interface, which is visually oriented and uses a single button roll-around mouse, about the size and shape of a pack of cigarettes, for control. Ease of use and visual impact are better on the mouse-icon microcomputer: Instead of typing confusing command sequences to control the computer and applications software, the Macintosh provides a "desk top

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* IBM is a registered trademark of International Business Machines Corp.

analogy, with documents and folders and even a trash can for throwing documents away, that is controlled almost exclusively via the mouse. Therefore, the Macintosh interface supports those managers that are not typists and may even be intimidated by the computer; it provides the user interface that userfriendly criteria indicate necessary for a manager's DSS.

Alter agrees that the common belief is that managers should be encouraged to use DSSs but he has found that problems occur when untrained people use a system they are unfamiliar with. He concludes *"that the direct use of decision support systems by nonexperts should be discouraged rather than encouraged"* which is "in contrast to suggestions that better man-machine interfaces are the key to greater managerial usage of decision support systems" (2:111-112). However, managerial and military use of DSSs is already a fact; the military uses many custom DSSs which were designed and written for a single application, almost all of which were acquired through software development efforts as described in Chapter I. The use of commercial DSS software will undoubtedly increase as software, and microcomputer power and utility increase.

This research is focused on the location and acquisition of a commercial microcomputer DSS which a manager can use for project selection. As just discussed, the Macintosh microcomputer provides a user interface, with both the hardware subsystem and the operation software subsystem, that facilitates managerial use. Therefore, these are the first parts of the system that is used for this research and only the application software subsystem, the "decision support" in DSS, is yet to be determined. The next step in this location process is a look at a few of the custom DSS software subsystems that have been implemented.

22

Some Existing DSS Software. The Army and the Navy both have developed specialized DSSs. One of the Army's DSSs is called a "Competition Decision-Assist Package (CDAP)" and had as a study objective the "Development of a decision-making package for use by the project manager to aid making competition decisions" (6). This DSS requires a mini-computer (which is in between the size and power of a microcomputer and mainframe computer) for operation. The Navy has developed a DSS called "A Personalized and Prescriptive Decision Aid" (6). The Navy DSS is implemented on an IBM personal computer and was customized as an attack submarine commander's DSS. However, it is designed as a generic DSS. The report summary describes the DSS as follows:

> This report describes the development of a computer-based display and analysis system which caters to the personal decision-making styles of users while hedging them about with safeguards against potential errors or biases. The general conceptual design brings together descriptive research in cognitive psychology on individual strategies in judgment and choice, and prescriptive theories which constrain optimal solutions while accommodating differences in judgment and ways of structuring the problem. A demonstration prototype aid, incorporating an advanced user interface, has been designed and partially implemented in a specific testbed and has successfully undergone a preliminary test with representative potential users. [5:v]

In another attempt at using DSS techniques, two Air Force Institute of Technology graduate students have written "A Decision Support System For Bare-Base Planners" which addresses the need for a specific DSS at Air Force Major Command level (21). It is useful only in the intended scenairo of bare-base planning. In a different effort at solving a specific problem, a DSS model was designed and implemented to assist the Xerox corporate

23

staff to decide if they should build a new plant. The report makes no mention of what computer system is used. It is a good example of successful application of DSS theory but also only supports the scenario it was designed to address (20). One Air Force custom DSS is the "Integrated Decision Support System (IDSS) (14)". It is designed to aid in the solution of various manufacturing problems. Some of the many functions the IDSS provides is computer simulation of manufacturing problems to generate alternative solutions that are then evaluated using techniques such as financial, statistical, and inventory analysis (14:1-2). It too is implemented on a mini-computer. All but one of these DSSs is the result of a software development contract as described in Chapter I, and the one exception was the result of development efforts by two Air Force officers. Next is a look at some of the commercially available microcomputer DSS software.

Commercial Microcomputer DSS Software. According to product reviews and advertisements in some of the computing literature, at least 19 DSSs or DSS-type programs have been developed that run on the two most popular microcomputers, IBM and Macintosh. These are listed in Table I along with their manufacturers (in the Name/Mfr column), the microcomputer that they operate on, either IBM or Macintosh (MAC) or both (H/W SYS column), and their retail cost (Cost column) as of April 1986.

As was mentioned previously, a properly used spreadsheet program can provide many DSS-type benefits. A decision model of almost any complexity can be built with a spreadsheet but it can be very hard to see the relationships that are modeled since they are not represented graphically and nearly impossible for anyone but the model designer to change the

24

TABLE I.

Macintosh/IBM Microcomputer DSS Software

Name/Mfr*	H/W Sys	Cost ($)
1. Lightyear/Lightyear , Inc.	IBM	595
2. Jazz/Lotus Development Corp.	MAC	595
3. Lotus 1-2-3/Lotus Development Corp.	IBM	495
4. Trigger/Thoughtware, Inc.	IBM	495
5. Reflex/Analytica Corporation	IBM	495
6. Javelin/Javelin Software, Inc.	IBM	695
7. DecisionMap/SoftStyle, Inc.	MAC	145
8. MindSight/Execucom Systems Corp.	MAC	195
9. ods/Consultant/ODS, Inc.	MAC	200
10. Expert Edge/Human Edge Software Corp.	IBM/MAC	795
11. Expert Ease/ "	IBM/MAC	695
12. The Management Edge/ "	IBM/MAC	250
13. The Negotiation Edge/ "	IBM/MAC	250
14. The Sales Edge/ "	IBM/MAC	250
15. The Communication Edge/ "	IBM/MAC	250
16. ExperLisp & OPS5/Expertelligence, Inc.	MAC	398
17. Ensemble/ Hayden Software Inc.	MAC	300
18. Excell/Microsoft Corp.	MAC	395
19. Quartet/Haba Systems Inc.	MAC	200

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* Lightyear is a registered trademark of Lightyear, Inc.
  Jazz and Lotus 1-2-3 are registered trademarks of Lotus
  Development Corp.

25

weights of the decision factors. Thus they allow DEM building, although not always easily, and sensitivity analysis, which also is not easy. This lack of ease of use, or userhostility, means that few managers will ever take the time to perform an analysis of any complexity using a spreadsheet. However, if the results are properly depicted, perhaps graphically, they can be as beneficial to decision making as those of a DSS. Therefore, the new "integrated" programs such as Lotus 1-2-3, Jazz, Quartet, Reflex, et al. that provide graphics capability as well as data base and/or spreadsheet capabilities fall into the category of "decision support" and are also listed for consideration. The specific criteria for selecting the decision support software are developed next.

DSS Criteria

The research objective is to locate, acquire, demonstrate realistically, and assess a DSS that aids the R&D project manager's project selection decision process. The DSS should aid the transition from a semi-structured to a structured decision process. The list of DSS software has already been limited to those that are commercially available and operate on IBM or

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Trigger is a registered trademark of Thoughtware, Inc.
Reflex is a registered trademark of Analytica Corp.
Javelin is a registered trademark of Javelin Sostware, Inc.
DecisionMap is a registered trademark of Softstyle, Inc.
MindSight is a registered trademark of Execucom Systems,Inc.
ods/Consultant is a registered trademark of Organizational Development
    Software, Inc.
Expert Edge, Expert Ease, The Management Edge, The Negotiaton Edge, The
    Sales Edge, and the Communication Edge are all registered trademarks of
    Human Edge Software Corp.
ExperLisp and OPS5 are registered trademarks of Expertelligence, Inc.
Ensemble is a registered trademark of Hayden Software, Inc.
Excell is a registered trademark of Microsoft Corp.
Quartet is a registered trademark of Haba Systems, Inc.

26

Macintosh microcomputers. To further qualify the DSS that best meets the research objective, and research constraints identified in Chapter II, the following categories of DSS performance are derived from the literature and Chapter II, and further refined into the criteria listed below each.

Perform the Decision Analysis. The decision analysis is to choose among or rank order several pre-determined alternatives. The first two criteria are:

1. The DSS should allow establishment of criteria/decision factors for each specific decision.

2. The DSS should in some way rank-order pre-determined projects based on the decision factors.

Support, Not Replace, the Manager's Judgment. The manager's judgment is necessary to determine the importance of decision factors in the DEM, and may be required to determine a qualitative measure of merit for an alternative. The next two criteria are:

3. The DSS should allow different weights/priorities to be assigned to each different decision factor in the DEM.

4. The DSS should allow the ranking of each project alternative on the decision factor.

Structure the Decision Environment. Prince found that the decision techniques most often used by project managers are checklists and profile charts, scoring models, decision trees, and goal programming (15:38). Therefore, a project manager's DSS should aid the manager in accomplishing one of these techniques. Thus, the single criteria for this category is:

5. For the R&D environment, the DSS should aid at least one of the project selection techniques such as checklists and profile charts, scoring

27

models, decision trees or goal programming.

Userfriendly. Both the hardware and software must work together to provide a userfriendly managerial system. Two criteria for judging this are:

6. The DSS should allow easy DEM building.

7. The DSS should facilitate sensitivity analysis after the DEM is built and the data entered.

Provide a Relevant Output. The output should be easy to understand and should not require searching through extraneous material to find the result. To provide this:

8. The DSS should provide multiple graphic and text report formats.

9. The DSS should allow comparison/analysis of the results with respect to the decision criteria/inputs.

Additional Research Criteria. The criteria (constraints) identified in Chapter II are:

10. The DSS must operate on a Macintosh microcomputer.

11. The DSS can be acquired by 31 April 1986.

12. The DSS can be bought for under $100.

This list of 12 criteria is the yardstick by which all of the candidate DSSs are measured. The next section provides a matrix chart for the selection of the DSS software that best satisfies these criteria.

DSS Software Selection

The 19 DSS software programs identified previously can now be rated against the 12 DSS criteria listed above. The DSS /Criteria Matrix is shown below in Table II. The left column of numbers corresponds to each DSS as it

28

TABLE II.

DSS Software/Criteria Matrix

Criteria #:	1	2	3	4	5	6	7	8	9	10	11	12	Total Y/N
DSS: 1	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	10/2
2	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	N	8/5
3	Y	Y	Y	Y	N	N	N	Y	Y	N	Y	N	7/6
4	Y	Y	Y	Y	N	N	N	Y	Y	N	Y	N	7/6
5	Y	Y	Y	Y	N	N	N	Y	Y	N	Y	N	7/6
6	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	10/2
7	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	11/1
8	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	11/1
9	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	10/2
10	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	N	9/3
11	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	N	9/3
12	N	N	N	N	N	Y	N	N	Y	Y	Y	N	4/8
13	N	N	N	N	N	Y	N	N	Y	Y	Y	N	4/8
14	N	N	N	N	N	Y	N	N	Y	Y	Y	N	4/8
15	N	N	N	N	N	Y	N	N	Y	Y	Y	N	4/8
16	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	N	9/3
17	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	N	7/5
18	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	N	7/5
19	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	N	7/5

is listed in the section on commercial microcomputer DSSs. The top row of numbers corresponds to each of the 12 DSS criteria derived previously. In the table, Y = yes and N = no; each DSS is scored against each of the criteria according to whether it meets the criteria (Y) or does not satisfactorily meet the criteria (N). The last column under Total Y/N is the total number of yes answers and no answers for each DSS. For example, the last DSS

29

listed (19) has seven yes answers and five no answers which results in an entry of 7/5 in the Total Y/N column. None of the DSSs listed satisfy all of the criteria, but DSS numbers 7 and 8 both have 11 yes answers. The no answer for both is a result of the price criteria: $145 for number 7 and $195 for number 8. Since both DSS numbers 7 and 8 have the same criteria score and operate on a Macintosh microcomputer, DSS number 8 is eliminated due to the higher price. In fact, when DSS number 7, DecisionMap, was ordered the price had dropped to $76 while DSS number 8 was still over $100. Therefore, DSS number 7 is the only one that actually meets all 12 criteria.

Thus, the first part of the research objective, to locate and acquire a DSS, is complete; the hardware subsystem is a Macintosh, which includes the operation software subsystem, and the application software subsystem is DecisionMap. The next part of the research objective is to realistically demonstrate and assess the DSS to see if it aids the project selection decision process. The data necessary to enable a realistic assessment is discussed next.

The Data

Inherent in performing a realistic assessment of this DSS is the data. The use of simulated data would provide only a simulated utility assessment. Therefore, actual project data, which are derived from the respective projects, are the best test of DSS utility. The data for this assessment were derived through a complicated methodology that involved numeric scoring and written comments on each of 49 projects and resulted in an unusually large amount and high quality of data not normally available

30

to the project manager-decision maker upon which to base a project selection decision. In brief summary, the method chosen for this task was first to provide a general overview of specific AI research areas and example AI projects to various experts in industry, academia, and the government. Each expert was requested to suggested at least one AI research project of his or her own design. The experts were then assembled to judge the merits of the prospective research projects. Thus, the research planning workshop for artificial intelligence in manufacturing was held on 31 July 1985 to 1 August 1985 in which the experts were each assigned to one of three groups corresponding to the project application areas of unit processes (Group 1), manufacturing systems (Group 2), and intelligent information handling (Group 3). Each panel of experts then scored the suggested projects in their area on criteria such as impact, payoff, and technical feasibility. The Group 1 projects were scored on a total of five criteria while the Groups 2 and 3 projects each were scored on six criteria. Each criteria was scored on a nine point Likert scale where one indicated a strong disagreement and nine a strong agreement. In addition, the scoring methodology required each panel of experts to score and discuss the projects in three assessment rounds in which commentary was specifically solicited from those experts that had marked a project significantly higher or lower than the mean score, also called the outlier comments, in an effort to capture information not apparent with numeric scores alone. (12:1-7)

In total, the AI project data presents the manager, faced with selecting which projects to pursue, a variety of information with which to make the choice; the project data consists of numeric data which gives a quantitative value for each project and expert (outlier) commentary data which gives a

31

qualitative value provided by those experts that rated a project significantly different from the mean score. Thus, a DSS could aid the project selection process by assisting the transition from a semi-structured to a structured decision process. This assistance could be provided through an evaluation of the numeric data along with an indication of the outlier comments that are associated with each project such that the project manager is provided a comparative view of each project with respect to the other projects in a group.

