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DECISION SUPPORT SYSTEMS FOR SOURCE SELECTION IN THE PROCUREMENT OF MILITARY EQUIPMENT

by

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DECISION SUPPORT SYSTEMS FOR SOURCE SELECTION IN THE PROCUREMENT OF MILITARY EQUIPMENT

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ABSTRACT

Any large procurement is of necessity a multi-criteria decision. The military acquisition decisions are typically complicated by military requirements and political considerations. A Decision Support System (DSS) can play an important role in helping military decision makers to come to better acquisition decisions.This thesis introduces the current system of military acquisition used in the Republic of China Navy and demonstrates a small DSS for assisting higher level managers in making acquisition decisions. A survey of ROC Navy Officers at applicable levels of the procurement system was taken to determine the criteria to be modeled in the DSS. This criteria were weighted using typical statistical methods. The results of the survey were used to construct a model for the decision to purchase a fictitious weapons systems. The model was extended for the purpose of the thesis to create a more realistic list of criteria used in a typical weapons system acquisition. An example, software system (Criterium software) was used to simulate the model and the software was exercised to demonstrate the interactive nature of the DSS. The alternative selected by the software was in accordance with experience and a direct reflection of the results of the survey.

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I. INTRODUCTION

A. MOTIVATION

The advances in computer technology in the last decade have made available the tools to accomplish certain missions that before that time would have required much greater involvement of programmers, technicians and other people with specialized knowledge. These advances have also made the solution to some problems more economically viable. Decision Support Systems (DSS) have become more useful and accessible to managers because of the wider availability of more economical hardware and software. The computer's ability to organize and present data for a manager to analyze and the increase in the capacity of desktop computers, make them an ideal tool and/or element in a Decision Support System.

This thesis will address DSS as used in a large-scale procurement decisionmaking process. It will address military procurement and the factors and information that the DSS should provide to the decisionmaker. Some of these factors are costs, availability, capabilities, maintainability and other factors which could be considered political. To be useful the DSS should have in-depth and broad capability to present the results of data collection, budget information and other input variables that the decisionmaker would in fact use to make these procurement decisions manually.

The decisionmaking process in any large-scale organization has many factors that may directly or indirectly affect any given decision. Some factors which in reality should not effect the decision may nevertheless be used in the decisionmaking process and lead to a bad or costly decision. This process on the surface may appear to be simple. In reality, it is very complicated and a decisionmaker cannot be expected to reach a perfect decision. Complicating this are the normal human factors in any organization: negligence, simple mistakes, or malfeasance. These factors could lead to loss of money or property, endanger human life, or seriously undermine the nation's ability to defend itself.

A goal of any procurement system is to reduce the possibility of mistaken decisions or errors in procurement. I believe a DSS would be useful to the Republic of China, to reduce costs and help decisionmakers make more accurate and timely procurement decisions.

The Republic of China has reached a point in time where it is necessary to replace or upgrade obsolete military equipment. The international situation and the needs of Republic of China require this process to be accelerated if we are to accomplish our goals of self-reliance and increase our combat capabilities. A sound procurement system based on accurate data collection and a DSS would serve as a much better basis for procurement than procedures used in the recent past.

The nature of military procurement systems is that decisions are more likely to be made in the political sphere than in the more practical sphere of military requirements. This process could ultimately lead to the Republic of China being unable to defend itself. The establishment of a DSS would lend to a procurement system as an institutionalized decisionmaking process, less influenced by the political process and more resistant to fraud and other abuses which lead to these scandals.

The quality of decisionmaking would also be improved with a DSS in that the system would present all the factors needed by the decisionmaker in any procurement decision. To present these factors an effective data collection system is necessary. This data collection system itself would minimize bad decisions.

B. BACKGROUND

I have spent a great deal of time in the study of procurement regulations and other documents related to procurement. The military procurement system is Byzantine in nature, changes from moment to moment and defies any attempt at simplification. I have also interviewed staff personnel involved in military procurement. The purpose of this study and interviews was to identify the problems and factors which should be presented by any DSS system. The following are initial findings:

- Procurement is a Multi-Criteria Issue. Factors such as cost, longer range, greater capabilities, or easier maintenance, must be considered together to reach a decision. This means that a single factor, cost for instance, cannot be used to make the decision.

- Dissimilar Selection Criteria. Sound procurement decisions rest on a wide variety of often dissimilar criteria, including various cost and performance criteria, risks, political interests and a number of support criteria affected by all of the above. The criteria falls into two basic categories: qualitative and quantitative. Quantitative criteria, such as the various costs, can often be directly compared with one another. However, dissimilar quantitative and qualitative criteria, such as procurement cost and degree of risk, cannot be easily compared. A DSS can help address this problem of reconciling dissimilar criteria.

- Procurement Time. Each procurement regardless of size requires a certain minimum of time for decisionmaking and decision implementation. This time is required for research and study of the factors and the effects of the decision.

- Political Consideration. The political situation is more complex than ever before. It is difficult to find a decision that can be satisfactory to all parties. Unnecessary complications and limitations are generated, and even worse, some political scandals emerge, such as corruption, hidden agendas and favoritism.

- Conflicting Interests. In large systems there are many stakeholders and it is inevitable that there will be conflicting interests. It may be impossible to equitably balance the interests of every stakeholder.

- Subjectivity. The objectivity of procurement personnel is influenced by their experience and position in the system. Their thinking is subject to factors of career and acceptability in the group. Their decisionmaking process cannot be normalized without the help of an institutionalized system of decisionmaking. Military personnel, in particular, are subject to changes in status and position which will have varying effects on their morale and their ability to make objective decisions with regard to procurement.

- Time Constraints. A supervisor's time is usually filled with urgent problems and this leads to the syndrome of "fighting fires". The inefficiency of this approach leads to the neglect of the long-term procurement process and results in inefficiency and higher cost. The supervisor's decisionmaking is unduly affected by whatever fire he may currently be working on. Significant errors cannot be avoided because of the supervisor's short horizon. He is unlikely to see far enough into the future to predict them. Nor is he likely to have the time in study to make efficient and correct or timely decisions.

- Day-to-Day Process. Data collection and analyses in the procurement processes are done repeatedly. New data require new analyses. The repetitive nature of these operations leads to errors and lackadaisical performance by personnel involved in this task. These same personnel are subject to the feeling that a task that is done over and over again cannot possibly be of any importance, since it will again have to be done next week or even tomorrow. This will lead, in time, to an accumulation of errors that will make the data collection worthless.

C. WHY USE A DECISION SUPPORT SYSTEM?

A successful procurement decision depends on the information available to and influences on the decisionmaker. A good decision will improve the capabilities of the military and/or save taxpayer's money. A bad decision may result in inefficiency and the reduced effectiveness of the Republic of China's combat forces or in a worse case scenario the failure of those forces in combat. These problems should be studied very carefully and the decisions should have the best support systems available. If a DSS can be developed for the Republic of China, it would provide decisionmakers at different levels with better information to base their decisions.

Computer capabilities and tools to accomplish our mission of improving the procurement process are readily available. These tools would be used even if the DSS system were a manual system; therefore, it would improve the process if a standard computer system, hardware and software, were made a part of the design of the DSS.

I believe a computer base DSS would be the best solution for our military procurement problems. It would improve the quality of decisionmaking, providing the best recommendations for procurement. In Chapter II, I will cover in detail the type of system and software that would meet the Republic of China's requirements.

D. METHODOLOGY

Shown in Figure 1 is a flow chart depicting the design of a suitable DSS for military procurement decisionmaking problems. The major steps include the following:

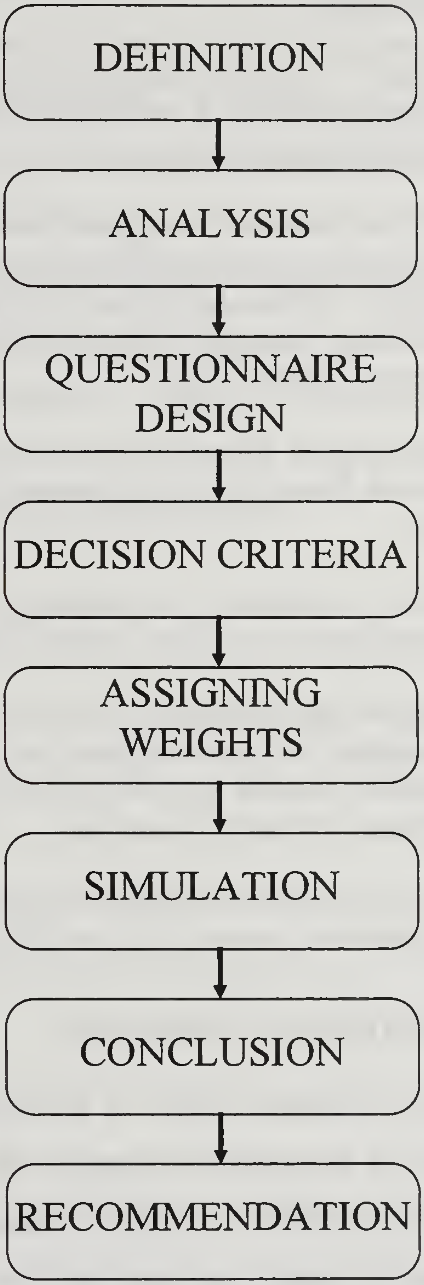


Figure 1. Design Process of DSS

- Definition - Definition of the problem. The definitions of the goals we expect to achieve and the definitions of the factors important to the decision.

- Analysis - The characteristics of the problem are systematically analyzed for their influences on the decision. The most important characteristics are used to develop the questionnaire.

- Questionnaire Design - The questionnaire is designed with the results of our definitions and analysis in mind. It should also reflect relevant questions for the stakeholders involved in the decision.

- Decision Criteria - The results of our questionnaire are used as a source of statistical data to develop the system. With these results weights are assigned to the various factors. This should produce a prioritized list of factors from most important to least important. This list is used to capture the most important criteria in the decision model.

- Assigning Weights - Using the results from the statistics package, assign weights to the various factors that are representative of the results from the user's questionnaire.

- Simulation - Choose a small-scale procurement problem as an example and perform a test with the software and the weighted criteria.

- Conclusion - Determine the effectiveness of the DSS by interviewing a user of the system and weighing the results against the users criteria and probable decision. The interview should also include the users opinions as to the usefulness of the system for making decisions.

- Recommendation - Recommend expansion of the system or modification of it as a result of the conclusions reached in the previous step.

E. SCOPE AND LIMITATIONS OF RESEARCH

Military procurement is a dynamic system. It is impossible to design a perfect solution that will be applicable in any particular scenario. My intent in this thesis is to provide some solutions that will be helpful in making procurement decisions in a limited scope of problems. For a general solution to these problems, a great deal more study would be required.

Many elements of military procurement are classified. It is therefore difficult to collect actual data which could be used in my demonstration. As a result, I have created data that reflects the data from real procurement scenarios, in order to avoid the issues of classification, clearances, and confidentiality. Although the data I use is not confidential, I believe it represents a normal procurement and will demonstrate the concept outlined in the thesis. In Chapter II of this thesis, I will discuss the theory of Decision Support Systems and their structure and how they differ from expert systems. I will also review some examples of Decision Support Systems that have been used in civilian and military procurement. In Chapter III, I will discuss the design of the DSS that I will demonstrate in this thesis. Chapter III will consist of step-by-step procedures and the design decisions made for each step shown in Figure 1. Chapter IV will be an explanation of the results of the simulated procurement problem using the DSS designed in Chapter III. In Chapter V I will present my conclusions and recommendations.

II. DECISION SUPPORT SYSTEM STRUCTURE

A. THE DEVELOPMENT OF DSS

In the early 1950's the computers use was restricted to scientific and engineering uses. However, improvements in technology and availability moved the computer from scientific uses to business uses. One of the first uses of the computer in the commercial world was for Transaction Processing Systems (TPS). TPS includes such things as payroll, record keeping and billing systems. Even with these uses, no one could have predicted the impact that computers would have on business and management at the present time. Speed, accuracy and storage capacity are the three characteristics of computers. Since that time, the computer's capacity in all three of these categories has increased geometrically. These improvements are the very reason that computers are so useful as information processing devices.

There are five uses for computers in management. The first, Transaction Processing Systems (TPS) is the most obvious and still the most common use of large computer systems. The next uses have more impact on management decisionmaking. Management Information Systems (MIS) are used for production control, sales forecast and monitoring these items. Decision Support Systems (DSS), the subject of this thesis, are used for long-range planning and complex decisionmaking. Expert Systems (ES) are used for diagnostics, internal controls, planning and maintenance areas that have a limited domain. The fifth use is as Executive Information Systems (EIS), these systems are used to support top management decisionmaking and provide top management with reports. [Ref. 1]

The classification of these tools does not necessarily indicate that any particular computer system is dedicated to any one of these operations, or in fact, that any particular data source is dedicated to one management system. These technologies are made up of three dimensions: a particular computer/hardware, several programs/software and the management processes that gather information to support these systems. [Ref. 1]

The development of these systems are as follows:

- TPS was first used in the early 1950's and is still the main use of large computer systems.
- MIS was first used in the 1960's by upper management mostly to produce standard operating procedures, decision rules and reduce cost. This was typically done by replacing clerical personnel who were employed to produce reports with a computer system. These systems were restricted to higher management for reasons of equipment cost as much as the utility of the MIS.
- DSS. In the 1970's Keen/Morton coined the term DSS [Ref. 2]. DSS is used to address semistructured problems and one of a kind or once in a lifetime decisionmaking situations. This differs from MIS which generally supports only recurring reports or highly structured situations.
- ES were developed in the 1960's as part of research in artificial intelligence (AI). Expert systems have a limited domain in that they are only applicable to recurring problems and are intended to assist or replace a human expert. These systems are not adaptable to new or unique situations.

From the above list we have a basic knowledge of management's support systems and we can easily distinguish between them. Figure 2 indicates the relationship between these systems.

Figure 2 is a notional view of these relationships. This view shows the evolution of the use of data processing systems in decisionmaking, but does not represent the future development of management uses of computers. Figure 3 represents the theoretical view of DSS and the effects of information technology on an organization.

B. WHAT IS DSS?

Decision Support Systems (DSS) are defined by Sprague and Carlson "... as interactive computer-based systems that help decisionmakers utilize data and models to solve unstructured problems" [Ref. 3]. The key points of this definition are interactive

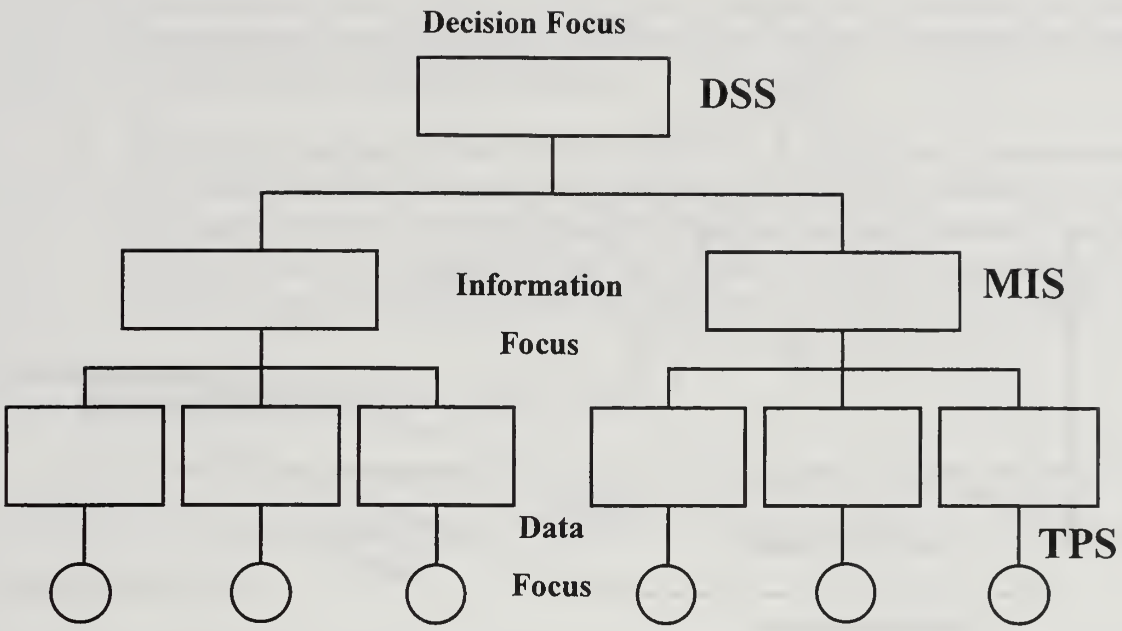


Figure 2. The Notional View After Ref. [3]

and unstructured. MIS is not usually interactive and the reports generated for the manager are usually structured and repetitive. Another important point is that the purpose is to help the decisionmaker to solve the problem. It is not to replace the decisionmaker as in an Expert System. Bennett's definition of DSS:

> A coherent system of computer-based technology (hardware, software, and supporting documentation) used by managers as an aid to their decisionmaking in semistructured decision tasks. We stress supporting rather than replacing managerial judgments. We focus on improving the effectiveness of decisionmaking rather than on merely improving its efficiency. [Ref. 4]

Bennett defines when a task is considered an unstructured task:

- Objectives are ambiguous and nonoperational, or objectives are relatively operational but numerous and conflicting.

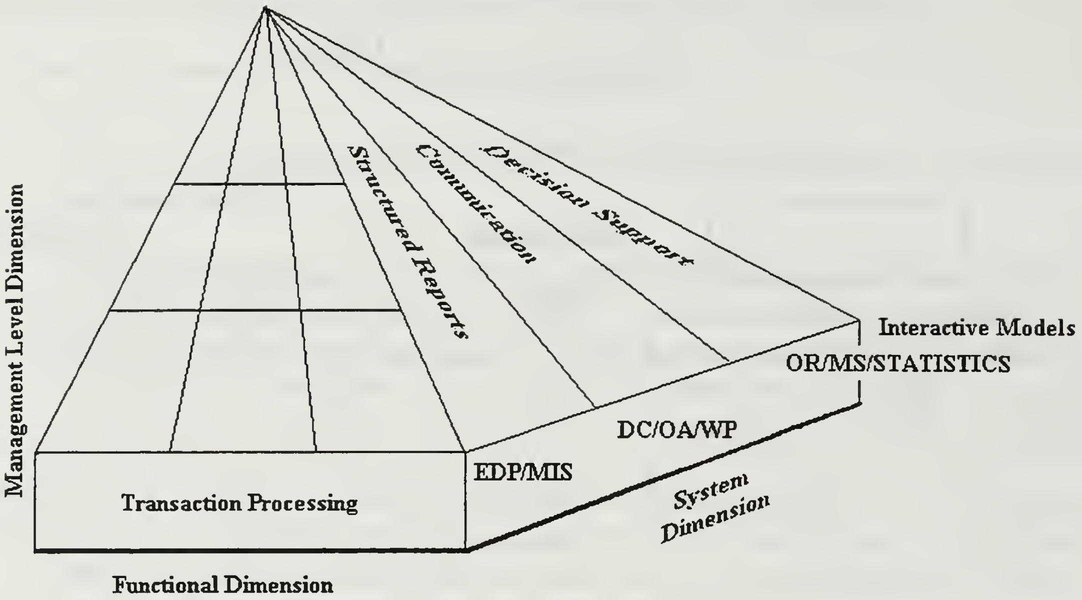


Figure 3. The Theoretical View After Ref. [3]

- It is difficult to determine the cause (after the fact) of changes in decision outcomes and to predict (in advance) the effect on decision outcomes of the actions taken by the decisionmaker.

- It is uncertain what actions taken by the decisionmaker might affect decision outcomes. [Ref. 4]

C. COMPONENTS OF A DSS

There are three components of a DSS:

- Language System (LS) - This system is used by the user to interface with the DSS. It may include direct retrieval languages and computation languages. This allows the decisionmaker to express commands and statements, but at the same time, limits the decisionmaker to a finite number of expressions.

- Knowledge System (KS) - This system contains the knowledge of this decisionmakers problem domain. The knowledge must be organized and must be retrievable in a systematic manner.

- Problem-Processing System (PPS) - The PPS is a system which understands the decisionmakers statements or commands and the representation of the knowledge in the KS. The PPS takes the relatively simple commands from the language system and processes them into the more complex operations of the retrieval system or the KS and the computations required for the DSS. [Ref. 5]

D. THE CHARACTERISTICS OF A DSS

Even though there are various definitions of a DSS, usually dependent upon the viewpoint and background of authors in the field, the characteristics of a DSS can be summarized as follows:

- DSS assists decisionmakers to deal with multi-level problems structured and unstructured [Ref. 6].

- DSS supports the decisionmaker with an adaptive point of view. In this point, a DSS is better than a conventional MIS in that a MIS cannot adapt itself easily to new or unique situations.

- A DSS is interactive. The decisionmaker can use the system to collect, process, display, store and retrieve information in real time.

- A DSS is used to support the decisionmaker not replace the manager's judgment and experience.

- The purpose of a DSS is to improve the effectiveness of the decisionmaker and is not generally targeted at efficiency.

- A DSS must be easy to operate because it is designed to be used by the decisionmaker not computer experts or even specially trained clerks. The system is interactive and is intended for the direct use of the decisionmaker.

- The DSS must be adaptive. Over time, the type and nature of the decisions that the DSS is used for will change. If this were not the case, the DSS might better be replaced by an expert system. A DSS is intended to be used for one time only or unique decisions that are unstructured.