The whole system can be exercised to determine its utility once the data are entered in the DSS. The majority of the utility evaluation is as a result of the data preparation, data entry, and resultant DEM manipulation and decision results that are necessary for this research project. However, since this DSS is for managerial use the satisfaction of the intended users, managers, is paramount. Therefore, the instrument used for determining manager/user satisfaction with respect to this DSS is discussed in the next section.

The Management Questionnaire

The last section in this chapter is on the management questionnaire that is used to assess the degree of satisfaction that managers associate with this DSS. "Satisfaction of users with their information systems is a potentially measurable, and generally acceptable, surrogate for utility in decision making" (8:785) and several studies have been conducted on how to measure user satisfaction (1 and 8). The instruments that have been used for measuring user satisfaction contain questions that cover the range from DSS development and vendor support to DSS utility as perceived by the user

(1:336, 8:798). Since many of these areas are irrelevant to this effort a questionnaire was developed (Table III) that incorporates those areas that are relevant. In addition, since the DSS criteria for this project were developed, addressed, and met on a case by case basis previously and the "best fit" was chosen, the questions are designed to assess the utility of this DSS as it is perceived by the manager/user.

The general assessment areas are the DSS capabilities, output, preparation, userfriendliness, and overall satisfaction with the DSS. These areas correspond to question groups 1.2, 2.0 and 3.0 developed by Adelman, Rook, and Lehner (1:336). The specific questions on the management questionnaire relate to specific points and perceptions to assess about this DSS and also correspond to specific points of interest as indicated by Adelman et al., and Reimann and Waren (1:336, 18:168). Each question is scored on a five point Likert scale, as indicated in Table III, to indicate the managers' degree of agreement with the question. Thus, questions 1 through 4 ask the managers' perceptions about how well the DSS fits his or her decision environment. The perceived benefit and speed of the DSS output is judged by questions 5 through 7 and the manager's judgment of ease of DSS preparation for future decision situations is asked by questions 8 and 9. Next, the userfriendliness of the DSS as a whole, and the hardware subsystem and software subsystem individually, is asked by questions 10 through 12. Finally, the manager's actual perception of overall satisfaction with the system is addressed: Would improved decision making result if he or she used this DSS, would the manager use it, and recommend its use? These are asked by questions 13 through 15. Comments and

33

TABLE III.

MANAGEMENT QUESTIONNAIRE

Use a number from the scale below to indicate your
agreement/disagreement with questions 1-15.

```
NO                              YES
├─────┼─────┼─────┼─────┤
1     2     3     4     5
```
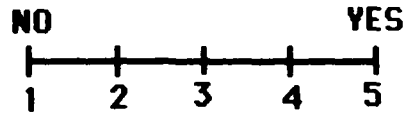
1. Is sufficient data incorporated for this to be a useful decision aid?
    ----
2. Could sufficient data be incorporated for future decisions?
    ----
3. Does this decision aid react reasonably when manipulated?
    ----
4. Does this decision aid simulate real world relationships?
    ----
5. Does this decision aid provide an understandable output/result?
    ----
6. Is the output/result relevant to the decision?
    ----
7. Is the decision aid operation sufficiently fast?
    ----
8. Do you think that future decision aid preparation would be easy?
    ----
9. Do you think that future data preparation would be easy?
    ----
10. Is the system (computer and software) easy to use?
    ----
11. Is the computer easy to use?
    ----
12. Is the software easy to use?
    ----
13. Would this decision aid improve your decision making?
    ----
14. Would you use this system?
    ----
15. Would you recommend use of this system?
    ----
16. Comments or recommendations?

recommendations are solicited for any area of interest or perception that the manager wants to add.

Conclusion

Chapter I set the stage for the potential use of commercial software for Air Force applications and identified the specific application as a managerial decision support system for project selection. In this chapter the system, Macintosh hardware and operation software subsystems and DecisionMap application software subsystem, has been selected. The project data necessary for a realistic demonstration of this DSS has been discussed and the instrument for assessing managerial perceptions about this DSS has been developed. The next step, operating the DSS with the data is performed in Chapter IV; the results of exercising the system with the data and the managerial assessment are discussed in Chapter V.

IV. Utility Analysis

Introduction

Chapter III concluded with the selection of the DSS program DecisionMap for the data analysis and managerial use, and development of the questionnaire for subsequent managerial feedback. In this chapter the general utility, including the decision model, the data, and the operating steps for this DSS, is discussed first. Then the specific utility and operation with respect to the AI project DEMs and project data are discussed, followed with the DSS results for each of the three groups of projects. One method for including the expert commentary, collected when the projects were scored, into the decision process is discussed and last, an example sensitivity analysis is performed. The managerial assessment of this DSS, as well as the impact of the general and specific DSS utility on the prospective manager/user is discussed in Chapter V

General Utility: The Decision Model and Data Structure

Previous research by Prince identified one of the techniques preferred by managers for project selection as a decision tree (15). The format used by DecisionMap is a decision tree; it provides a structured tree format for graphically building decision models. Each branch of the tree has a decision factor, or criterion, at the end of it. The criteria can each be weighted, to indicate their importance in the model, either as a quantitative amount on a scale from 1 to 100 or as a qualitative amount on a less-to-more weight scale. They can be called anything from "Bosses' Preference" to "C1", within a 20 character limit. After the decision criteria are identified, each

36

alternative is ranked on the criteria, again on either a quantitative or qualitative scale. Then the decision results are displayed as text or graphic outputs and the decision factor weights can be shifted for a sensitivity analysis. Thus, DecisionMap provides a structured decision tree format that fits any decision situation that requires a choice among pre-determined alternatives, where the relevant criteria for the decision can be identified, and the alternatives can be ranked on the criteria either quantatively or qualatively.

Operating Steps. The steps that must be followed to operate this DSS fall into three categories: DEM building, data entry, and sensitivity analysis. The steps should be followed in order if a new decision analysis is initiated, but the decision analysis could begin with data entry if a template is used , or sensitivity analysis if new data (or new weights for the decision factors) for a pre-built DEM is used. Throughout the following steps "menu selections" refer to the series of words in the menu bar across the top of the computer screen, each of which may be selected with the mouse causing a "pop down menu" to appear with DSS options in it. Various actions, indicated by the menu options, can then be caused to occur by selecting one of the menu items. The complete sequence begins with turning on the computer, inserting the DecisionMap disk and continues as follows:

1. Select and open the DecisionMap icon by "pointing and clicking," which means to move the mouse so the pointer/arrow is over the desired icon and press the mouse button twice. This process starts the DSS software.

2. The software automatically requests a name for a new decision, which is entered via the keyboard. Any name up to 20 characters long may be used, after which "OK" is entered by the mouse as explained above.

37

3. A blank DEM appears with the decision name at the "root" of the decision tree. The decision factors are then entered by selecting, again with the mouse, an empty factor rectangle. The software requests a name, not more than 20 characters long, for the decision factor which is entered by the keyboard. When OK is selected by the mouse the factor is added to the decision tree. Thus, a decision tree is built by adding all the decision factors; a factor on Level 1, the first layer of decision factors, can be sub-divided into five more factors on Level 2 and each of these can be further sub-divided in five more factors on Level 3. Therefore, there can be a total of five factors on Level 1, 25 on Level 2, 125 on Level 3 and and so on until the maximum memory of the computer is reached. In addition, if a decision required 25 factors, the Level 1 factors could be used as "dummy" factors, or non-weighted place holders, for the 25 factors in Level 2.

4. After the decision tree is complete the factors are weighted as to their importance in the decision model. This is accomplished first by selecting the level above the factors to be weighted and from which the factors are sub-divided, called the summary factor. For example, the Level 1 factors are weighted from the root decision name, selected by the mouse, and then selecting the "Weight" option from the "Factors" menu. The weight screen presents the user a set of columns with the name of the factors under them. Each column height is adjusted, with the mouse, to a height corresponding to the importance of the factor in the decision. The weight may be judged qualatively on a less to more scale or quantatively on a 1 to 100 scale. The columns are the same for both scales but the numeric values are displayed in the columns when the "Numeric" option is selected from the "Decision" menu. After all of the factors are weighted, the DEM is

complete and ready for the alternatives to be added.

5. Selecting the "List" option from the "Alternatives" menu presents the user with a screen for listing the alternatives. They are listed by selecting a blank alternative rectangle, typing in a name of 20 characters or less and comments of 50 characters or less, and selecting OK to continue. A maximum of five alternatives can be listed in each decision tree, which are then ranked on the last decision factors at the end of each branch of the decision tree, called the detail factors.

6. The alternatives are ranked on the detail factors by first selecting one of the detail factors and then the "Rank" option from the "Alternatives" menu. The rank screen is similar to that of the weight screen except that the columns have the alternatives listed under them instead of the decision factors. Each alternative is ranked on the decision factor, either qualatively on a worst to best scale or quantatively on a 1 to 100 scale, as described in Step 4. When the alternatives are each ranked on all of the detail factors the decision results can be viewed and a sensitivity analysis performed.

7. Selecting the "Results" option from the "Decision" menu presents the user with either the rank-ordered decision results or additional analysis outputs, some of which will be discussed later. In addition, to perform a sensitivity analysis, the user can switch between the decision results output and the weight screen to change the weights of the decision factors and then switch back to view the effects of the change on the results.

The seven steps discussed above are the basic process for operating this DSS. The DSS user can devise additional analysis techniques of his or her

own; decision factors can be added or deleted to see the results on the decision in addition to adding pertinent decision information in the comments of each alternative. In fact, the latter technique is used later with the AI project data as an indicator of relevant decision information that otherwise might not be provided to the decision maker. These seven steps, along with relevant comment information, are the process used for the specific utility analysis which includes building the project DEMs, entering the project data, and an example sensitivity analysis.

Specific DSS Utility: The Project Data

The numeric data set for each of the three project groups was collected during the Research Planning Workshop for Artificial Intelligence in Manufacturing. As discussed previously, the projects were scored by experts in the areas of unit processes, manufacturing systems, and intelligent information handling for Project Groups 1, 2, and 3 respectively. The Group 1 score sheet consists of five criteria (C1 through C5) while the Group 2 and 3 score sheets consist of six criteria (C1 through C6) each. Each criteria is ranked on a nine point Likert scale. Group 1 contains 15 projects, Group 2 contains 20 projects, and Group 3 contains 14 projects. Therefore, there is a maximum of 1,080 possible numbers necessary to fully describe the Group 2 scoring data, (20 projects X 6 criteria X 9 point scale = 1,080), 756 for Group 3, and 675 for Group 1.

DEM Data. Due to the large number of possible inputs, the mean score for each criteria is used as the basis for the numeric input data in the DEMs for the decision analysis. This requires a great deal of extra data preparation, in computing the mean of each score and then entering them into the

40

decision model, and results in a lack of versatility in identifying those projects that may have a bi-modal, or split, distribution due to a wide range of scores. Such projects may be of further interest to the decision maker if the accompanying outlier commentary indicates a discrepancy with the DSS numeric results; a technique is needed to link the DSS numeric results to the expert commentary since the raw data is not present in the DSS to provide the link. The DecisionMap software is not modifiable nor does it provide access to other software to supplement its capabilities. One method for providing the necessary link between the numeric results and the expert commentary is presented next.

Aggregrate Standard Deviation. A measure of the score dispersion is indicated by the standard deviation of the Likert scale scores. Since outlier comments were specifically solicited from those experts that ranked a project criterion significantly different from the mean of the panel, dispersion can be related to the commentary. In other words, the experts that caused a large standard deviation also wrote the comments. The aggregrate standard deviation (ASD) is simply the sum of the individual standard deviations of the five criteria for that project. The ASD is included in the DSS text report (Figure 4) under the comments column, next to the respective project score. It provides a quick system tie to the verbage.

It is difficult, at best, to judge the variance in scores on a project by looking at the individual standard deviations since they only vary from just under 1.0 to approximately 2.5; differences in project scoring are very hard to detect through a row of numbers. Therefore, the sum of the row, the ASD, is used as an indicator of score variance. A project that is numerically

ranked very high or low by the DSS and has a comparatively high ASD should be carefully reviewed by the decision maker to determine why, and if it should be considered for further development regardless of the DSS rank. The individual criterion standard deviation (Appendix B) can be inspected to determine if one or two specific criteria, or all criteria, contribute to the wide score dispersion. In either case, the expert commentary (Appendix A) can be reviewed to learn the experts' opinions about the project. Thus, not only is numerical ranking and analysis facilitated, but the judgment of the experts on the subject can be called upon, when needed, to assist the decision maker in the qualitative, semi-structured, decision process.