- A DSS must efficiently assist decisionmakers in making decisions. If the system is not efficient it simply will not be used by managers who must budget their time in the most effective manner to realize the goals of their organization.

- A DSS should assist in training inexperienced managers in that it will present to them information for a decision which their inexperience otherwise may have led them to overlook.

E. THE FRAMEWORK OF A DSS

The information used by the DSS is generated from interaction with the user, information from the database and model analysis. Figure 4 shows the components of a DSS which consists of five parts.

1. Personnel

There are three levels of DSS technology and five associated roles for managers and technicians in both the use and development of a DSS. They are shown in Figure 5:

- Manager or user - The person faced with the responsibility of the decision.

- Intermediary - The assistant or the staff of the manager or user of the DSS.

- DSS Builder - The person who is familiar with computer systems and also familiar with the problem area of the decision.

- Technical Support - The person or a team who is acquainted with the problem area but whose expertise is in database, management, model building and the computer system that supports the DSS.

- Toolsmith - A person or a team whose responsibility is to develop new technologies, software and hardware to provide the DSS with better or more complete data or models. [Ref. 6]

2. Hardware

Computers, peripheral equipment and facilities for the maintenance and use of this equipment are required. Telecommunication equipment for remote connections to databases and other information sources are needed for large systems. Hardware to maintain backups of the software and databases used by the system are required except for the simplest systems. Remote storage facilities to maintain archives of the systems software are necessary for safety.

3. Software

Software consists of Database Management Software (DBMS), Model Base Management Software (MBMS) and dialogue generators for the interactive element of the DSS; compilers and special software used to maintain the system and the networks used by the system; software for maintaining archives of databases and program sources

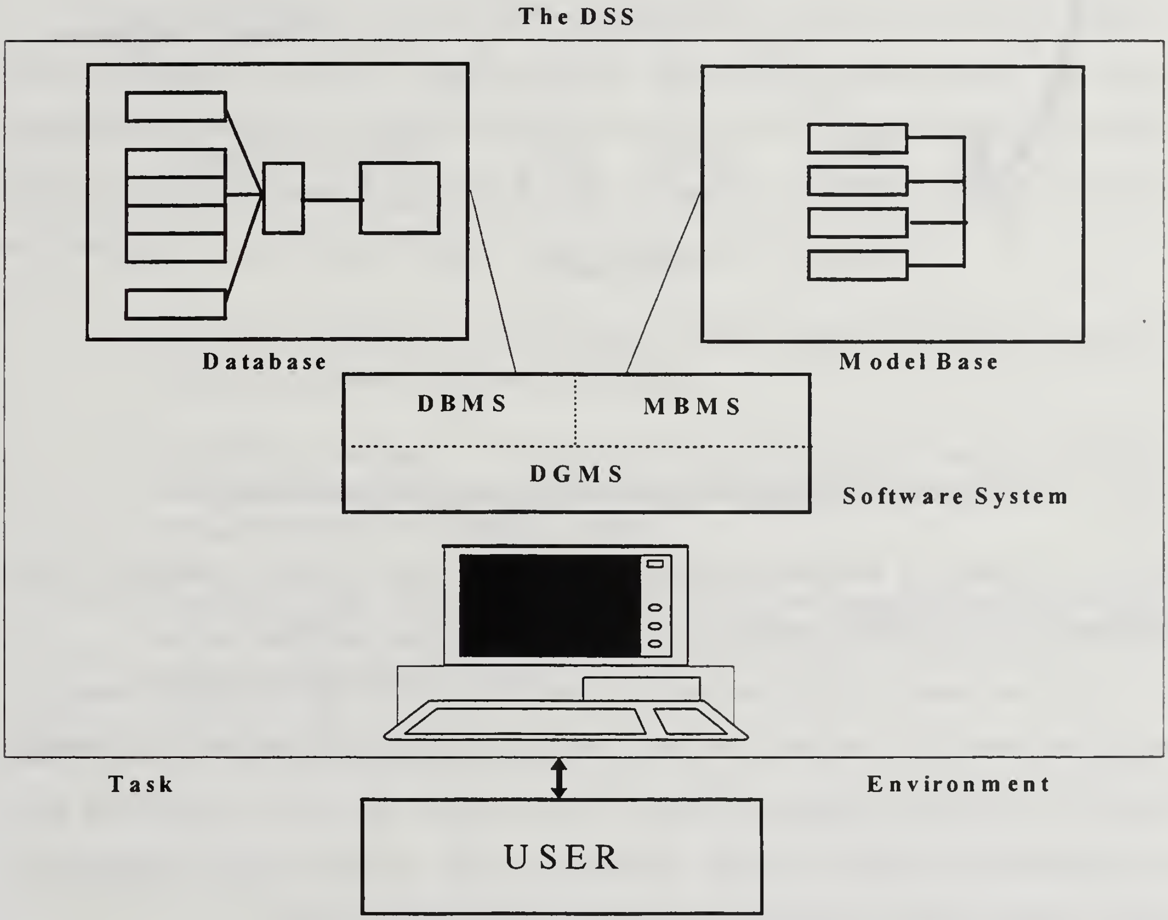


Figure 4. Components of a DSS After Ref. [6]

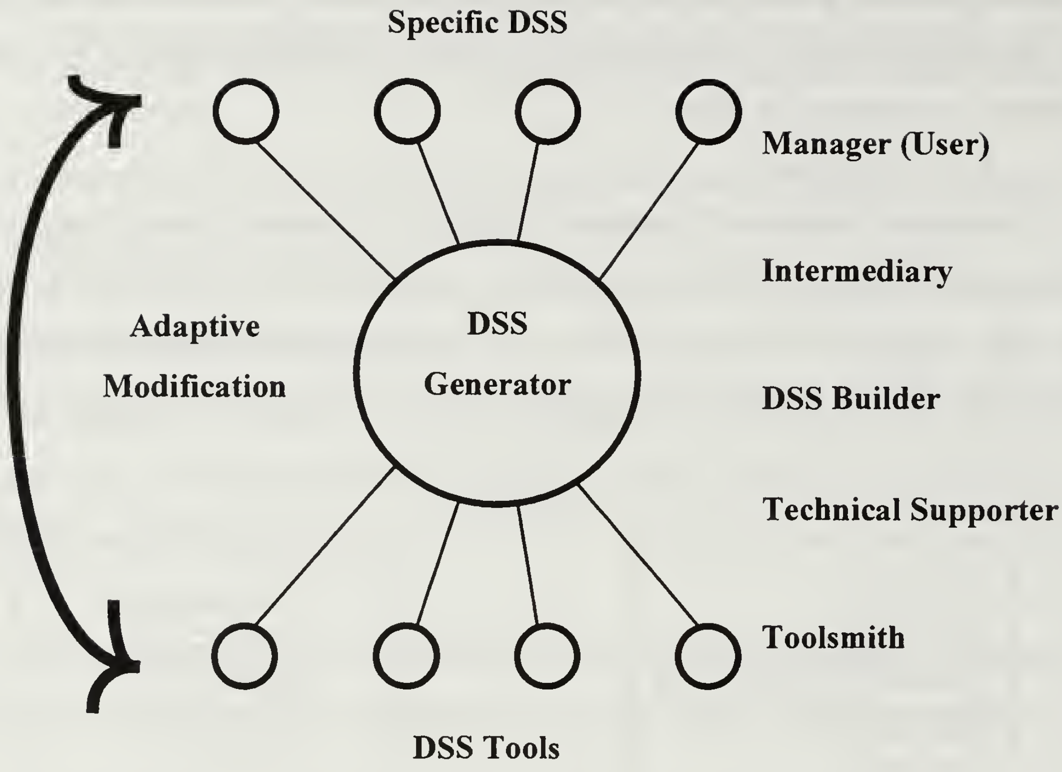


Figure 5. DSS Levels and Associated Roles From Ref. [6]

used in the system and software for debugging the DSS; and diagnostic software for the maintenance of the systems computers and telecommunication facilities.

Software makes up three subsystems of the DSS, the dialogue subsystem which is used for interacting with the user, the data subsystem which supplies the DSS knowledge system and the model subsystem software which is used by the PPS in calculations and the presentation of data to the user. Peripheral to this, are the normal maintenance software used to maintain the data system and the hardware of the DSS.

4. Database

The database used by the system is a collection of information necessary for the DSS to function. It must include software and hardware required to maintain any database system. This includes backups and conversion software to present the database in a usable form to the DSS. It may include software required to access remote databases across networks or other telecommunication links.

5. Model Base

The model base is made up of standard mathematics and statistic packages used by the DSS. It may include special purpose software created to support a particular decision process.

F. DIALOGUE SUBSYSTEM

Much of the power, flexibility and usability characteristics of a DSS are derived from its interface to the user. This makes the dialogue subsystem software the most important subsystem in the DSS. Without a flexible and very usable interface, the DSS will not be used by managers who cannot devote time to overcoming limitations in the user interface. The dialogue subsystem is itself made up of three systems:

- The Action Language - The software which interprets the users input and conveys commands or requests to the DSS.
- The Display Language - The software which displays the results of requests, commands and model runs to the user. This may be in the form of a CRT screen, printers or other graphics output.
- Knowledge Base - Knowledge base consists of the organizational knowledge and the users previous inputs. This may include manuals and help files for the operation of the DSS. [Ref. 4]

Figure 6 shows a typical dialogue system.