Data Entry. As mentioned above, the mean criterion score is the basis for the numbers entered into the DEM. For example, the Likert scale for criterion 1 of project 1 in group 1 is scored:

Scale:	1	2	3	4	5	6	7	8	9
Score:	0	0	1	3	2	4	5	0	0

This results in a C1 mean of $(3X1 + 4X3 + 5X2 + 6X4 + 7X5) + 15 = 5.60$. However, DecisionMap handles input data rounded to the nearest 0.5 and requires a scale from 1 to 100. Therefore, to minimize the effects of rounding and to facilitate data entry on the 1 to 100 scale, the means are multiplied by 10 and a mean of 5.47 is entered as 54.5, 7.13 as 71.5, 6.21 as 62.0, 3.68 as 37.0, etc. The tables of means/entered values, standard deviations, ASDs, and an examination of the rounding error, are in Appendix B.

42

DSS Results

DecisionMap can operate on only five alternatives at a time. Therefore, the project groups must be divided into sets of five or less. This results in four DEMs for Group 1 (which has 15 projects), five for Group 2 (20 projects), and four for Group 3 (14 projects). The extra DEM in each group provides for ranking the top five projects identified in each set of five. The general DSS operating procedure was discussed previously; only a brief explanation and the results are presented here.

Group 1, Projects 1-5 Results. After the DEM is built and the project scores entered as the rank on each criterion, the decision results for projects 1 through 5 can be viewed as text, graphically, or in two different graphic comparisons for analysis. The Text Report (Figure 4) presents the projects ordered from highest (on top) to lowest (on bottom) numerical rank with the ASD for each project listed in the comments. The Graphic/Numeric Results (Figure 5) show the relative rank of each alternative compared to the other in a graphic format. Either Figure 4 or 5 will show the decision maker the top ranked alternative, but only Figure 4 indicates the ASD, which is discussed more later. The Numeric Comparison (Figure 6) indicates the importance of each criteria in the total score for each project. Last, the Graphic Comparison (Figure 7) is an illustration of the individual score that each project had on a specific criterion. Each figure is taken directly from the DecisionMap program but they have been edited to better fit in this report. Therefore, the vertical scales are not full size but the representations are accurate otherwise.

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         Alternative          Score   Comments

         Proj #4              93.34 ASD : 5.91

         Proj #5              92.80 ASD : 6.15

         Proj #1              82.22 ASD : 6.35

         Proj #2              80.72 ASD : 7.73

         Proj #3              80.12 ASD : 9.68
```

Figure 4. Group 1 Projects 1-5 DSS Text Report
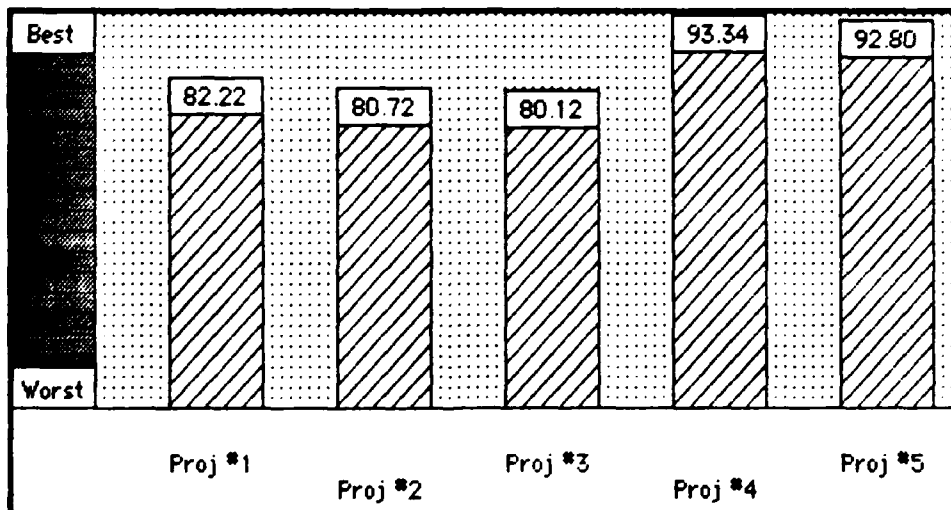
Figure 5. Group 1 Projects 1-5 Graphic/Numeric Results

44
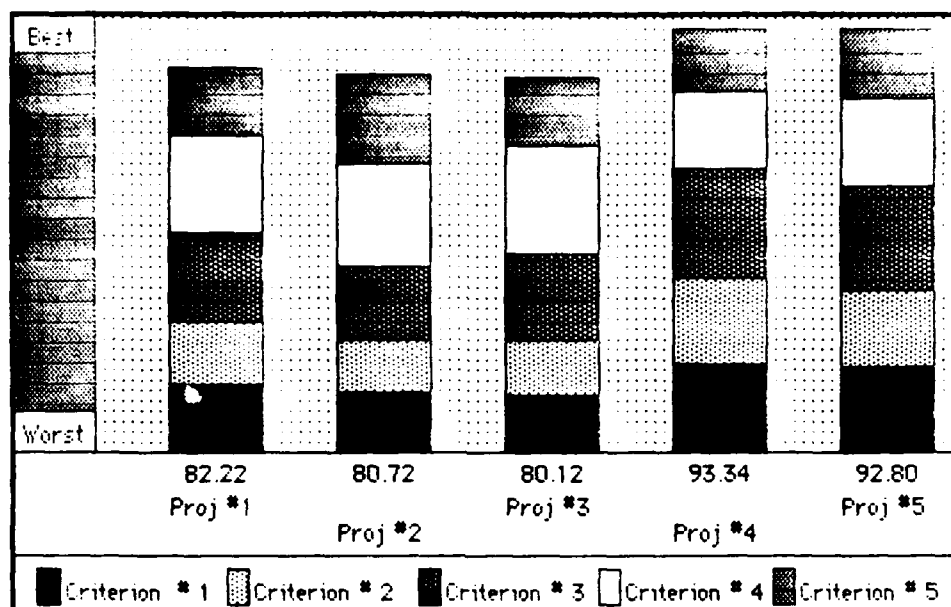
Figure 6. Group 1 Projects 1-5 Numeric Comparison of Results
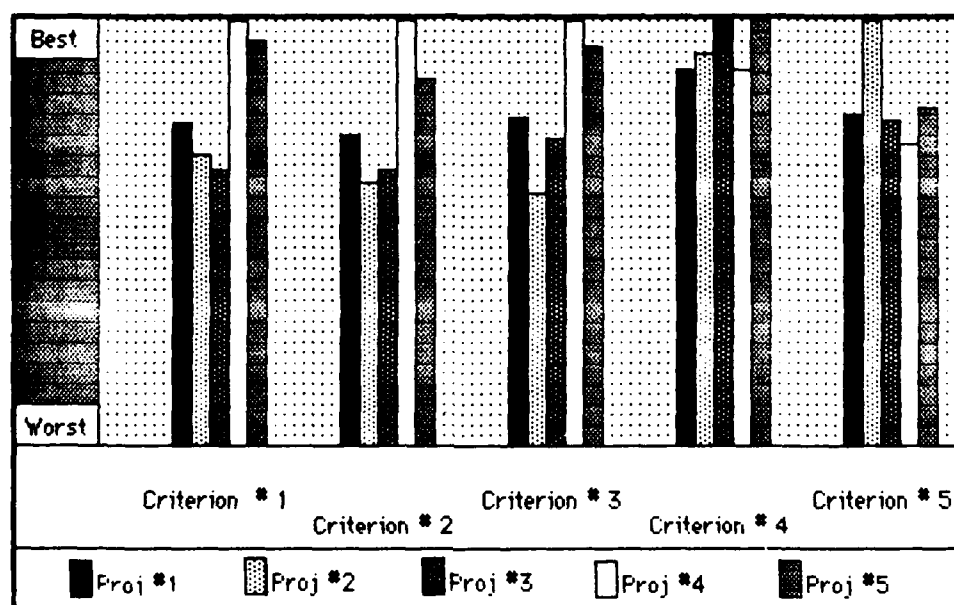
Figure 7. Group 1 Projects 1-5 Graphic Comparison of Results

As mentioned above, Figures 6 and 7 illustrate one of the analysis tools provided by this DSS. Figure 7 shows how each project compares with respect to the others on the Level 1 criteria, and can be used by the decision maker to see which alternatives scored highest or lowest on a particular criterion. However, Figure 6 gives a visual indication of the contribution each criterion makes toward the total score of a project. A sensitivity analysis is facilitated by changing the weight of one of the criteria and then viewing the resultant change on the numeric comparison. Thus, the importance, or insignificance, of a particular criterion on the decision results can can be revealed by a large change in the result or very little change in the result.

Group 1, Top 5 Projects. The decision process described above results in identification of two high DSS score projects in the first five project set in Group 1. As mentioned previously, four DEMs are built for Group 1: One for projects 1 through 5, one for projects 6 through 10, one for projects 11 through 15, and one for the top five projects identified in the other three DEMs. The same DEM is used for each set of five projects and the project data are entered exactly the same way. Then the projects with the highest numeric scores are reentered into the Top 5 DEM to prioritize them. Thus, the top five projects in Group 1 are listed in order in Figure 8 and shown graphically in Figure 9.

```
       Alternative          Score   Comments

       Proj # 14            94.76 ASD : 5.77

       Proj # 6             91.80 ASD : 6.77

       Proj # 5             90.78 ASD : 6.15

       Proj # 4             90.68 ASD : 5.91

       Proj # 10            90.44 ASD : 5.79
```

Figure 8. DSS Text Results on Group 1 Top 5 Projects
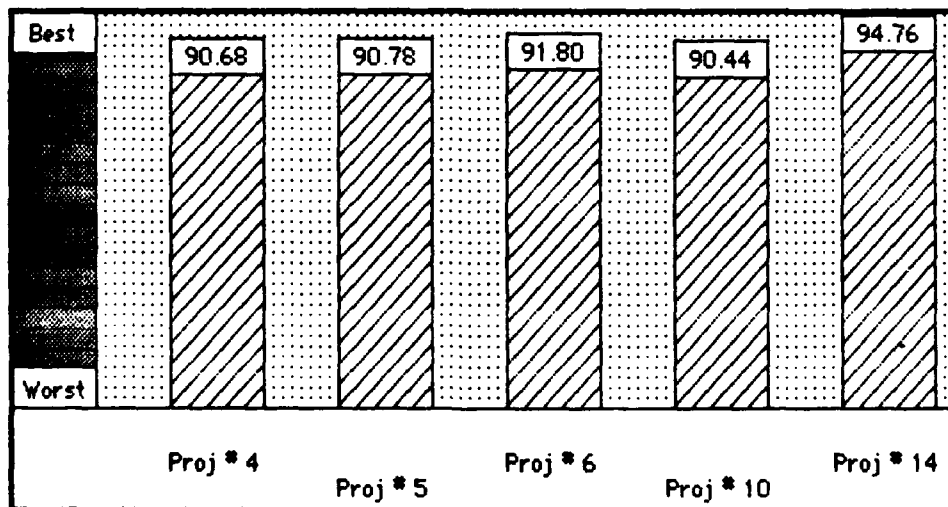
Figure 9. DSS Numeric /Graphic Results on Group 1 Top 5 Projects

Groups 2 and 3 DEM. Groups 2 and 3 are treated like Group 1 with the exception of adding criteria 5 and 6 to level 2 via the dummy factor called Time & Resources, as discussed in Step 3 of the operation steps. The weight of the Time and Resources factor is twice that of the other factors since it contains two criteria.

Group 2,Top 5 Projects. The following figures, 10 and 11, are the decision results for the Group 2 projects.