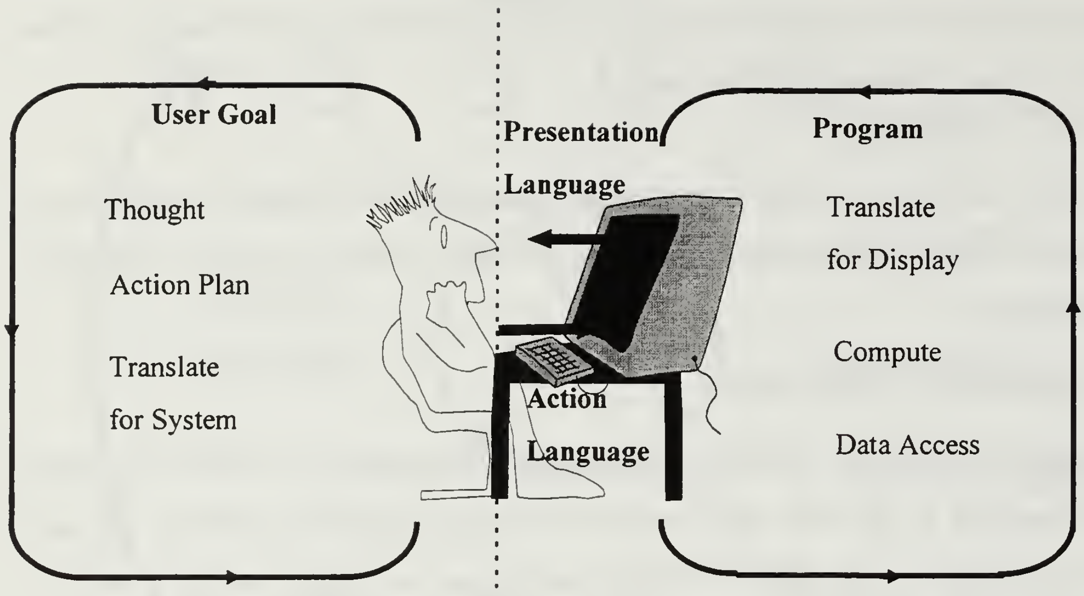


Figure 6. User/Terminal Interface After Ref. [4]

G. THE DATA SUBSYSTEM

The functions of the data subsystem are to query the database as a result of requests from the models and dialogue subsystem. This should include the ability to maintain the database records by inserting, deleting and adding individual records. This system should, in addition, be able to request updates to databases that are held locally at the users site so these databases reflect data whose original source is from remote systems. The data subsystem is shown in Figure 7

1. Rich Set of Data Sources

The data for the DSS must come from external sources and cannot depend solely on local or internal sources since the decisions made by upper management levels are heavily dependent on external data sources. In addition, management decisions must also

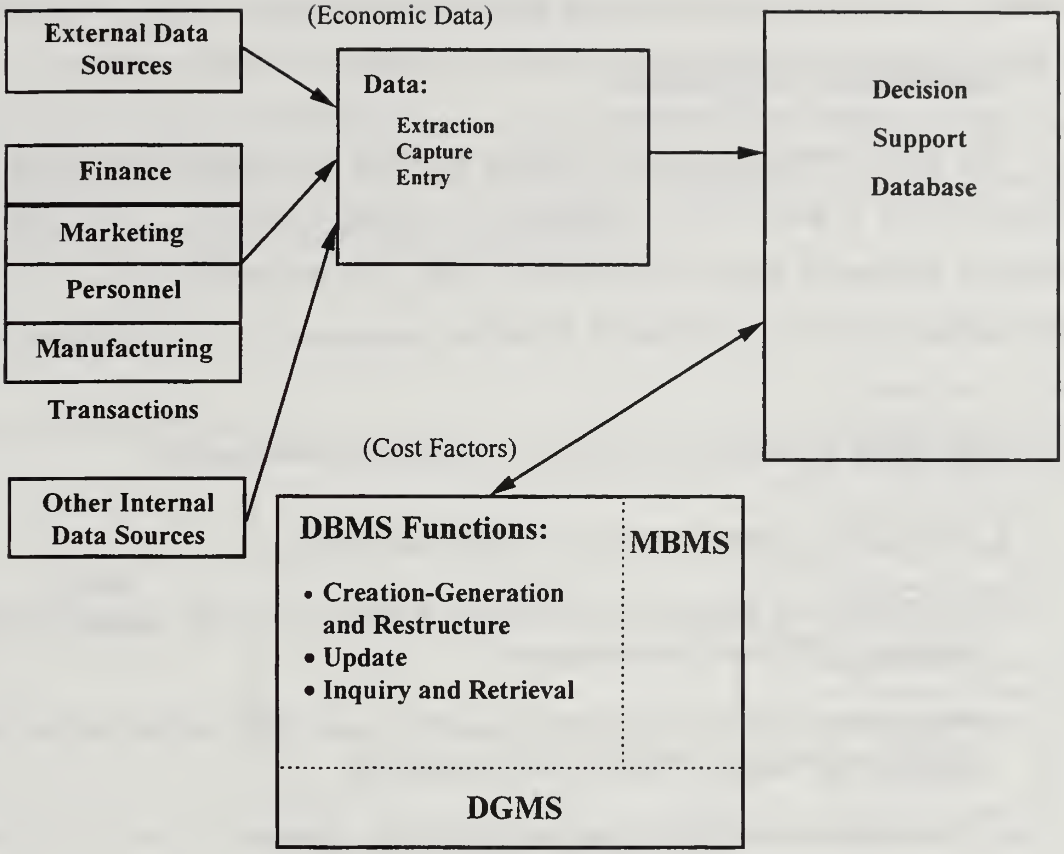


Figure 7. The Data Subsystem From Ref. [3]

be based on decisions made in the past. This requires local historical data be presented by the DSS.

2. Data Capture and Extraction Process

The nature of the DSS requires that the data extraction process and the DBMS which manages the database be flexible and allow rapid response to users request for data. This is because of the interactive nature of the DSS. If a manager spends too much time waiting for a request to be satisfied by the DBMS, the next time he will not make the request, thereby, bypassing that piece of information in making the decision and essentially disregarding the DSS in his decisionmaking process. If the system is not flexible the manager may not even be able to request the information he requires to make the decision, which will again result in the DSS not being utilized.

H. THE MODEL SUBSYSTEM

The most promising aspect of DSS is its ability to integrate data access with decision models. It does this by imbedding the model subsystem in the DSS and providing a database on which to operate the models. This integration provides powerful what-if scenarios for the user. Figure 8 shows the components of the model subsystem. [Ref. 3]

The key capabilities provided to the DSS by the model subsystem include:

- The ability to create new models rapidly and easily.
- The ability to catalogue and maintain archives of a wide range of models supporting all levels of management.
- The ability to access and integrate models to create other models and use these as building blocks to more complex simulations.
- The ability to interrelate these models with the database.
- The ability to manage, maintain and archive these models as if they were records in a database.

I. THE DEVELOPMENT APPROACH FOR DSS

There is no universal decisionmaking theory; varying conditions and rapidly changing circumstance make a DSS a good tool for tracking change. In order to track changing circumstances an interactive system combining analysis, modeling, data access and presentation in a single step is required. An initial system can be built to solve a small problem. Once this system is capable of supporting decisions in a limited area, it can be expanded and improved until it will support a wide variety of decisions required by the organization. DSS are in a constant state of change reflecting new technology, new data sources and new management strategies. This in itself should lead to a system which is adaptive and flexible.

An adaptive system is defined as a system with three abilities related to time. In the short term it must be flexible enough to solve a given problem within a given scope. In the midterm, the system must evolve to accommodate changes in scope and in the long term, it must accommodate itself in any given situation.

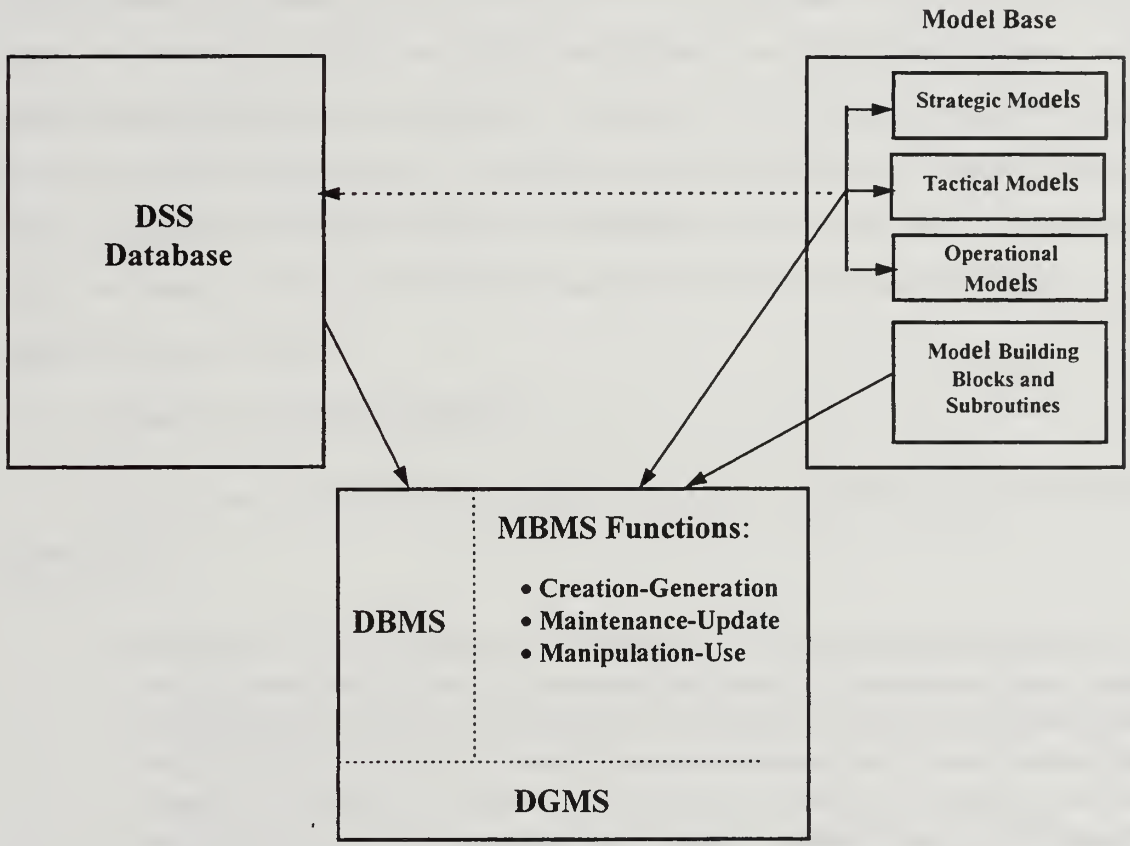


Figure 8. The Models Subsystem From Ref. [3]

III. DSS APPLICATION DESIGN

This chapter will cover my design of a DSS to support the decision to acquire a fictional weapons system from either a domestic supplier in the Republic of China or from a group of international suppliers. Decisions of this kind involve cost, political, technology transfer and support factors. Decisions to acquire a system that are based on these factors are made at very high levels of government. At this level of government, a decision maker can demand very detailed and extensive information from the bureaucracy below. My model of a DSS is very simple and includes very few criteria included in the decisionmaking system, but nevertheless, I believe it is a very valid system because at this level, decision makers need to reduce the detail involved in a decision down to factors which will make their decision understandable and in fact, make it possible to come to a decision. So the criteria I have selected for a decision at this level represents a large collection of criteria.

A. DESIGN CONSIDERATIONS

The first step in this chapter will be to select a DSS that has the following characteristics:

- Simple to Use - This system will be designed for very high level users who do not have the time to learn obscure user interfaces or interpret computer output which cannot be grasped immediately. For people at this level, the best system and the most likely to be used system is one that has a very simple user interface and presents to them easily understood results. In modern computer terms that would be a graphical user interface where input is performed by clicking and dragging objects with a mouse. The normal output from these interfaces are usually colored graphics. Graphics have the capability of presenting large amounts of information almost instantaneously.