```
Alternative          Score   Comments

Proj *  5            97.55 ASD :  10.26

Proj * 2             92.15 ASD :  9.75

Proj * 16            90.47 ASD :  7.66

Proj * 13            86.34 ASD :  7.10

Proj * 10            85.78 ASD :  7.53
```

Figure 10. DSS Text Results on Group 2 Top 5 Projects
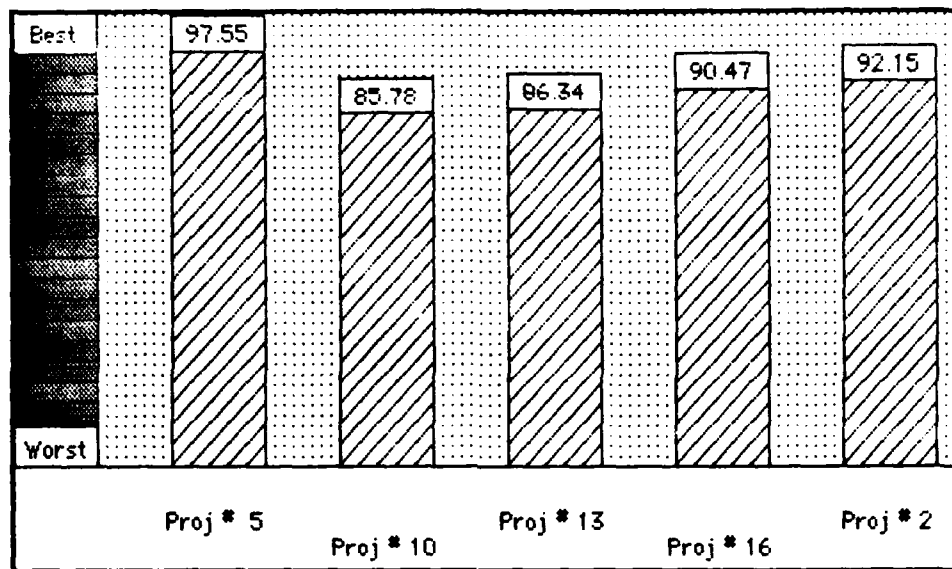
Figure 11. DSS Numeric/Graphic Results Group 2 Top 5 Projects

Group 3, Top 5 Projects. Last, the Group 3 top five projects are
presented in Figures 12 and 13. The Group 3 DEM is the same as the Group 2
DEM; the data preparation and entry is the same for both groups also.

Alternative	Score	Comments
Proj # 4	97.84	ASD : 6.73
Proj # 2	91.72	ASD : 8.17
Proj # 8	89.24	ASD : 8.20
Proj # 14	87.02	ASD : 9.40
Proj # 6	85.97	ASD : 6.69

Figure 12. DSS Text Results on Group 3 Top 5 Projects
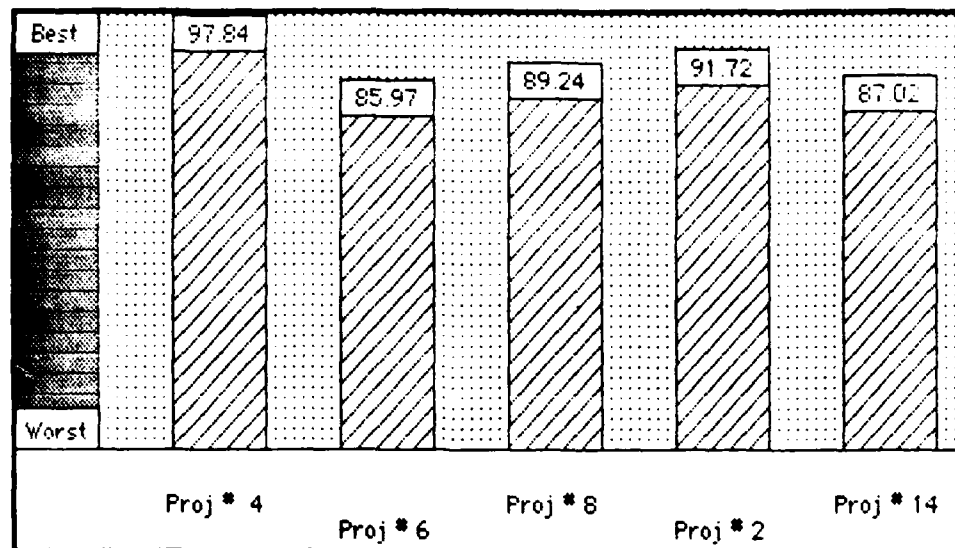
Figure 13. DSS Numeric/Graphic Results on Group 3 Top 5 Projects

ASD Analysis. As discussed previously, the ASD is included to decrease some of the uncertainty associated with the project ranks. For example, the ASDs corresponding to the first five projects in Group 1 (Figure 4) indicate an increasing score dispersion as the project rank decreases; there is more agreement by the experts on the top two projects, 4 and 5 with ASDs of 5.91 and 6.15 respectively, than there is on the bottom two projects, 2 and 3 with ASDs of 7.73 and 9.68 respectively. The ASDs for the top five projects in Group 1 (Figure 8) however, show no trend and little variance (5.77 to 6.77). This may indicate an agreement by the experts as to the relative merits of these projects.

The ASDs for the top five projects in Groups 2 (Figure 10) and 3 (Figure 12) are larger due to more decision criteria (Six for Groups 2 and 3,

50

five for Group 1). Also, these indicators have a wider spread, from 7.10 to 10.26 for the Group 2 top five projects and from 6.69 to 9.40 for the Group 3 top five projects. This indicates more disagreement by the experts on scoring both groups.

Two points are noteworthy on the ASD:

1. Two projects in the Group 2 top five, projects 5 and 2, and one project in the Group 3 top 5, project 14, have high ASDs. Each of these projects, and their corresponding expert commentary, should be reviewed before proceeding with them. For example, Group 2 Project 2 has a total of seven comments, three of which consider it too narrow in scope while two other comments suggest either that this project is not an innovative AI application or alternative approaches to the problem. The Project 2 negative comments suggest that although the DSS numeric score is high the project is not worth pursuing. Group 1 Project 5 has four comments; three say that there is not enough knowledge about or explanation of the project and one says the impact is substantial but says nothing about how the project is to be accomplished. Having such a relatively high ASD and negative comments, Project 5 of Group 2 should be eliminated also. On the other hand, Group 3 Project 14 has only four comments all of which agree that this is an ambitious, important, but very difficult project. The Project 14 comments, unlike those discussed above, reveal that the experts think this project is worthwhile and should be developed with the awareness of its difficulty and possible problem areas.

2. At least one project in each group has a very high relative ASD and was not ranked in the top five projects for that group by the DSS. (Appendix B, Group 1 project 7, Group 2 project 11, Group 3 project 7)

51

These projects, and commentary, should be reviewed to determine the cause for the dispersion, if possible, and to decide if one or more of these projects should be considered for further development regardless of the actual scores by the experts.

Group 1 Project 7 has four comments, three questioning the project's concept, objectives, and technical feasibility and one suggesting that the basis of the work is already accomplished. Project 7 is rightfully scored low by the DSS and should not be considered further.

Group 2 Project 11 has 18 comments. Most of the comments indicate that this project takes the wrong approach to the problem, is simplistic and vague. Only in one of the 18 comments does the expert see this project addressing an important problem that can be solved. Project 11 is properly ranked by the DSS and also should not be considered further.

Group 3 Project 7 has 12 comments. Only two comments are clearly negative while six comments suggest that this project very important and achievable. Many of the comments have mixed content such that the project is recognized as important but the experts feel that it is being addressed by other means or that the project description lacks content. With such an overall agreement on the importance of Project 7 and general agreement that it is achievable, Project 7 should be considered for further development.

Example Sensitivity Analysis. This DSS is intend for managerial use. The manager can perform a sensitivity analysis simply by shifting the weight on any of the criteria to see what effect it has on the decision results. For example, if the manager decides that criterion 5 in the Group 1 top five DEM is twice as important as the other four criteria, the weight is

changed to two and the decision result is then reevaluated. This result is shown in Figure 14.

```
Alternative          Score   Comments

Proj # 14            94.24 ASD : 5.77

Proj # 6             92.14 ASD : 6.77

Proj # 5             92.03 ASD : 6.15

Proj # 4             90.46 ASD : 5.91

Proj # 10            88.07 ASD : 5.79
```

Figure 14. Example Sensitivity Analysis: C5 Shifted X2

The numeric score of each project is changed as a result of shifting C5 to twice the weight of the other criteria, but the rank of each project has remained the same. This indicates that the project ranks are stable with respect to small changes in C5. Figure 15 shows the results of a large change in C5: The weight is changed to five times that of the other four.