- Flexibility - The nature of a DSS is that it is flexible. It is required to present results in real time to the user so that the user can make a decision. Different users will require different criteria or weights to that criteria and may require different presentations of the results. The key ingredient of a DSS is that it is intended to provide information to the user so that the user can make a decision. Without flexibility the DSS may not be able to present data to the user in a form he requires or adjust itself to new decision criteria that will naturally evolve over time. In addition, a DSS is designed to assist in making a decision to a unique problem. Therefore, if it was inflexible, it would not be used more than once.

- Quick Results - A system which is particularly slow in displaying results may be used the first time by a busy manager. However, the loss of time and the period of idleness represented by it will be considered when he is deciding to use it again. Depending on how slow this system actually is, he may not use it at all, and invest that idle time in more traditional methods of making a decision. This problem would probably not show up on a small system that does not depend on queries to large and/or remote databases. If the DSS and its data can be centrally contained in a small computer, quick results can be expected. Decisions to buy floating point units or simply better software would be expected to overcome problems associated with speed. Quick results are also necessary for a truly interactive system. If the user is not presented with immediate feedback, he will not be able to rapidly test scenarios and an important feature of a DSS used in generating information for the user will be lost.

- The Ability to Quantify Criteria - The system must be able to represent criteria as a number. For some criteria this would be a simple process, but usually this is only true of factors involving cost. This number scale must also effectively represent quantities that are less tangible, for example, the effectiveness of a weapons system, the political cost or risk factors.

- Interactive - One of the key ways for the user to simulate the effects of his decision is to modify the various factors until an acceptable result is achieved. This process begins when the user changes the model, examines the results, and uses those results to make improvements to the model. This process can also be used to discover the critical points in the criteria which would result in a different decision being made. This feature will generate better decisions over time as the user gains a better understanding of the criteria or factors that affect his decisions. Without an interactive feature, the decision maker would be presented with results which he would not understand and in all probability, lose confidence in over time.

The software package selected for this demonstration system is Criterium Decision Plus made by Sygenex. This software runs under the Windows Operating System and it meets the design considerations listed above. It is very easy to use, and has a graphics interface. It can use one of two models, Analytical Hierarchy Process (AHP) or a Simple Multiattribute Rating Technique (SMART). It has output capabilities which will show the user the most critical factors in the decision and show the points at which the alternatives will change. The hardware requirements for the program are very ordinary and can be met by any recently purchased PC. The system includes a brainstorming feature which leads to a rapid design for the DSS. The software includes more advanced capabilities which I have not used in this demonstration. They include an uncertainty capability and the ability to generate reports.

This software operates on the following three principles:

- Hierarchy Representation - The problem is divided into definable elements.
- Priority Discrimination - Elements are ranked relative to one another.
- Synthesis - Individual judgments are combined into an overall rating.

Criterium software allows a comparison of each combination of alternatives for each criteria and allows the user to assign weights to each criteria. This software is extremely useful in organizing and prioritizing multiple alternatives and multiple criteria. The software performs a pairwise comparison between criteria and then selects the best alternative for the user.

This software could also be used in a Group Decision Support System (GDSS) but it would require good leadership and management skills to bring various stakeholders into the process. The software has no automatic communication features (electronic mail) nor does the software provide for database queries normally associated with GDSS.

B. DESIGN METHODOLOGY

For the design of the DSS, we did not have access to the Taiwan Navy database. In order to make our system represent a real system, we have developed a questionnaire and generated data that would represent this database.

1. Definitions

The initial step in the design of the DSS is gathering definitions of criteria and the problem domain. The problem domain is to decide which one of four fictitious weapons systems to purchase. System A is a weapons system produced by the French, System B is produced by Korea, System C by the United States and weapons system D is produced by the Republic of China. These systems all have different capabilities, costs and political considerations.

The criteria used to make the decision was set to the feasibility of acquiring the equipment, the cost of the equipment, delivery schedule, political factors, the technology transfer to be gained by the ROC, the feasibility of acquiring the weapons system and of course, the capabilities of the weapons system. This is a short list of criteria to be considered when purchasing a weapons system. A more complete list would include detailed factors involved in cost and equipment capabilities. The factors of politics and technology transfer probably cannot be further detailed simply because they are subject to the decision maker and would represent his opinion. Nevertheless, the initial factors were broken down into subfactors which represent a more realistic level of detail. The subfactors were given decision level data not based on the survey, but based on my experience in purchasing weapons systems. The definitions for all the criteria used in the model are listed in Appendix B.

With the Criterium software the first step is brainstorming which is quite easily done by simply defining a goal for the DSS and creating a block for each of the criteria listed above without regard to the structure of the decision. The brainstorming window of the Criterium software is shown in Figure 9.

2. Analysis

The second step is the analysis of the criteria selected in the first step. This requires us to determine the relationship or hierarchy of the criteria in relation to our goal or decision domain. The analysis of the criteria that make up the decision results in six groups, they are:

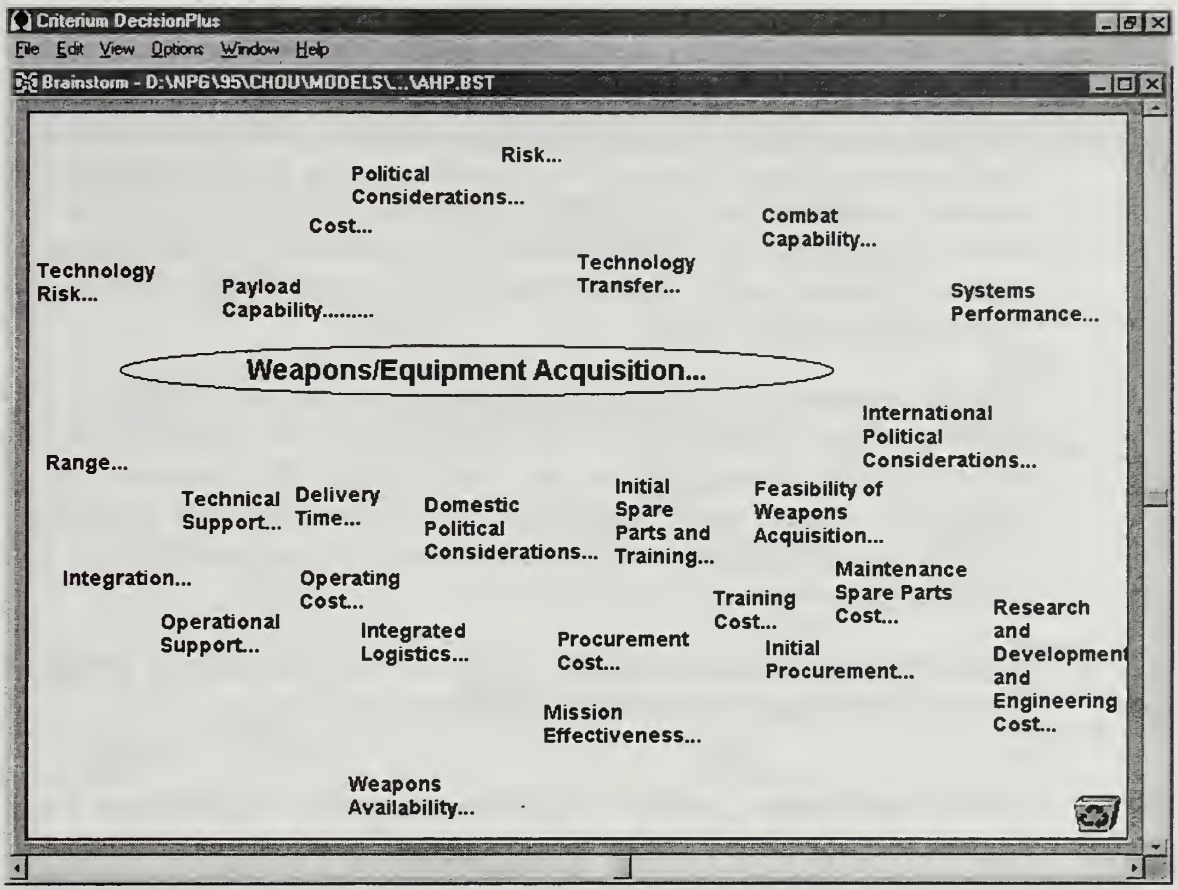


Figure 9. Brainstorming Window

- Technology transfer which is the only item in its group. This criteria indicates the technical capacity which will exist after the procurement of the weapons system. This criteria represents an advantage for domestic development and research.
- Combat capability, which is the only item in its group. This criteria represents the performance characteristics of the weapons system evaluated on the same numeric scale as other criteria. It is a composite of the capabilities of the weapons system. In a more realistic DSS this group would be a sum of the many subgroups representing the detailed capabilities of the system.
- Cost, which is made up of two subgroups. The initial purchase price of the weapons system and its lifetime support or logistics support and the

operational cost of the weapons system or operational support. Logistics support represents part support for maintenance of the system, the reliability of supply (domestic or international), and the cost of tooling up for parts that have become obsolete. Operational support is the cost of supporting the weapons system when it is in use. This includes training, maintenance and the personnel to operate and perform these functions. This cost in a real world system would have to reflect increases in personnel for maintenance, operation, training and the effects of the weapons systems space and weight requirements on board a vessel.

- Risk, which is made up of political considerations and the delivery time of the weapons system. Certainly in a real world system there would be more detailed criteria contributing to the risk criteria, for example, early obsolescence of the system, unsuitability for shipboard use, low reliability, does not meet the specifications as advertised, cost overruns, and/or the possibility of non-delivery.

- Feasibility of weapons acquisition, which is the international political considerations involved in acquiring a weapons system.

- Political considerations, which is the effect of political considerations both domestic and international on the selection of a weapons system. For example, in the international category political considerations would include internationally recognized embargoes or acquisitions of weapons systems which may initiate an arms race with a neighboring country. Domestic considerations would include high government level strategies for purchasing the weapons systems or the wishes of the legislative body for either domestic purchase or foreign purchase of the weapons system.

The results of the analysis are shown in Figure 10.