```
          Alternative           Score   Comments

          Proj # 5              94.77 ASD : 6.15

          Proj # 14            94.04 ASD : 5.77

          Proj # 6              93.38 ASD : 6.77

          Proj # 4              90.79 ASD : 5.91

          Proj # 10           84.81 ASD : 5.79
```

Figure 15. Example Sensitivity Analysis: C5 Shifted X5

In Figure 15, the numeric scores of the projects reflect a change in
project rank; project 5 has moved from third rank to first while the other
four have only shifted down in rank. This indicates that only project 5 is
sensitive to large changes in the weight of C5 and the other four remain
relatively stable with respect to the others. The manager can shift the
weights of the other criteria in the same way to assess the sensitivity of
this project group to the other criteria. In addition, the numeric
comparison, illustrated in Figure 6, could be used to see the effect that
changing the criterion weight has on each project score. However, each DEM
must be analyzed separately and if a shift in criteria weight causes a
change in project rank in the other DEMs, the new top scoring project must
be reenterd into the top five project DEM for further analysis. Thus, the
limit of five alternatives per DEM could cause the sensitivity analysis of a
large number of alternatives to be an iterative process consisting of
analysis and reentering the project data if a change in criterion weight

changes the result.

Conclusion

The general DSS utility been discussed, which led to the specific DSS utility and exercising the DSS with actual project data. Exercising this DSS with the AI project data has revealed some deficiencies and strong points in the system. These points, along with the managerial assessment, are discussed in the next chapter.

V. Discussion and Conclusions

Introduction

Inherent in the general and specific utility analyses performed in Chapter IV are the general use case, and the specific use case which is a single situation sub-set of the general case and utility. In other words, there are many decision situations and data types, illustrated by the general decision structure, data structure, and operation steps, for which this DSS may be used. The specific utility relates to the specific situation that results when one decision situation and data type, illustrated by the AI project selection and data, is applied to this DSS.

This DSS has several limitations that were identified through exercising it with the project data for this thesis. These limitations are first discussed as a special case of operation and use. Some of the criteria identified in Chapter II are well met, and this is discussed next as a general case along with the results of the management questionnaire. Then, some conclusions are drawn from the lessons learned about the special and general cases. Some ideas for future DSS research, and possibly development, are presented last.

The Special Case

The special case of exercising the hardware sub-system and DSS software sub-system with the AI project data presented a unique problem: The AI projects were scored in such a way as to elicit the most possible information from the experts about the projects, including their comments which comprise an integral part of the information. A DSS is needed to

56

assist the project manager not only with the structured, numerical, analysis, but with the semi-structured, expert commentary, analysis also. The special case of the AI project data and the expert commentary as it is used in this DSS is discussed first.

The Expert Commentary and ASD Utility. As discussed in Chapter III, the AI project data was collected through a complicated methodology that resulted in numeric, quantifiable, scores as well expert comments, or non-quantifiable scores. The methodology was designed to provide data superior to that normally associated with project selections.

The data is incorporated into this DSS on a strictly numeric basis. This required a great deal of data preparation, which is discussed later, and the development of a technique for alerting the decision maker when the expert commentary could significantly alter the DSS-suggested numeric-only decision result. The technique devised is the aggregrate standard deviation (ASD). As indicated in the ASD analysis in Chapter IV, it provides an indication of overall numeric score dispersion on each project by way of the standard deviations of the individual criteria scores for each project; comments were solicited from those experts that scored a project significantly different from the group mean and therefore aided in the resultant high standard deviation. Therefore, the ASD provides a numeric indicator of, or a signal alerting the decision maker to review, the non-quantifiable expert commentary. The ASD provides the benefit of the expert commentary without the task of reviewing every comment for each project. Only those comments that are significant as indicated by a relatively high ASD need be reviewed. In addition, a connection to the information provided by the expert commentary would not be provided by

this DSS without the ASD due to the almost non-existent text capability of DecisionMap. This limitation is discussed more later but means that the expert commentary relating to a specific project must be looked-up in the project report (12) by the decision maker. The ASD-expert commentary connection, or text-to-DSS capability of this system, leads to some specific limitations.

Three areas of limitation are apparent as a result of the special case, or exercising this system with the project data: The number of alternatives, the data preparation/entry, and the text capability.

Number of Alternatives. The number of alternatives allowed by DecisionMap, five in each DEM, is the first limitation encountered. This will not permit a complete decision analysis that involves more than five alternatives to be performed in one model and necessitates the building of multiple DEMs as in the specific utility analysis. One method that eases this problem is to build a blank DEM, called a template, which is used for each set of alternatives and just enter the data and alternatives for each part of the analysis. However, this still does not provide analysis of the whole problem in a single model. In addition, approximately one hour is required to build the template and enter the data, by hand, for an analysis of a group of 15 or 20 projects as was performed on the AI project data. This does not include any data preparation such as calculating standard deviations or ASDs. A project manager would not have the time nor the inclination to perform these tasks. Thus, an analyst would almost always be needed for DEM preparation. Only in the case of an occasional, or "sensitive" (e.g. One that the manager wishes to keep private), analysis with five or less alternatives and little or no data preparation would a manager be likely

58

to prepare the DEM instead instead of having it prepared.

As a last point on the number of alternatives, every change requires a trade-off: If the maximum possible number of alternatives was increased to 50 or 20 or even 10, system complexity would also increase while ease of use and speed of output would decrease. For example, 10 alternatives would require multiple alternatives list screens instead of just one, a compressed or multiple ranking screens, and a compressed numeric/graphic output similar to Figures 9, 11 and 13 but with all 10 alternatives presented instead of only five. In addition, 10 alternatives would require approximately two times the calculations required for five alternatives, slowing the output response speed and forcing the decision maker to wait for the output.

Data Preparation/Entry. Data preparation may range from easy, requiring no change from its raw form, to difficult, requiring financial or statistical manipulation. Much of the statistical data preparation for the project analysis was performed and is presented in the project report (12:A-39 to A-42, B-49 to B-54, and C-47 to C-50). However, if the mean criterion scores and standard deviations were not available, they would have had to have been calculated for the decision analysis. As it was, the ASD for each project had to be hand calculated and entered, as well as multiplying and rounding the mean criterion scores as described in Chapter IV. This process added another half hour to the preparation for each DEM. Again, a project manager is not likely to perform this type of data preparation.

The data manipulation described above and in Chapter IV results in a loss of some versatility since the raw project scores are not used. For example, if the Likert scale scores and the scale weights were entered in a

table format from which the DSS could read, the decision maker could review them to see if there is a split opinion causing a high standard deviation instead of depending on the ASD, etc. A split opinion, or bi-modal, indicator could be programmed into the DSS to alert the project manager if the expert commentary should be reviewed instead of requiring the project manager to visually review the ASD along with the project rank to determine if the comments should be reviewed. In addition, the criteria score standard deviations were previously calculated; if the DSS had a statistical calculation capability the standard deviations and the ASD could be computed directly from the data and used in the DSS. However, both modifying DecisionMap and linking it to other software are not possible, as mentioned in Chapter IV.

Two additional points about the AI data and its preparation are noteworthy. First, if the AI project data had not been available it would have been necessary to find other, and possibly less complete, project selection data with which to test this DSS. This means that appropriate project data would have to have been located, and, if not already available with the data, the decision criteria would have to be established for a decision model and a ranking methodology for the projects on the criteria would have to be developed. Second, in all likelihood only a numeric decision analysis could be performed since expert commentary does not usually accompany project scoring data.

The data entry is the easiest part of this process; a bar graph scale is moved by the Macintosh mouse to the appropriate number (Operation Step 6, Chapter IV) for the alternative and the ASD is typed into the comments space provided for each project. However, this becomes laborious with a

large number of alternatives and/or a large number of decision criteria and it took approximately an hour and a half total for data preparation and entry for each project group. An analyst is needed for large decision projects of this type.

Finally, as mentioned above, there a trade-offs involved with every increase in system power or flexibility. If the raw scores were used in this decision situation there would be 2511 numbers to enter (Chapter III), rather than the 279 mean scores. This is not only more work, and nine times the possibility for more errors in data entry but, would require a link between the data and the DSS and would require the DSS to perform additional calculations to arrive at the decision results, both of which would slow the output and reduce userfriendliness. In addition, a direct link to the data indicating a bi-modal distribution would result in an increased complexity of DEM building, decreased manager userfriendliness and only further ensuring that the manager would not be involved in the DEM building process.

Text Capability. Most project assessment data do not include expert comments, or a qualitative assessment, associated with attributes of the numeric, or quantitative, assessment as does the AI project data descr ued in Chapter III and discussed above. The "richness" of the AI project data would be lost without the expert commentary. Therefore, the method developed with the ASD provides a "flag" for the manager to review the expert commentary, but they must be looked up in the AI project report. This is not a hard process, and the necessity may not arise often in project selection, but in this case text handling capability would have been beneficial. It would be easier to incorporate all of the comment data in the

DSS for review by the manager when desired. In addition, the name length of 20 characters for the alternatives and decision criteria and 50 characters for the alternative comments causes a restriction on the descriptive nature of names and comments that can be used. For example, "Consistency With Overall Goals/Objectives" (12:A-5) would be preferable to C1 as a criterion name and would facilitate sensitivity analysis by clearly indicating which criterion weight is being changed rather than having to know each criterion or look it up. In the same way, Proj 1 for "AI Configuration Design of Modular Fixing Based on System (12:A-7) does not provide the decision maker any information about the specific project. On the other hand, short non-descriptive names prevent bias from entering, either intentionally or unintentionally, into the criterion weights or project ranks. As discussed above, every increase in power results in a trade-off and in this case the trade-off includes increased name length in trade for an increased possibility of bias and a decrease in ease of use, possibly by having multiple name entry screens to accommodate the increased name length.

The General Case

The areas discussed above indicate the limitations revealed through the special case of exercising the system for this project. The general situation assessment is a result of demonstrating this DSS to managers for their perceptions of DSS utility. As argued in Chapter III, an assessment of managerial satisfaction with this DSS may be used as a measure of DSS utility (8:785). This DSS was demonstrated to 11 managers, ten of which were either military or civil service employees involved in Air Force project management and one civilian involved in DSS development. Most of

62

the demonstration/assessment sessions were one-on-one, with only the manager and researcher present, but in one session three managers were present and in another two managers were present. As described in Chapter II, the demonstrations were considered "hands-on" since each manager had the opportunity to manipulate the DSS after the DSS operation was explained to them. The demonstrations were accomplished by carrying the system, comprising of the microcomputer and software, to each manager's office. The hardware set-up only required connecting the keyboard and mouse to the computer and plugging the computer into a wall outlet. An verbal overview of this research effort was provided to each manager, after which the specific case of the AI projects was explained and the demonstration of this DSS began with starting the software as explained in Step 1 (Operation Steps, Chapter IV) and progressed through Step 7, decision results and sensitivity analysis. Each demonstration lasted approximately 20 minutes, followed by an opportunity for the manager to manipulate the system for approximately 40 minutes; in the cases where more than one manager was present the hands-on session was extended to as much as one and one-half hours. At the end of the session each manager completed the management questionnaire, developed in Chapter III, which asked the manager's perceptions about this DSS with respect to the areas of the decision environment, output and speed, ease of preparation, userfriendliness, and overall satisfaction with the system. The mean scores on the questionnaire questions are in Table IV along with a representation of the questionnaire; each question was scored on a five point Likert scale where a score of three on a question indicates no opinion,

Table IV.

Management Questionnaire Mean Scores

Use a number from the scale below to indicate your
agreement/disagreement with questions 1-15.

NO   YES

| | | | | |
|1|2|3|4|5|
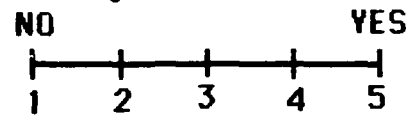
		Mean Question Score
1.	Is sufficient data incorporated for this to be a useful decision aid?	4.27
2.	Could sufficient data be incorporated for future decisions?	4.64
3.	Does this decision aid react reasonably when manipulated?	4.80
4.	Does this decision aid simulate real world relationships?	4.18
5.	Does this decision aid provide an understandable output/result?	4.55
6.	Is the output/result relevant to the decision?	4.55
7.	Is the decision aid operation sufficiently fast?	4.64
8.	Do you think that future decision aid preparation would be easy?	3.82
9.	Do you think that future data preparation would be easy?	3.50
10.	Is the system (computer and software) easy to use?	4.73
11.	Is the computer easy to use?	4.82
12.	Is the software easy to use?	4.73
13.	Would this decision aid improve your decision making?	4.18
14.	Would you use this system?	4.27
15.	Would you recommend use of this system?	4.27

16. Comments or recommendations?

one indicates a negative response and five indicates a positive response. In addition to the responses in the above areas, the managers were asked for comments and recommendations and they identified training and the Macintosh hardware subsystem, which is not Air Force standard equipment, as problem areas. Training and hardware are discussed later as they relate to the broader issues of the general case as opposed to the more narrow scope of the specific case.