3. Questionnaire Design

Military procurement is a complicated issue. A questionnaire to survey every aspect of military procurement would be prohibitively large. Such a survey instrument would be unlikely to gain an adequate response or to be willingly completed. I have designed a questionnaire to obtain the criteria needed for a simple decision hierarchy. It includes eight questions with the possibility of the respondent filling out an additional seven questions. The questionnaire is short, but the questions have been designed such

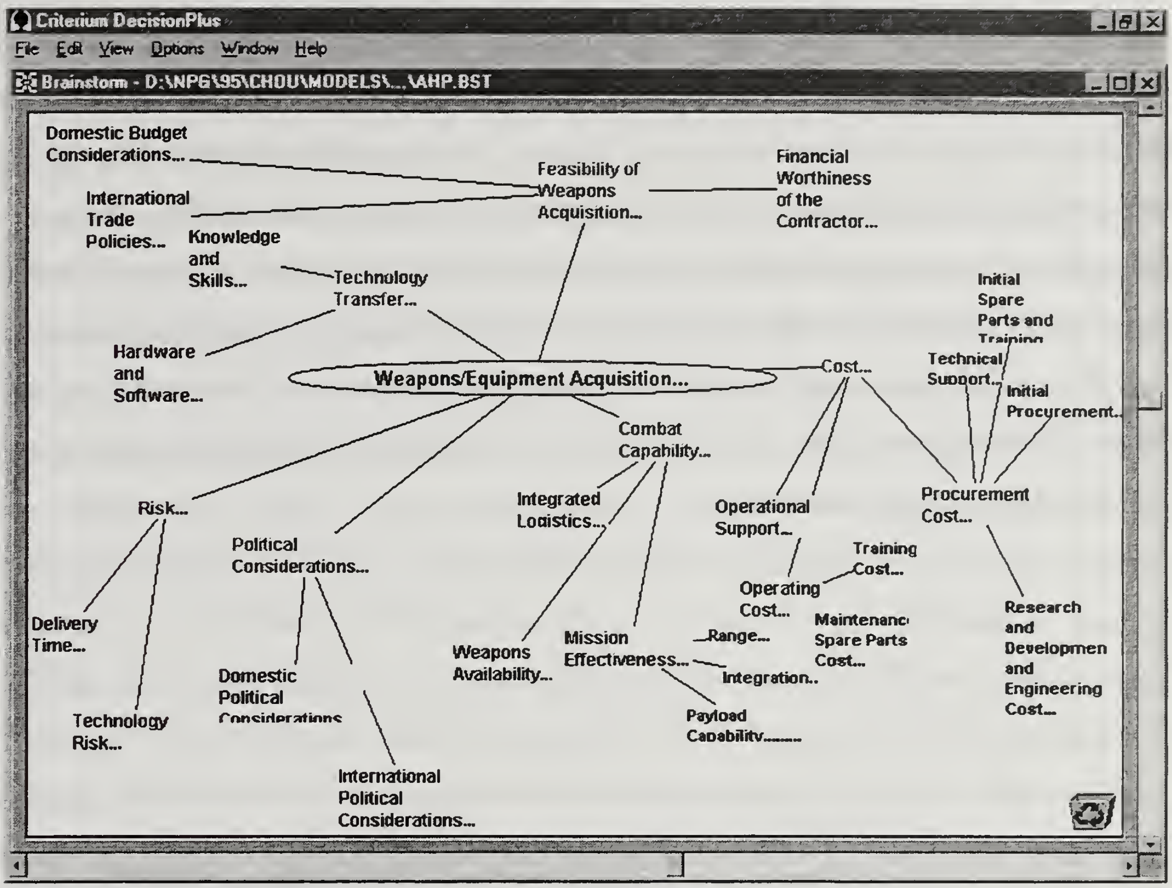


Figure 10. Results of Analysis

that their scope will provide the information needed to design the DSS. Additionally, some of the questions were designed to solicit information outside the scope of the DSS, but indicate the willingness of the respondent to use a DSS. Several questions are designed to see if the respondent is familiar with the term DSS.

When designing a questionnaire for the development of the DSS, it is necessary to develop questions which will return measurements for the various factors or criteria that are required for the operation of the model developed in the analysis step. The survey questions are in Appendix A. Question 3, which has seven optional questions, and

Question 4 are the questions which will be used to generate the weights for the criteria developed in the previous section.

Questions 3 and 4 only support the generation of criteria at the second level of the hierarchy, with the first level being the goal level. The hierarchy is shown in Figure 11 and detailed information can be found in Appendix C. The other levels of the hierarchy are based on my experience and are intended to show a more realistic hierarchy for the decision. For this thesis I could not expect to have the organizational backing for a more extensive survey that would provide the depth of information required for the actual factors at lower levels in the decision hierarchy. Therefore, I limited my survey to the first level of the decision hierarchy.

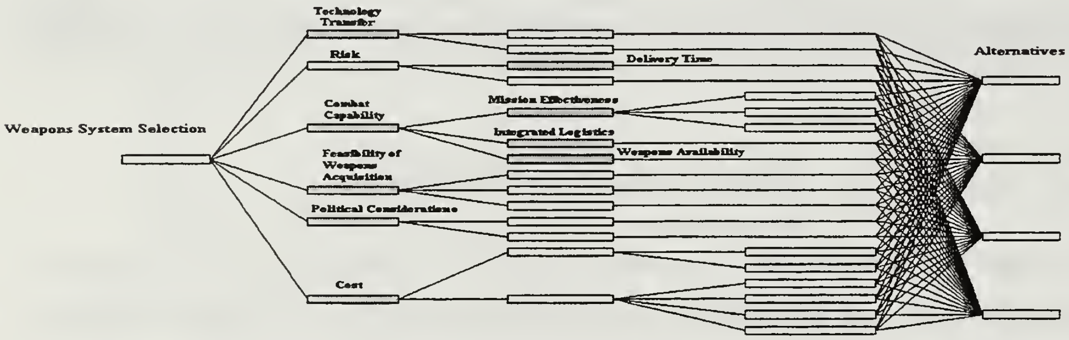


Figure 11. Decision Hierarchy

The other questions in the survey are intended to create a common vocabulary and direct the respondent to the subject of the survey. Naturally, this cannot be an extensive survey. My respondents are senior officers in transit between commands, going to military schools in the ROC.

The respondents to the questionnaire are at different levels of the procurement system. Since this system is designed for very high level management, I have weighted the responses from the questionnaire in a ratio of 3:2:1. The ratio 3 is for respondents who are the actual decision makers. These are high ranking executives usually in headquarters commands. The ratio of 2 is for staff and other commands that make recommendations directly to the decision maker. The ratio of 1 is for the user of the weapons system at a level of commanding officer and leaders who may be directly responsible or involved in the equipment's use. Each of these respondents have a different view of the purchase of a weapons system. For example, the user of the system is usually overly concerned with the capabilities of the weapon. The staff concerns are directed towards planning and support for systems throughout the fleet. The decision maker is concerned with the political and budgetary concerns and must look to the long range planning for the organization.

The method of the survey included a recorded tape with a background of DSS and an explanation of the survey. Respondents who were studying in the National Defense University were surveyed collectively. Some other respondents were contacted individually. I sent out 262 copies of the questionnaire. I received 179 copies. From those, I randomly picked 100 copies for statistical analysis. The purpose was to reduce the mathematics involved in calculating statistics of the results of the survey.

To be properly done, a survey for the development of a DSS should attempt to identify all criteria used by decision makers in the domain that the DSS is intended to function. I have provided in the questionnaire two questions which can be filled out by the respondent if the criteria listed is inadequate.

4. Decisions of Criteria

From the results of the statistics obtained from the questionnaire, the importance of various criteria on a decision can be determined. The quality of output from the DSS is directly related to how well the criteria represent the decision process of the user. This step is the most important step in the design process. If there is some criteria not covered by the DSS or the definition of a criteria is not precise, the selection of the criteria will produce a system that is unsound or produces dubious results. To increase the credibility of my system and the likelihood that it will produce quality information, I have performed three steps:

- Consulted with decision making staffs to acquire the factors or criteria that they consider important. Discussed with them actual example weapons procurement.
- Taken into account the regulations for procurement in the ROC and related information and incorporated it into the demonstration DSS.
- From the statistic results of the questionnaire, selected the most significant eight factors which will be incorporated into the DSS model.

The results of the survey indicate that most respondents agree that the six factors selected are important considerations when making a purchase of equipment. When compiling statistics to generate the actual factors for each of these criteria, I selected at random only 100 of the responses to simplify the process of computing the statistics. Question 3 was used to determine whether the respondents agreed that these were important criteria. Question 4 was used to generate the weights that the respondents believed these criteria should have. The six criteria targeted in the questionnaire are:

- Technology Transfer. The technical capacity which will exist domestically after the procurement of the weapons system. The greatest advantage is represented by a purely domestic development and research followed by the relative willingness of the source country to supply technical expertise and information.

- Delivery Time. The time required to deliver an operational system, and possibly the time to train personnel in operation and maintenance of the system.

- Combat Capability. Represents the performance characteristics of the weapons system evaluated on the same numeric scale as the other criteria. This is a composite of the capabilities of the weapons system.

- Feasibility of Weapons/Equipment Acquisition. The feasibility of acquiring the weapons system, this factor involves trade restrictions, international embargoes, and domestic budget considerations.

- Political Considerations. The sum of all political considerations both domestic and international.

- Cost. The cost of both purchasing the system and operating it.

5. Assigning Weights

The most significant problem in assigning weights is assigning the weights to non-numeric criteria. For example, the only numeric criteria available in the list of six first level criteria is cost. In the design of my questionnaire in Question 4 the respondents responded to the importance of each factor as a percentage of all factors. Additionally, they responded to the combat capability subcriteria in the same way. For example, combat capability equals 100% and the subfactors are a portion of this 100%. I used this response to generate a factor that represents the importance of each item in the decision. Further, I gave more weight to the actual decision makers response in the ratio of 3:2:1 as mentioned in the previous section. The sum of these multipliers and the response was used to generate an average weighting from the survey response. Since I have no actual cost data to generate a numerical criteria, I performed the same operations for cost as the other five factors. Appendix C is a spreadsheet listing of the factors used in the model. The only factors computed from the survey were the six listed previously. The remaining factors in the model were generated ad hoc using my personal experiences and I believe they would represent the criteria at that point in the model.

The two most significant factors in the decision from these calculated results are technology transfer and the combat capability of the system. All other factors have approximately the same weight in the decision making process

Technology Transfer calculated to a weight of .22. This weight is entered into the Criterium software as 22. All ranges in the Criterium software are from 0 to 100. In the Decision Hierarchy technology transfer consists of:

- Knowledge and skills. Intangible skills and knowledge gained with the use and employment of advanced or new technologies.
- Hardware and software. The actual equipment or software gained by the ROC.

In this section of the hierarchy knowledge and skills was assigned a value of 60 and hardware and software transfer was assigned a value of 40. The alternatives are each assigned a value which is representative of that source for knowledge and skills and hardware and software transfer. The hierarchy of technology transfer is shown in Figure 12.