In summary, the questions are designed to elicit a manager's perceptions with respect to this DSS about how well it fits the decision environment (Questions 1-4), the output and speed (Questions 5-7), ease of preparation (Questions 8,9), and userfriendliness (Questions 10-12). Although the number of managers surveyed is not large enough to be valid for a statistical analysis, a preliminary indication of whether or not this DSS aids the decision process can be derived. A discussion of these results follows. The raw scores and comments are in Appendix C.

The Decision Environment. In an effort to represent the decision environment this DSS was assembled to simulate one type of decision trade-off that project managers make for project selection, a decision tree as was found by Prince (15). This includes the amount of data incorporated into the DEM and how the DEM reacts when manipulated, as well as the real world decision relationships that the DSS that is intended to support. Questions 1 and 2 on the management questionnaire ask about the amount of data used in the project DEMs and the amount of data that may be incorporated in future DEMs. The amount of project DEM data are considered sufficient with a mean question score of 4.27, but the limit of five alternatives per DEM has an impact on this question; over half of the

managers felt that this limit is a problem. Others felt that it could be adequately worked around or they do not routinely have more than five alternatives to choose among. Very large DEMs, of 125 factors on Level 3 and 625 factors in Level 4, can be built and are limited in size only by the memory in the computer. The managers recognized this; the mean score for question 2 is 4.64 which indicated a high degree of agreement with the question of sufficient data for future DEMs. However, a decision requiring even 100 separate factors would be incomprehensible to most people; it would need to be divided into smaller parts that could be easily managed and understood by the decision maker. There were no comments, verbal or written, about the amount of data but one manager did comment that the link to a data base, and the corresponding functions, is a necessity that is missing.

Question 3 asked if the DSS reacts reasonably when manipulated; this is an effort to determine if the managers understood the decision model and what it does when the weights of the criteria are shifted. The mean question score is 4.80 which indicates a high degree of agreement with the question. The only comment on this question suggests that automated sensitivity analysis, by computerized subroutines, would be a help.

The heart of the DSS is its ability to simulate the real world relationships that the manager must deal with to make a project selection. Question 4 asks this and the managers responded with a mean question score of 4.18. Written and verbal comments reveal that the managers feel that real world decisions are less structured and require more interaction with people, with the emphasis on people making decisions, not machines. This same point is made by both Davis (4:368-369) and North (13:200). However,

66

the mean question score indicates that the managers answers tend more toward the positive than a neutral or negative response.

DSS Output and Speed. Questions 5 and 6 deal specifically with the understandability and relevancy of the DSS output. For example, the managers were shown the numeric/graphic outputs as in Figure 9 and text outputs as in Figure 8 which show the rank-ordered alternatives, as well as the decision analysis outputs as in Figures 6 and 7. The mean question score on both questions is 4.55 which indicates that most managers understood the outputs and that they are sufficient for the project selection type of decision situation. The text capability was not identified as a problem in the general case as it was in the special case; sufficiently descriptive alternative and decision factor names, for general use, can be entered into DecisionMap's 20 character length name limit. Verbal comments indicated that the graphical outputs are much more preferred by the managers than the long lists of numbers that they are accustomed to receiving from other computer applications. In addition, the DSS response when the decision results are requested, or when a criterion weight is changed for a sensitivity analysis, is almost instantaneous. "Speed of response" is an important DSS attribute identified by Wagner (22:78). Question 7 asked if the DSS is sufficiently fast and the question mean score is 4.64, which indicates that the managers felt that the outputs are presented sufficiently fast.

DSS Preparation. The DEM and data preparation have been discussed previously. Most of this information (With the exception of the ASD which had not been included in the DEM when the demonstrations were accomplished) was discussed with the managers. The managers all felt that

the problem definition, building a proper decision model, and then preparing the data are the most difficult parts of a decision analysis. This is reflected by the mean question scores of 3.82 and 3.50 on Questions 8 and 9 which ask if the managers think that future decision aid preparation and data preparation would be easy. The subject of DEM and data preparation evoked the second-largest number of verbal and written comments. For example, two managers felt that the process of building the DEM and entering the data on the computer is almost trivial but that defining the problem and the decision criteria before building the DEM is often an almost impossible task. Another manager preferred computer simulation techniques for "Selection and structuring of the decision model". One manager noted that this DSS only manipulated the data, that data gathering and preparation is the hard part. However, the managers felt that the decision-tree format provided by DecisionMap does aid the process of converting their mental decision trade-off to a more structured and understandable decision format, even if defining the problem and gathering the data are the hardest parts of the decision analysis.

Userfriendliness. "Perhaps the single most vital criterion" (17:23) for a DSS intended for managerial, and possibly infrequent, use is userfriendliness. This subject provided the greatest number of comments, both verbal and written. Thus, Questions 10 -12 ask the manager's perceptions about the system, computer, and software userfriendliness. The sub-system components are separately identified in these questions in a effort to see if the managers perceive a distinct difference in the computer subsystem operation (Macintosh) as opposed to the application software subsystem operation (DecisionMap) and the operation in combination, or the

68

system as a whole. A single question about the system userfriendliness could hide the perception that the hardware is easy to operate while the software is confusing, or vice versa. However, this is not the case since Questions 10 and 12 both have a mean question score of 4.73 (On userfriendliness of the system and software, respectively) and Question 11 has a slightly higher mean score of 4.82 (On userfriendliness of the computer). The managers agree that this is the most userfriendly system that they have encountered; all but one felt that the icon/mouse operating system is superior to menu-driven command-oriented computers, is easier to use, and provides a pleasing graphics interface. In addition, all but two managers verbally commented that they felt that the system provided an environment that aids the decision process through the visually oriented process of building decision models and sensitivity analysis. The manager's understanding of the DEM building process and sensitivity analysis is discussed in the section on training. Finally, the managers (Again all but one) expressed the desire for this type of userfriendly interface to be transported to other microcomputers and applications even if this specific application does not completely fulfill their requirements.

Overall Satisfaction. Rather than ask each manager's opinion about overall satisfaction with this system, which could be interpreted in many different ways due to the complexity of the system and the one-on-one demonstration scenario, the managers were asked if they thought this system would improve their decision making and if they would use, and recommend use of, the system. Question 13 asks if the managers think that this DSS would improve their decision making; the question mean score is 4.18. This indicates that some improvement in decision making may be

perceived but there were no specific comments, other than those mentioned previously on the number of alternatives and DEM preparation, about this subject. Questions 14 and 15 ask if the manager would use and recommend use of the system, respectively. Question 15, asking if the manager would recommend use of the system, was included to add additional information on how satisfied a manager is with the system; he or she might say that they would use the system, but are they satisfied enough with the system to recommend its use to someone else? The mean question score on both questions is 4.27 which indicates that the managers feel the same about using the system and recommending its use. Four managers thought that they could put the system to immediate use on current decision problems that they were working on if they had it available. All but two of the managers responded verbally that this DSS would be an aid for improved decision making in some situations, but most wanted the capability for more alternatives, as indicated previously. Finally, some managers were "overwhelmed" by the system as a whole since it is so drastically different from any that they had seen before. They would have liked more time to learn and use the system.

Training. The objective of the managerial demonstrations was for the manager to learn the basic operation of this DSS and put it to immediate use. Two points were stressed for the managerial demonstrations: First, the managers do not have much time to give for testing a system and second, the system is targeted for managerial use with minimum training and therefore exhibits extreme, almost intuitive, ease of use. Every manager quickly caught on to the system operation, DEM building and sensitivity analysis, and decision result manipulation. However, they had trouble

70

relating to a decision situation that they were not familiar with before hand (Such as the AI projects) with the result that some managers built a DEM for a decision that they were currently working on and therefore familiar with. The other managers preferred to exercise the system with other pre-built examples on such things as buying a car or house. This illustrates the need to be familiar with a specific problem before a rational decision analysis can be performed. In addition, every manager felt that they did not have enough time with the system to fully judge its capabilities and weaknesses. Although the brief training demonstration was sufficient to get the managers started, an extended amount of time with the system is required for a better analysis of it and therefore, an improved feedback for future DSS research.

Conclusion and Recommendations

The research objective was to locate, acquire, demonstrate realistically, and assess a commercial microcomputer decision support system that supports and aids the R&D project manager's semi-structured project selection decision process. The research objective resulted in two investigative questions:

1. What are the semi-structured decision processes that Air Force R&D project managers use now when assigning program priorities? This question was answered by two previous researchers, Lee (11) and Prince (15), and was found to be checklists and profile charts,scoring models, decision trees, and goal programming. A project manager faced with the particular decision situation of deciding which alternative project (or technology) to pursue, using one or more of these techniques, is termed

71

to be operating in the decision environment.

2. What commercial microcomputer decision aid best fits the specific DSS criteria and will aid this R&D semi-structured decision environment? This question required multiple steps to arrive at an answer.

First, the composition of a computer based decision support system was determined to be the hardware sub-system, the operation software sub-system, and the application software subsystem.

Second, the characteristics and functions of a DSS were found in the literature. These characteristics and functions, along with some research constraints, were used to develop 12 specific criteria for this managerial DSS.

Third, the hardware sub-system was selected on the basis of research constraint number three (criteria number 10 in Table II) and the specific DSS criterion that dictates userfriendliness for a managerial DSS. Although userfriendliness, like beauty, is in the eye of the beholder, the hardware sub-system trade-off revolved around a typed-command keyboard-entry computer (IBM or compatibles) that is widely available in the Air Force and a mouse operated visually-oriented computer (Apple Macintosh) that is much less available in the Air Force but requires little typing to operate and simulates the manager's desk-top working area. The Macintosh was chosen due to research constraint number three and in a specific effort to assess manager's perceptions of "userfriendliness".

Fourth, microcomputer software that in some way fit the decision environment (Not just DSS software but microcomputer software that aids one of the techniques identified by Prince) was evaluated against the 12 criteria developed previously. DecisionMc) met 11 of 12 criteria and was

72

chosen as the best alternative, with price being the deciding factor.

Fifth, a realistic demonstration was accomplished through a specific utility analysis involving actual project data and a general utility analysis involving project managers operating this DSS. The specific utility analysis included structured (numerical) analysis and semi-structured (expert commentary) analysis. The general utility analysis concluded with the managers providing their perceptions of this DSS on a questionnaire.

Thus, a microcomputer decision aid that fits the specific DSS criteria and aids the R&D semi-structured project selection decision process has been located, acquired, and realistically demonstrated. But, is this the "best" decision aid? The results of the general and specific utility analyses indicate that more functions are needed while retaining the Macintosh-type of user interface. Some additional functions are discussed more in the section on recommendations for future research.

Is there a commercial microcomputer decision support system that will aid the Air Force project manager in project selection? Possibly, but this DSS does not provide a complete answer. The areas discussed previously indicate some limitations and some strengths of this DSS. The managers feel that this DSS is a step in the right direction for userfriendliness and modeling the decision environment, but it would be more useful as a decision aid if it could handle more than five alternatives at a time and had a link to a data base. In addition, a word processing capability, or extended comment pages for each alternative, would help improve its capabilities. However, this DSS provides an excellent system, for the price, for decisions involving interrelated decision factors with five alternatives or less. It is extremely userfriendly, fast, and aids the visualization, understanding, and

73

analysis of many decision problems within its capabilities. The second place DSS software in Table II, Chapter III, does provide some additional capabilities at almost three times the price. However, this introduces another problem: Software product sheets often indicate that the product can accomplish almost anything, which is obviously not the case, and commercial software developers are very reluctant to answer specific questions over the telephone. Every commercial software developer contacted with respect to this research said they never supply evaluation software for academic research projects. Therefore, there is virtually no way to adequately evaluate the capabilities of different DSS software short of purchasing each program and evaluating each one individually. Some recommendations for the evaluation of DSSs is presented next.

Improved DSS Criteria: A System Specification. Before additional DSS research is performed, an improved list of DSS criteria is needed. It is recognized that any one of the following criteria result in system trade-offs of increased system capabilities with increased system complexity and decreased ease of use, and the proposed manager-user should be kept as a reference point at all times. The DSS criteria should evolve from necessary system characteristics to a system specification that can be used for an assessment of DSS capabilities, either for commercial software evaluation or for future DSS software development. Then an extended managerial assessment (Discussed more in Training Sufficiency) should be conducted to determine system utility and how well the system specification is met. Some examples of the system characteristics and specifications required are:

1. The system should provide a user interface that the manager can

easily learn and use (10; 3). This may be provided by either a desk-top pictorial interface with which the manager is already intuitively familiar or an improved command-keyboard interface that compensates for inferior typing skills and eliminates the confusion associated with microcomputer operation (10:24).

2. One or more of the techniques identified by Prince (15) should be incorporated as the basic DEM structure. Depending on the method(s) used a graphic representation of the DEM should be provided to facilitate understanding of the relationships of the decision factors. In addition, the DEM should provide an "elimination rule" capability such that a specific decision criterion can be used as a go/no-go decision point (Such as an over budget cost estimate), provide easily weighting of, and easy changing of weights on, decision criteria, and provide easy ranking of alternatives on the decision criteria (22:77,78). Like userfriendliness, "easy" is in the eye of the beholder; The determination of what is easy for managerial use could be the subject of another complete research project.

3. Alternative ranking on the decision criteria may be achieved by ranking them directly on the decision criteria, through a link to a specific part of a data base (Such as time, cost, potential pay-off, and/or other decision critical resource factors on a data base form), or through a spreadsheet link which could use specified spreadsheet cells as alternative ranks on the decision factors.

4. There should be an "optimal limit" on the number of alternatives allowed in the DEM. Again, determination of an optimal limit of alternatives is the subject of further research to determine the number of alternatives with which project managers routinely work.

5. The DSS should provide some type of extended text handling capability that can be linked to the DEM both quantatively and qualatively in an attempt to assist in semi-structured decision analysis (4:368-369; 13:200).

6. If a commercial DSS is used, modifiable source code should be purchased, if possible, to provide DSS tailoring when necessary.

One system specification not addressed is the specific hardware sub-system of a DSS intended for Air Force users. As mentioned previously, the managers involved in the managerial assessment were dismayed at the fact that this DSS could not be immediately transferred to their microcomputers and put to use; the current potential for this specific DSS to be widely used in the Air Force environment is small. However, a conversation with Captain William J. Raissle revealed that there is "A Macintosh on every desk" at his program management office. After a demonstration of this DSS like that provided the other managers, Captain Raissle said that they are looking for applications software such as DecisionMap and could put it to immediate and productive use for source selections (17). Thus, there is some potential for use of this DSS and other Macintosh-based decision aid applications in the Air Force environment.

Recommendations for Some Future DSS Research. In addition to the research areas indicated previously, some future DSS research projects could fall into four different categories: Commercial DSS software, integrated software, self integrated software, and developing DSS software. Whichever route it taken, an easily visualized (As opposed to the numeric formulas used in spreadsheet programs) decision modeling interface, such as that provided by DecisionMap, should be the central core of the DSS and it should be supplemented with the capabilities identified in the additional

requirements and illustrated in Figure 16. The ovals, in Figure 16, represent
DSS capabilities, or software module sub-systems, while the bottom figure
represents the user.
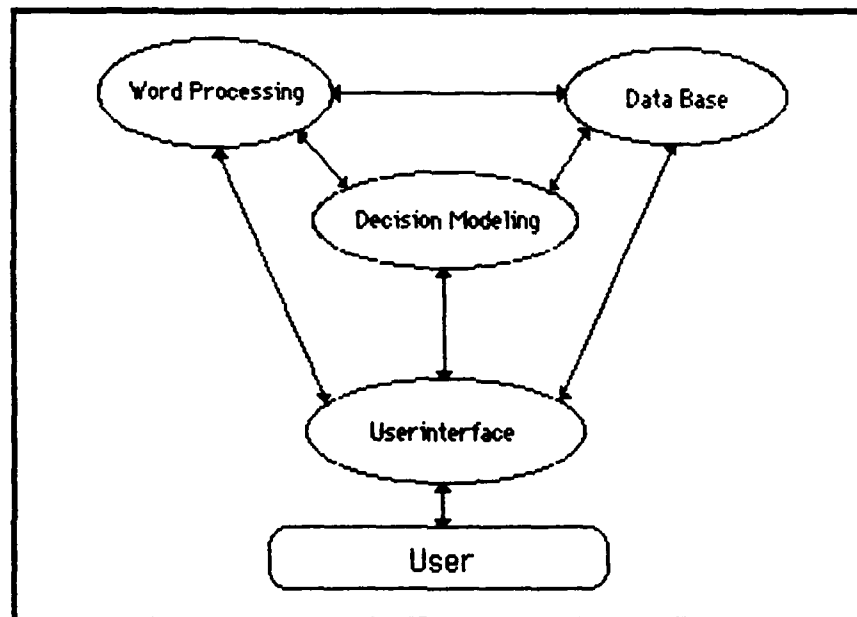
Figure 16. DSS Requirements/Capabilities

Each double-headed arrow illustrates the transfer of data and information
to and from the corresponding sub-system, with the only access by the user
to the DSS sub-systems being through the userfriendly user interface. In
this way the analyst-user has full access to the DSS capabilities but the
manager-user only needs to operate the decision modeling subsystem,
through the user interface, once the DEM is built and data are entered.

   Commercial DSS Software. Many of the DSSs identified in Table I have
additional capabilities at a higher price. However, as pointed out above it is

77

difficult at best to obtain complete information about a product without first buying it, and a sponsor is needed for software purchases. But, many of these DSSs may be worthy of further analysis, and may even provide a user interface similar to that provided by the Macintosh/DecisionMap combination on the command-driven computers.

Integrated Software. As mentioned previously in Chapter III, many of the new integrated software packages provide the features illustrated in Figure 16. Software such as Jazz and Lotus 1-2-3 do not provide the graphic DEM building and sensitivity analysis that is suggested, but an add-on user interface could be developed to provide these features. Therefore, one of these products could provide a multiple-function integrated software core for a future DSS.

Self Integrated Software. Many software products individually provide the capabilities required of a DSS; separate products exist for data base management, word processing, and decision modeling that operate on the same microcomputer through a userfriendly interface. These products can be linked together to produce an operational DSS. Since the products already exist, an integration-code module would be written to combine the product functions. Hence the term "self integrated software".

A problem with the "software baseline" is involved with both the integrated and self integrated software projects. Software developers are continuously improving and updating their products which could result in an incompatibility problem between the privately developed programs. Thus, once the DSS software is fully integrated the numbered software versions with which the DSS operates should be established as a baseline. Establishing this software baseline rests with the DSS developer; there is

78

no easy solution to the problem of who will update the DSS software if a future, privately developed, software update causes an incompatibility problem with the DSS software. However, many software developers are attempting to provide a "standard" data transfer format which will minimize the compatibility problem.

Develop DSS Software. As a last resort and in spite of the case made for commercial software in Chapter I, new DSS software could be developed. The DSS software should be capable of, and provide an interaction or trading of data between, data base and mathematical manipulation, word processing, graphical decision modeling and sensitivity analysis, through a userfriendly interface. The heart of this system, as in those above, is the decision modeling capabilities and user interface.

Training Sufficiency. The training for future DSS projects should encompass two objectives: First, manager-user training for the intended users and second, analyst-user training for the person that builds the decision models and prepares the data, if necessary. If the system provides userfriendly, graphic, decision modeling and sensitivity analysis the managerial training could be limited to a demonstration to explain the system and DEM operation, supplemented with a short text manual of commands and operations on how to perform decision analysis with the DSS and how to access the data base and word processing functions. The manager should then use the system to build DEMs and perform decision and sensitivity analysis. An extended period of managerial use, perhaps a month if system availability and time permit, should be provided to accomplish a more complete assessment and allow for the initial "amazement" of the system to wear off and the actual utility of the system to be realized. The

79

user/analyst training should provide complete text direction on all DSS features, capabilities, and data requirements such that he or she could perform all of the necessary actions to present the managerial user with a complete decision model, ready for manipulation and sensitivity analysis.

Appendix A: <u>Expert Commentary</u>

The expert commentary for the only the top five projects, as ranked by this DSS, from each group is presented here. A complete list of the commentary can be found in the AI workshop report (12).

<u>Group 1 Expert Commentary</u>. The top five Group 1 projects, in order from top ranked to bottom, are projects 14, 6, 5, 4, and 10. The expert commentary is listed below. The Groups 2 and 3 commentary follow Group 1 and are also in rank order.

<u>Project 14.</u>

Still have a problem with including "adaptive control" as an AI issue in recovering from changes in structure.

Why?

       1- Adaptive control   AI

       2- Changes in structure require more

I view this project as feasible with respect to integration of automated statistical quality control within a flexible manufacturing system. Process diagnosis could result in automatic machine compensation to keep the process in acceptable limits.

The creation of an inference engine should be straight forward and the inspection knowledge is well defined and specific; these combine to make this a very feasible project.

I view this project as providing very important contributions to AI in manufacturing at the inspection end. The project will be limited to milling and lathe operations. With this limitation, I view the technique feasibility of the project to be quite high.

Project 6. ·

Project is ambitious and technically difficult.

The process is feasible if approached as a shell of intelligence that integrates discrete processes through a communication facility. The real-time definition would need, in this case, to be defined in terms of minutes or seconds.

I did not change my 2 on feasibility because I believe that it will be very difficult to "... formulate (swiftly) an alternative plan"... based on sensory input.

Project 5.

It's not clear to me that the behavior of composites is well enough understood - even at a heuristic level - to make this feasible as a 2.5 year project.

Is the knowledge all there?

There is not adequate explanation about the performance strategy of this

82

research project.

Impact is substantial - shows up wherever tools and AI both are useful for different parts of same problem.

Project 4.

No comments.

Project 10.

No Comments.

Group 2 Expert Commentary. The following are the top five Group 2 projects, and the associated expert commentary, ordered from top to bottom.

Project 5.

C1: The author states in milestones "Determine how to analyse CAD data to generate knowledge" - this is a difficult problem in its own right and shouldn't be mixed into a generative planner.

If the project were intended as exploratory development or advanced development, I would agree with the assessment, but I don't think a "basic research" project would require that much time.

I strongly feel that the project is feasible since processes are known today

except they reside within the experience of the process planner. If design information can be passed from engineering to manufacturing in terms of features, tolerances, and specifications, it is possible to combine this information with a rule based system to create process plans.

Generative process planning should be addressed in exploratory range. Other efforts are already generating results and potential near term benefits. This statement is so general that it would not contribute to knowledge of an expert in the area and would not advance payoff a significant increment.

The project is too far-out and too general.

I have revised C5 and C6 but only on the basis a 3-D solid geometric CAD system that is a real-time system, is available for design and detailing and dimensioning.

C6: no change - not enough detail to evaluate - 50 my for whom?

To accomplish objective will result in significant step in feature recognition and thus contribution to AI.

This project is so global, so poorly defined, that it has no value in its present form.

Approach not clear. If it's not feasible it's not important and has no payoff. 10 cy and 50 my also make me question feasibility.

Not easy. Secret is to segregate process requirements from equipment capabilities. Then generic approach is feasible.

Not easy. Secret is segregate process requirements from equipment capabilities. Then generic approach is feasible.

While much work is being done in this area, it is sufficiently complicated to warrant further study. Generative process planning is a fertile area for research and development.

I think the scope is too wide. Specifically, feature extraction should be a separate project.

Would like to see project separated into more definable parts.

Important problem - I feel it is part of unit process activity.

Scope needs redefining - must carve out the basic research, not "the whole enchalada".
Not enough detail in resource estimate.

A lot of projects are in progress already on computer-aided process planning. A clearer, more comprehensive write-up is needed.

Experience in building this type of system has taught us that generative

85
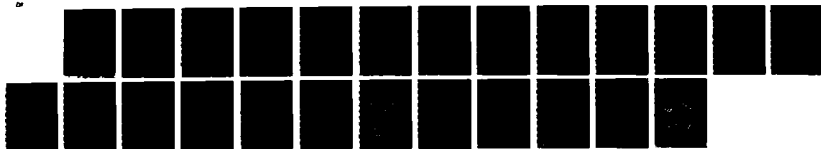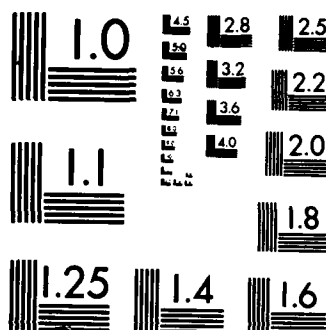
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

planning software flexable enough to apply to a broad range of
manufacturing environments would be so unstructured that it would be
practically indistinguishable from commercial AI development software
currently available or soon to be introduced.

Needs to be split and made more specific. Apparently applies only to
fabrication and should say so.

Still to general and global to be accomplished.
Time and resource estimates are too low for such a project.

Project 2.

The objective and approach says absolutely nothing! The design of a
real-time control system for cell-level manufacturing, I believe, has major
payback. I feel that more resources should be devoted to this project.

I feel to accomplish the project objective will require development of
learning capability which is a definite contribution to AI.

C1: NBS & TI are currently pursuing it.
C4: Exception handling involves context dependent diagnosis and planning
integrated together in a near real-time environment. No work has been
completed so the issue of architecture is an unanswered question.

Much of the software required has already been developed (will be shown at
upcoming IJCAI in LA.)

C1: Approach is ill-defined, how augmented?

C4: Rule based controllers are in production use, nothing new.

The approach and milestones do not give a picture of what will be done. There are lots of buzz words, not much substance.

As a basic research proposal, there is no statement as to "new" idea being pursued. There exist real-time ES systems today for non-manufacturing applications. Should state why these won't work.

In our FMS environment, the exception handling capability is a significant cost driver. This is not basic research, it is advance development and the project should take only 3 years.

Real-time control is now non-existent (virtually) in manufacturing. Basic research is extremely important in this area.

There are many kinds of cells. Is the control system cell-specific, or can a generic control system be developed?

Tremendous controversy between those who think problem is solved and those seeing more research required. No consensus.

Control important issue, proposal not good.

Might include example of type of rule to be generated.

For this and the other scheduling projects (Projects 4 & 12) my comments are the same: The system must interface to the shop floor equipment in a real-time manner through the use of sensors and status feedback to the cell. Emphasis needs to be placed on the parameters needed to make decisions. Also, the scheduling problem should be decomposed into sub-goals to allow the shop to perform at one level, the cells at a second level, and the work stations at a second level. We don't need optimal scheduling. What we need is a schedule that is feasible at time T. The schedule can be changed based on the environment at $T+\Delta T$.

Texas A&M University is under contract to produce a proof of concept prototype by Christmas which controls an operating FMS for a large Texas based company.

The issue of AI based control for due-date driven systems has never been addressed for large or small systems and what architectures are appropriate is an open question.

Project 16.

Response does not address this issue.

Rule based systems are too shallow to produce these explanations effectively. Some sort of causal model or qualitative physics approach would be better. The program should "understand" the origin of the defects rather than just identify them by rules.

I think 8.5 my is too much effort.

C1: Perhaps feasible in electronics manufacturing or for a rigidly structured cell environment, but determining the cause of defects produced in a shop with manually controlled machines by looking only at the end result is ridiculous.