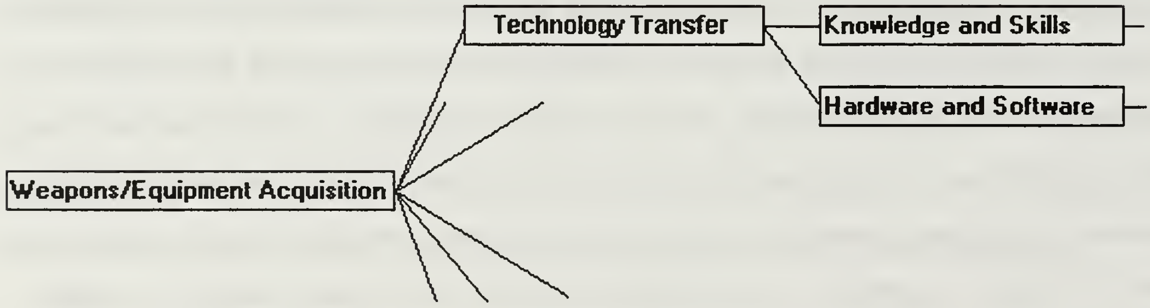


Figure 12. Technology Transfer

Risk consists of:

- Delivery Time. Calculated to a value of .11 from the survey results. This is entered into the hierarchy as 11 in a range of 0 to 100.
- Technology Risk. Represents whether the weapons system is a finished technology or a leading edge technology. This points to the risk that the weapon may in fact be ineffective since it is untested in combat.

Risk is set to a 60/40 ratio of delivery time to technology risk. Technology risk is made up of technology risk factors for each alternative. Delivery time was of course, a subject of the questionnaire and is set to 11. This is the only criterion that was subject to the questionnaire that was not at Level 2. The hierarchy for risk criteria is shown in Figure 13.

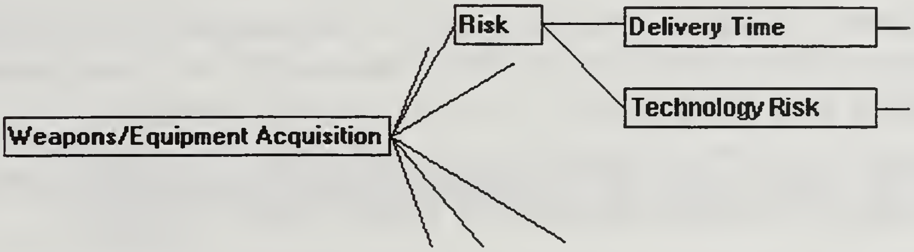


Figure 13. Risk

Combat capability is calculated as .22 and its effect on the goal of the hierarchy was set to 22. Combat capability is made up of three criteria:

- Mission Effectiveness. A reflection of the effectiveness of the weapons system.

- Integrated Logistics. Represents whether the technology of the weapons system fits well into the existing systems used by the armed forces of the ROC. A weapons which uses unique spares or supplies would require unique logistics to maintain and use.

- Weapon Availability. The reliability and maintainability of the weapons system.

Mission effectiveness is set to 80, integrated logistics to 5 and availability is set to 15 as to their effect on combat capability. The individual values for integrated logistics and availability are determined by the individual values for these factors from each alternative.

Mission effectiveness is broken down into three subcriteria:

- Range. The effective range of the weapon.

- Integration. Whether the weapons system is well integrated with the ship's existing weapons system. Does it provide extra capability or duplicate existing weapons.

- Payload Capability. Does the weapon have the capability of multiple types of warheads. Is the carrying capacity of the weapon suitable for the target.

Range, integration and payload capacity are set to a ratio of 60:30:10 and each criteria receives a rating from the four alternatives.

The hierarchy for combat capability criteria and its sub-criteria are shown in Figure 14.

Feasibility of weapons acquisition is made up of three subcriteria:

- Financial Worthiness of the Contractor is the ability of the company producing the weapons system to produce the system even though it may not be to their financial advantage to do so. It also indicates the companies technology expertise to research and ability to complete the project.

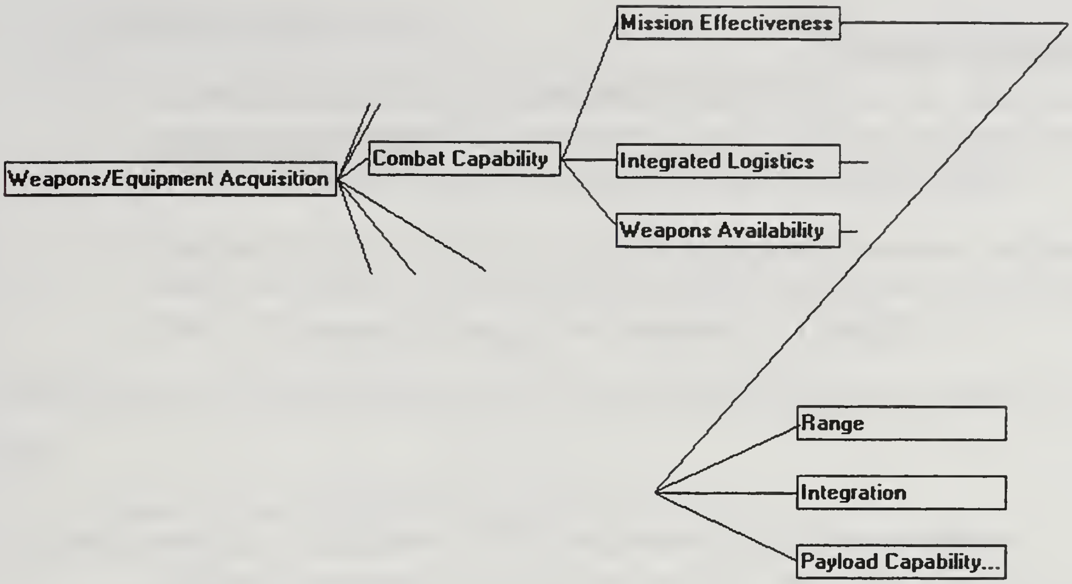


Figure 14. Combat Capability

- International Trade Policies. Some countries may have restrictions on the export of a particular type of weapons system, or there may be an internationally recognized embargo on the country that is the source for the weapon.

- Domestic Budget Considerations is whether or not the legislative branch of government will budget money for this particular weapons system.

Financial worthiness, international policies and budget considerations are set to a ratio of 5:80:15 and each receives a factor from the four alternatives. Feasibility has a value of .17 and is set to 17 for its effect on the overall decision. The hierarchy for feasibility of weapons acquisition is shown in Figure 15.

Political considerations are made up of two factors:

- Domestic political considerations include domestic politics involved with government contracting.

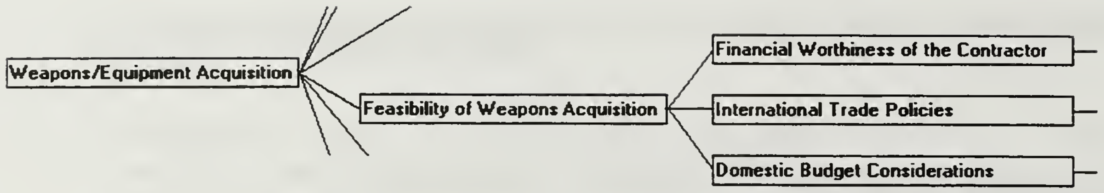


Figure 15. Feasibility of Weapons Acquisition

- International political considerations involve embargoes to outlawed countries or sources of supply which are not politically aligned with the ROC.

Political considerations calculated to a value of 0.08 and are set to 8 in the model. There was small response to part G "Other", that calculated to a value of .02. I included this response into political considerations rather than create a new criteria. Domestic and international political considerations are set at a ratio of 80:20. Figure 16 shows the hierarchy for political considerations.

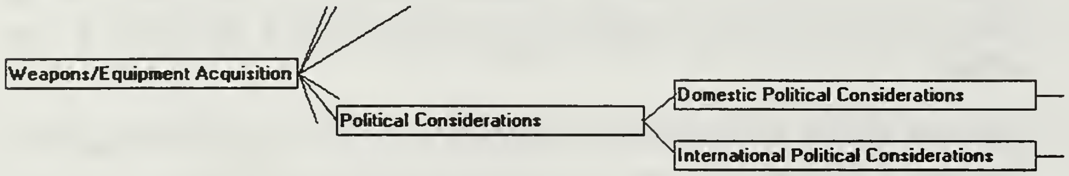


Figure 16. Political Considerations

Cost consists of:

- Operating Cost. The cost associated with the use of the equipment, for example, steaming time required to train with the equipment, the cost resulting from a training exercise which expends ammunition, missiles, etc.

- Procurement Cost. Cost of the equipment at initial purchase including the initial maintenance of the equipment and the initial parts support for the equipment.

Operating and procurement costs are set to an 80:20 ratio as to their effect on overall costs.

Operating costs are further broken down:

- Maintenance Spare Parts Cost is the cost of the parts to maintain the equipment and the cost of preventative maintenance spares to keep the equipment at readiness.

- Training Cost is the cost of training maintenance personnel and operations personnel.

Maintenance and training costs are set to a ratio of 80:20 and are represented in each alternative.

Procurement costs are further broken down:

- Research, Development and Engineering Cost is the cost of the development of the weapons system and the cost of its production.

- Initial Procurement is the minimum cost of acquiring a production run of the equipment.

- Initial Spare Parts and Training is the cost of initial parts support and the initial training of personnel to operate and maintain the system.

- Technical Support is the cost of technical personnel to support the weapons system while ROC personnel are being trained.

These costs are set in a ratio of 10:80:40:60 and are represented as individual factors for each alternative. The hierarchy for cost is shown in Figure 17.

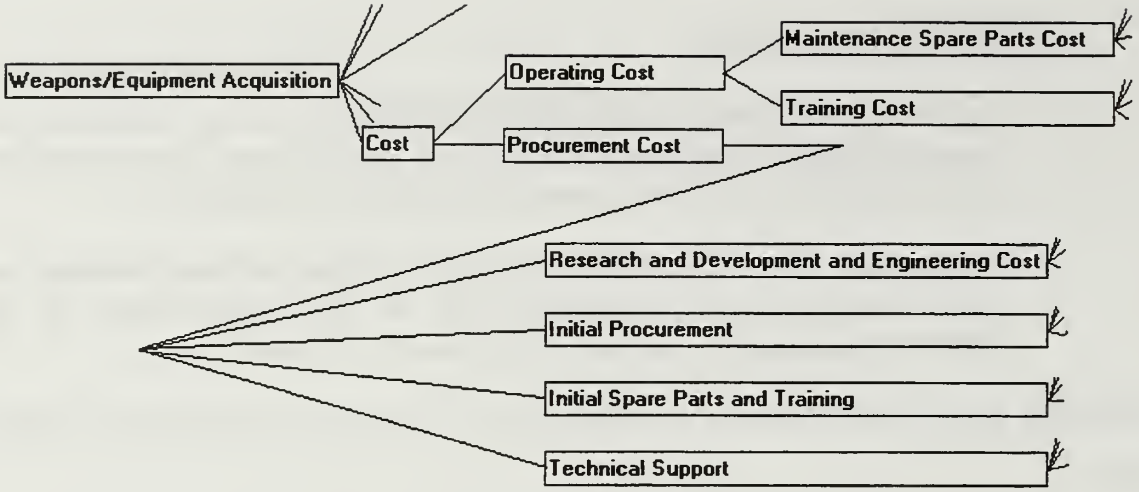


Figure 17. Cost

6. Simulation

The Criterium software uses a pairwise comparison method to simulate the decision process. A pairwise comparison is made between each criteria in each group of the hierarchy to determine the effect of that group on the next level of the hierarchy.