C4: There are a number of inductive techniques coming on the open market (i.e., EXPERT-EASE) which directly address this problem. Therefore, I don't see this pushing SOA.

C6: Seems well-estimated to me.

Note: the "Achilles Heel" of this project is that it assumes the existence of a large amount of data. Basically, you must instrument every process parameter capable of being a casual factor of a given condition. Data of this scope/quality doesn't ordinarily exist in a manufacturing enterprise (at least not now)... big practical problem!

Different approach, use causal model. This would be an advance in the state-of-the-art if done using some sort of causal reasoning.

This had the highest importance rating. In a meeting with GM, Ford, and Chrysler engineers about 18 months ago, a very similar topic was emphasized as important.

Very important, fundamental project but appears to fit under unit processes.

I still think that with sufficient inspection data this work can be accomplished in less than 8.5 MY.

Great idea, but I think some application in industry is possible in addition to basic research.

Project 13.

This project is a implementation of existing concepts. There is no additional contribution for the advancement of technology.

AI is not necessary for this project.

C4: Basic research on purchasing data bases?? What science or technology advance?

1) Purchasing/procurement functions are well understood, 2) many of the decision support elements required may already exist.

Vague approach.

Design of experiments is a excellent application area for capturing existing layman knowledge.

C4: Much attention has historically ben given to procuring parts in one's own

90

shop. little at all has been given to effectively procuring from outside sources. While vendor selection performance evaluation, and purchase activity optimization has been done to some degree, no attempt to my knowledge, has been made to intelligently treat vendors as resources which need to be evaluated, selected, managed, and controlled.

In our (defense electronics) business area, this is a tremendous problem - judicious selection of of materials can have many benefits well downstream of purchasing activity!

Possibly the greatest payback to manufacturing lies with this family of projects for material strategic and tactical planning. Another thrust appropriate here.

Not basic research as described. Construction would be to place the global, strategic problem of material management.

Good problem - experts exist. Activities possible in all 3 categories (research - MANTECH).

It's not clear how or whether AI would help.

I really think this system has merit, especially when the "global" aspects of outside procurement are considered. Remember, too, our factories are moving rapidly towards increased outside sourcing.

Project 10.

A lot of this kind of work has already been done. Is this really AI? If so, what will be done?

C3: I don't know where the sensory information about impending failures will come from. Sophisticated multi-sensory inspection techniques are difficult issues, but assumed here. The ES may not have many symptoms for its data base.

The project is incomplete. It must also analyze sensor data to take appropriate action. The problem is better suited to conventional techniques other than AI.

I believe this belongs to the unit process group.

C1 & C2: This system is absolutely necessary for successful automation of complex systems.

I still wonder how easy it is to "detect" failure across a broad range of applications. This capability is the starting point of the project. Can we monitor the machine only, or must we inspect the output of the machine - part inspection, a highly difficult proposition.

Good project. Important but belongs under the preview of unit processes.

Building an AI system using inputs from adaptively-controlled machines and

"expert" reasons is really a good idea, but I'm not sure that this isn't a basic research issue.

Very good proposal.

Is this really AI? Consider combining with Project 16.

Group 3 Expert Commentary. The following are the top five Group 3 projects, and the associated expert commentary, ordered from top to bottom.

Project 4.

This is an important problem, with high payoff and a very hard problem. I *see no evidence of any ideas of actually how to work the problem. Just the statement "extract expert knowledge ... represent it in experts system, etc."* [sic] Thus, I question the feasibility of the proposed effort.

My issue with C1 is with the use of group technology rather than other more powerful reasoning techniques for information retrieval and presentation of manufacturability advice.

Project 2.

The cost of four symbolics is sky high. Much cheeper computers can be used.

I doubt that it is feasible to model an "entire manufacturing capability", such as aircraft manufacturing or computer manufacturing in 3 years. The

project needs a more specific focus. I doubt that there is "a generic manufacturing process".

With no group discussion and no conflicting data from the computer analysis I can find no reason to revise. The reason for the importance is the fact that little actual scheduling is done today essentially rule based dispatching is what is performed. I believe that KB techniques applied to scheduling algorithm selection and supervisor level is important.

I feel very strongly that this comprehensive project would, like HEARSAY, produce significant manufacturing and AI contributions, but will take an effort that may exceed what is listed, definitely time resources. To produce a useful result would take a large effort, at least more than 3 years, I believe.

The project is an attempt within a near-term timeframe to solve problems that are better addressed in the near-term with existing approaches.Over the long-term, the program goals make since - but an exploratory or basic research program is different from the program described. This program will develop models and techniques that no one will use in real factories. The program could become acceptable with a reduced level-of-effort, longer timeframe and shift to exploratory development or basic research.

Wasted resources are so common and cost so much that the importance of getting a handle on them cannot be over-emphasized.

Project 8.

The problem which this project addresses is one of the key problems which our current assessment has found with trying to use existing AI/ES development tools to explore manufacturing problems.

C2: programming language project - attempts to design a data base using logic are unrealistic.

C3: object oriented programming area is well developed field using logic for data base design has been proposed years ago.

C4: I don't think the project is feasible in terms of data base design.

This is a very key project but also very difficult.

Project 14.

Adaptive data base systems are a good idea but the project proposes (on a minimal budget) to try to redo the IISS and multibase technology

- no new or real AI concepts.
- unrealistic expectations.

This is a very important topic but I question the feasibility of solving many problems in distributed data bases in 3 years. There is already a lot of unsuccessful work in this area.

Very hard problem. Not clear new approach will solve the basic problem.

I feel strongly about importance, contribution to science, and payoff of this

project. I believe this would revolutionize our capability to solve many problems.

Project 6.

I don't believe the project has a great contribution to make in terms of advancement of science.

Unlike frame based rule driven inferencing techniques GT schemes essentially freeze knowledge about a domain into one efficient but rigid structure. I do not believe that development of another GT scheme is a relevant AI topic nor do I believe that an approach predicated on achieving an optimal GT system could ever converge.

Appendix B: Criteria Means/DSS Input Data

Group 1 Project Data: Criteria Means/DSS Input Data

Criteria#	1	2	3	4	5	ASD
Project #						
1	5.60/56.0	5.27/52.5	5.40/54.0	5.80/58.0	4.47/44.5	
Std Dev	1.35	1.16	1.12	1.47	1.25	6.35
2	5.20/52.0	4.67/46.5	4.47/44.5	6.00/60.0	5.47/54.5	
Std Dev	1.57	1.84	1.68	1.13	1.51	7.73
3	5.00/50.0	4.80/48.0	5.13/51.5	6.40/64.0	4.00/40.0	
Std Dev	2.14	2.21	1.64	1.92	1.77	9.68
4	7.00/70.0	6.73/67.5	6.67/66.5	5.80/58.0	4.13/41.5	
Std Dev	0.93	1.22	1.11	1.52	1.13	5.91
5	6.73/67.5	6.00/60.0	6.33/63.5	6.40/64.0	4.53/45.5	
Std Dev	1.28	1.25	1.11	1.59	0.92	6.15
6	7.47/74.5	7.40/74.0	7.40/74.0	4.27/42.5	4.33/43.5	
Std Dev	1.25	1.24	1.30	1.44	1.54	6.77
7	6.00/60.0	5.93/59.5	5.87/58.5	4.07/40.5	4.93/49.5	
Std Dev	2.07	2.31	2.33	1.75	2.31	10.77
8	5.87/58.5	5.73/57.5	5.67/56.5	5.67/56.5	5.00/50.0	
Std dev	2.10	2.34	2.16	2.02	1.46	10.08
9	4.53/45.5	5.13/51.5	5.60/56.0	6.60/66.0	3.27/32.5	
Std Dev	1.51	1.41	1.50	2.16	1.33	7.91
10	7.20/72.0	6.60/66.0	6.67/66.5	6.53/65.5	3.53/35.5	
Std Dev	1.26	1.24	1.18	1.19	0.92	5.79
11	5.53/55.5	5.33/53.5	5.73/57.5	6.67/66.5	3.53/35.5	
Std Dev	1.88	1.76	1.58	1.36	1.49	8.07
12	7.13/71.5	7.13/71.5	6.67/66.5	6.53/65.5	3.67/36.5	
Srd Dev	1.13	1.06	1.05	1.32	1.11	5.67
13	6.27/62.5	6.53/65.5	5.73/57.5	3.93/39.5	4.53/45.5	
Srd Dev	2.05	1.88	1.83	1.71	2.00	9.47
14	7.53/75.5	7.33/73.5	7.27/72.5	5.47/54.5	4.27/42.5	
Std Dev	1.06	0.98	1.10	1.60	1.03	5.77
15	3.93/39.5	5.13/51.5	5.00/50.0	3.60/36.0	3.47/34.5	
Std Dev	1.83	1.25	1.51	1.12	1.36	7.07

Group 2 Project Data: Criteria Means/DSS Input

Criteria #	1	2	3	4	5	6	ASD
Project #							
1	6.71/67.0	4.82/48.0	5.14/51.5	3.39/34.0	3.93/39.5	4.07/40.5	
Std Dev	1.46	1.39	1.53	1.31	0.90	1.12	7.71
2	5.39/54.0	7.39/74.0	6.75/67.5	6.50/65.0	6.18/62.0	5.21/52.0	
Std Dev	1.85	1.47	1.73	1.77	1.59	1.34	9.75
3	4.32/43.0	6.68/67.0	6.39/64.0	4.14/41.5	5.93/59.5	6.50/65.0	
Std Dev	1.79	1.28	1.40	1.86	1.21	1.97	9.51
4	4.96/49.5	7.25/72.5	7.00/70.0	5.57/55.5	4.64/46.5	4.61/46.0	
Std Dev	2.12	1.67	1.25	1.60	1.25	1.31	9.20
5	6.21/62.0	7.39/74.0	7.21/72.0	6.54/65.5	6.36/63.5	5.86/58.5	
Std Dev	1.95	1.66	1.83	1.84	1.45	1.53	10.26
6	4.46/44.5	6.29/63.0	5.86/58.5	5.79/58.0	3.46/34.5	3.36/33.5	
Std Dev	2.10	1.80	1.65	1.47	1.32	1.28	9.62
7	5.54/55.5	6.36/63.5	5.75/57.5	5.68/57.0	4.11/41.0	4.39/44.0	
Std Dev	1.90	1.25	1.29	1.70	1.17	0.92	8.23
8	5.18/52.0	5.50/55.0	5.46/54.5	3.79/38.0	5.07/50.5	5.18/52.0	
Std Dev	2.09	1.75	1.79	1.79	1.30	1.52	10.24
9	5.39/54.0	6.04/60.5	5.86/58.5	6.39/64.0	3.82/38.0	4.54/45.5	
Std Dev	1.91	2.01	2.03	1.47	1.19	1.20	9.81
10	6.00/60.0	6.64/66.5	6.64/66.5	5.43/54.5	5.11/51.0	5.00/50.0	
Std Dev	1.89	1.16	1.06	1.37	0.96	1.09	7.53
11	4.11/41.0	5.96/59.5	5.96/59.5	5.46/54.5	3.68/37.0	3.54/35.5	
Std Dev	1.99	2.08	2.01	2.17	1.54	1.50	11.29
12	5.11/51.0	6.36/63.5	6.25/62.5	5.46/54.5	4.89/49.0	4.68/47.0	
Std Dev	1.81	1.59	1.51	1.50	1.26	1.56	9.23
13	5.89/59.0	6.54/65.5	6.32/63.0	4.46/44.5	5.46/54.5	6.29/63.0	
Std Dev	1.62	1.00	0.98	1.55	0.74	1.21	7.10
14	4.64/56.5	5.68/57.0	5.93/59.5	5.43/54.5	4.61/46.0	4.57/45.5	
Std Dev	1.47	1.54	1.61	1.43	1.03	1.26	8.34
15	4.79/48.0	4.64/46.5	4.68/47.0	4.32/43.0	5.46/54.5	5.39/54.0	
Std Dev	1.87	1.54	1.47	1.54	1.21	1.23	8.91
16	6.36/63.5	7.64/76.5	7.21/72.0	6.54/65.5	4.36/43.5	4.82/48.0	
Std Dev	1.50	1.10	1.42	1.48	0.91	1.25	7.66
17	6.25/62.5	6.68/67.0	6.50/65.0	5.50/55.0	5.21/52.0	4.71/47.0	
Std Dev	1.08	0.98	1.07	1.37	0.74	0.90	6.14
18	6.21/62.0	7.46/74.5	7.29/73.0	6.57/65.5	3.96/39.5	3.68/37.0	
Std Dev	1.20	1.20	1.08	1.32	1.10	1.28	7.18
19	6.46/64.5	7.14/71.5	6.71/67.0	6.54/65.5	4.32/43.0	4.43/44.5	
Std DEv	1.35	1.48	1.24	1.71	0.94	0.92	7.64
20	5.71/57.0	6.82/68.0	6.57/65.5	5.82/58.0	4.57/45.5	5.82/58.0	
Std Dev	1.58	1.28	1.32	1.68	1.20	1.61	8.67

Group 3 Project Data: Project Means/DSS Input

Criteria #	1	2	3	4	5	6	ASD
Priject #							
1	4.47/44.5	5.60/56.0	5.27/52.5	4.53/45.5	3.33/33.5	4.20/42.0	
Std Dev	1.77	2.16	1.91	2.29	1.11	1.66	10.90
2	6.07/60.5	6.93/69.5	6.73/67.5	6.73/67.5	4.27/42.5	5.07/50.5	
Std Dev	1.03	1.53	1.49	1.71	0.88	1.53	8.17
3	6.40/64.0	6.67/66.5	6.00/60.0	6.47/64.5	3.53/35.5	3.27/32.5	
Std Dev	1.30	1.45	1.46	1.30	1.13	0.88	6.64
4	6.67/66.5	7.67/76.5	6.27/62.5	7.20/72.0	5.07/50.5	5.27/52.5	
Std Dev	1.11	0.90	1.10	1.01	1.22	1.39	6.73
5	6.93/69.5	4.67/46.5	4.27/42.5	4.60/46.0	5.00/50.0	5.40/54.0	
Std Dev	1.10	1.80	1.22	1.64	1.56	1.45	8.78
6	6.53/65.5	6.33/63.5	6.00/60.0	6.60/66.0	4.20/42.0	4.00/40.0	
Std Dev	1.25	1.23	1.56	1.12	0.68	0.85	6.69
7	5.13/51.5	5.87/58.5	4.93/49.5	5.20/52.0	4.60/46.0	3.80/38.0	
Std Dev	2.56	2.23	2.46	2.48	1.59	1.47	12.79
8	6.80/68.0	6.67/66.5	6.20/62.0	6.33/63.5	4.27/42.5	4.60/46.0	
Std Dev	1.15	1.63	1.57	1.63	1.16	1.06	8.20
9	5.13/51.5	6.47/64.5	5.60/56.0	5.67/56.5	3.67/36.5	3.27/32.5	
Std Dev	2.00	1.96	2.10	2.53	1.40	1.16	11.15
10	5.13/51.5	5.27/52.5	5.67/56.5	4.73/47.5	5.13/51.5	5.13/51.5	
Std Dev	1.41	2.05	1.99	1.98	1.68	1.51	10.62
11	6.80/68.0	6.87/68.5	5.87/58.5	6.60/66.0	3.87/38.5	3.53/35.5	
Std Dev	1.52	1.06	1.19	1.59	0.99	1.19	8.34
12	6.07/60.5	6.33/63.5	5.27/52.5	5.47/54.5	4.73/47.5	4.40/44.0	
Std Dev	1.33	1.18	0.88	1.36	0.70	0.99	6.44
13	5.27/52.5	5.93/59.5	5.60/56.0	5.33/53.5	4.80/48.0	5.27/52.5	
Std Dev	2.28	2.31	1.84	2.13	1.26	1.62	11.44
14	6.07/60.5	6.93/69.5	6.87/68.5	6.40/64.0	4.13/41.5	3.87/38.5	
Std Dev	1.44	2.02	1.73	2.03	0.99	1.19	9.40

Rounding Error

On method of calculating the rounding error is as follows. If a number b is added to or subtracted from the raw score a the rounding error is:

$$\frac{a \pm b - a}{a} \times 100 = \left| \frac{\pm 100b}{a} \right| \%$$

If c is added to or subtracted from 10a the rounding error is:

$$\frac{10a \pm c - 10a}{10a} \times 100 = \left| \frac{\pm 10c}{a} \right| \%$$

Then:

$$\frac{100b}{a} > \frac{10c}{a}$$

or

$$10b > c$$

Therefore, as long as 10b > c is true the rounding error for the entered numbers will be less than the error than if they were rounded and entered without multiplying by ten. This is usually the case since the worst case for the raw score ends in x.25 (x could be any integer) and would be rounded to end in x.5, while multiplying by ten would result in the entered value having no rounding error, or x2.5. Only when the raw score ended in .x9, resulting in a multiplied value of x.9, would the rounding errors be equal.

Appendix C: <u>Management Questionnaire Results</u>

Question Number	Question Score											Mean
1	5	1	5	5	4	5	5	4	5	4	4	4.27
2	5	4	5	5	5	5	3	5	5	5	4	4.64
3	5	-	5	4	5	5	5	5	4	5	5	4.80
4	5	4	5	4	4	3	5	4	5	4	3	4.18
5	5	5	5	4	4	4	5	4	4	5	5	4.55
6	5	5	5	5	4	4	4	5	5	4	4	4.55
7	5	5	5	5	3	4	4	5	5	5	5	4.64
8	4	3	4	4	3	5	2	4	4	5	4	3.82
9	4	-	3	4	3	2	2	4	4	5	4	3.50
10	4	5	5	4	5	4	5	5	5	5	5	4.73
11	5	5	5	4	5	4	5	5	5	5	5	4.82
12	4	5	5	4	5	4	5	5	5	5	5	4.73
13	5	4	5	4	5	3	4	4	4	5	3	4.18
14	5	4	5	4	5	3	4	4	5	5	3	4.27
15	5	4	5	4	4	4	4	4	4	5	4	4.27

The last question on the questionnaire, number 16, asks for comments or recommendations. Not every manager made entries for question 16, but those that were made are listed below.

[Next to questions 13, 14, and 15]   For some things.
Nice equipment.
Good presentation.

Very important component: The link to a data base management system.
Very important activity: The selecting and structuring of the decision model.

Looks like great tool.
Should be used more instead of WAGs.
Is reproducible, traceable & can provide accountability.

Expansion to handle more than 5 units at a time would be very desirable.
Built-in sub-routines for sensitivity analysis and weighing trials/adjustments.

"Mac" environment is excellent, but not available in AF!

Looks Good.

Main ingredients needed to have this kind of system used is the "getting to know the Mac" system. In current environment of "command driven" IBMs

102

this represents an uphill battle. Also I feel the need to have more than a one hour familiarization time with such a system.

1. Emphasize aid - peopls make decisions.

4. Real world more human interaction - less structured.

6. More so the decision analysis

   better tool to use results after objectives structured -

   Defining the problem makes this a piece of cake.

9. This does not prepare data it only manipulates it. Data gathering & preparation hard part.

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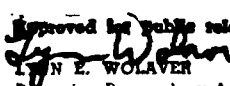
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Thesis advisor: William M. Henghold, Ph.D.

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· 7.
    The purpose of this investigation was to locate, acquire, and test realistically a commercial microcomputer decision support system (DSS) for the Air Force project manager. Only commercial microcomputer DSSs were considered in a effort to demonstrate the cost savings that could be possible by using off-the-shelf software for a dedicated application instead of engaging in an expensive software development project.

    A realistic test was achieved with actual project data collected specifically for a detailed project selection decision, which provided a specific utility assessment, and by managerial use of the DSS which provided a general utility assessment.

    The specific utility assessment identified some limitations with this system. The general utility assessment suggests this system provides useful managerial decision aid in many decision situations involving predetermined alternatives.

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