When the simulation is run with the criteria values entered in the previous section, it presents the weapons system produced by the Republic of China as the best alternative. The next best alternative is the system produced by the U.S. With the Criterium software, you can display a graph which shows the contribution of all criteria made to all the alternates. The magnitude of any alternate indicates its score and different colors indicate the contribution of each criteria to that score. In the same menu item, it is possible to display an ideal alternate which can be used to determine whether any alternate sufficiently meets the requirements of the decision. The results window for the Criterium software shown in Figure 18.

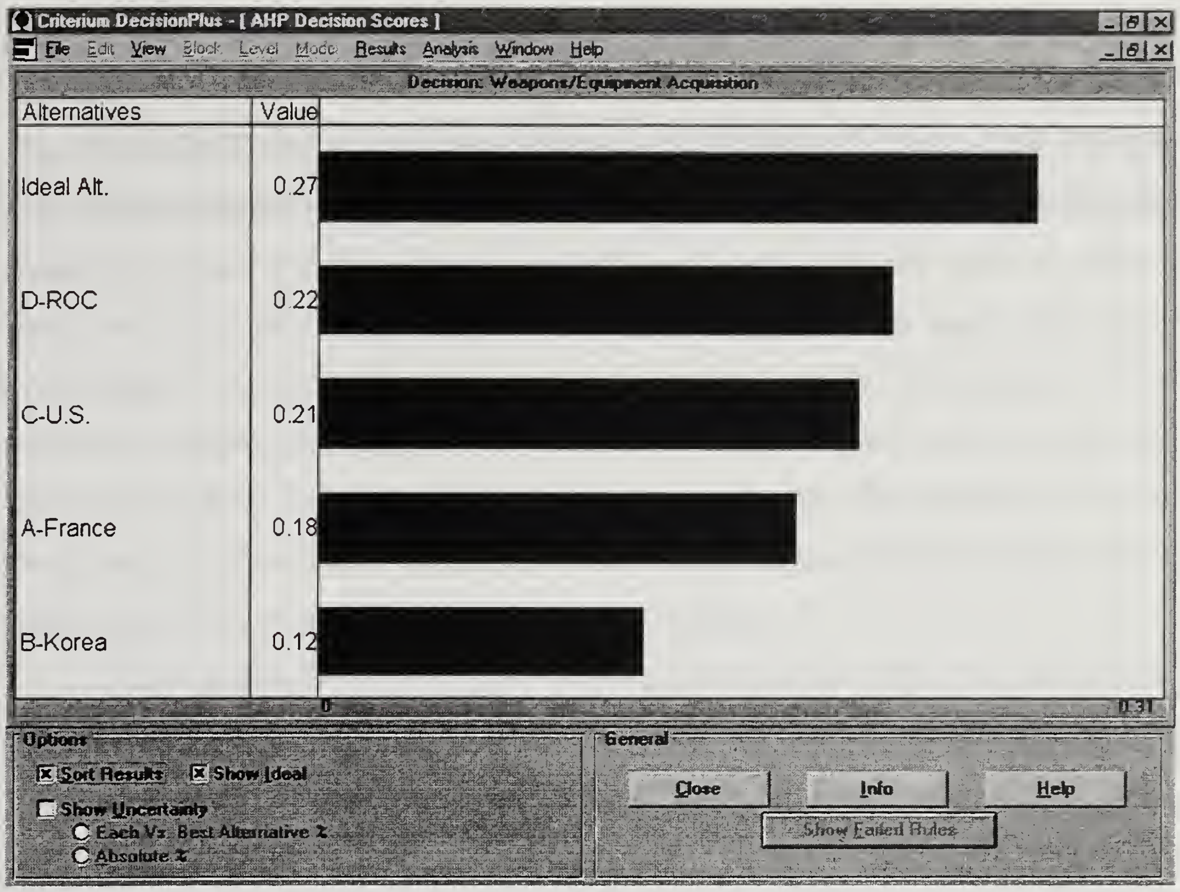


Figure 18. Results

The user of the system will naturally question whether this is a reasonable alternative. The Criterium software provides provisions which will be covered in Chapter IV for analyzing the sensitivity by weights and the contribution of various criteria. Additionally, not covered in Chapter IV, the Criterium software has provisions for tracking the uncertainty in the assignment of the weights to each criteria.

7. Recommendations

The last step in our design methodology is to compile changes required to make the model perform correctly. There are two types of changes: the first type are changes to the weights of various criteria that are already in the model so that each level will reflect a reasonable decision hierarchy. The second type are additions to the hierarchy or new connections between the levels of the hierarchy. These recommendations will be compiled after testing the model for reasonableness. Step 6 and 7 of our design methodology, shown in Chapter I, Figure 1, will be covered in more detail in Chapter IV.

IV. SIMULATION AND ANALYSIS

In order for a DSS to be effective, the user has to understand the assumptions and criteria that underlie the model used in the system. Without an understanding of it, the manager could not trust the result nor could the manager modify the model to achieve better results. The first step in the process of achieving good results from a DSS is the initial design of the DSS. This design must represent the hierarchy of the decision. This was done in Chapter III. Although this design lacks sufficient detail for a real system, this detail was added by incorporating experiences in procurement. This created a DSS with enough sophistication that in this chapter will cover modifying this initial design into a system likely to be used in the real world in a real decision.

A DSS is intended for use by the decision maker. In Chapter II, it was determined that the characteristics of a DSS require that it be easy to use and interactive. This chapter will demonstrate those aspects in the Criterium software. An understanding of the internal mechanisms of the DSS is not required for a user to modify the initial DSS created in Chapter III. If this kind of detail were needed by the user, this system would likely fail because the users at this level are only interested in the domain of the decision. These high level users cannot spend the time necessary in discovering the details of the software involved in the process. The software meets this requirement well by utilizing a graphics interface and displaying information about the process in a form easily understood by the user. The software provides tools so that the decision maker can modify the hierarchy and the weighting.

A. REVIEWING THE RESULTS

A DSS is intended to assist the manager make a decision. Although the manager could be the designer of the DSS, it is unlikely at this level of decision making (purchase weapons/equipment) that is the case. The best reviewer of the results of the model would in fact be the decision maker. In the weighting of the criteria for the initial model it was necessary to multiply the effects of the survey described in Chapter III by a factor of 3. This was done because the number of manager's surveyed at this level (high level decision makers), is very small and only they have a true feel for the political climate and long range goals of the ROC Navy. Others at a lower level tend to narrow their view to their own expertise and problems. This tends to make the lower level decision maker's view less pragmatic than that of the person who must champion the actual decision.

1. The Ideal Alternative

The results of the decision are displayed by the DSS as a bar chart showing the relative score for each alternative. These alternatives are for fictitious weapons system A, B, C, D. Figure 19 shows the results of this initial model. The best alternative was a

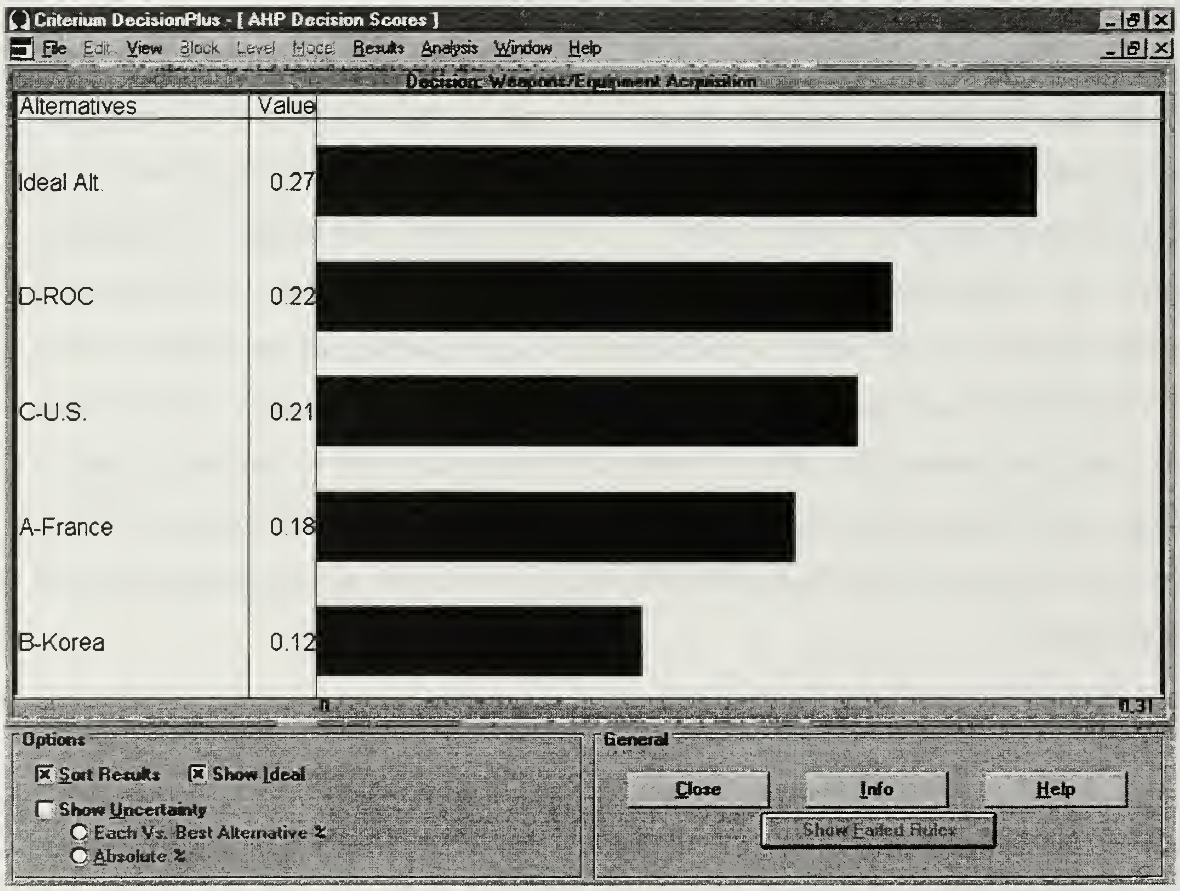


Figure 19. Initial Results

weapons system produced and developed by the ROC. The DSS also displays an ideal alternative. This alternative is defined as the "perfect alternative". This would be the alternative that had the highest weighting for any criteria. This is the simplest check on the reasonableness of the results. Compared against the ideal solution, we can ask ourselves the question of whether any solution compares well to the best solution. If the decision scores for the alternatives are a very low percentage of the ideal, it may indicate an unresolvable conflict in the criteria or tell the decision maker that he must look for better alternatives.

2. Contribution of Criteria

One of the simplest analysis done by the software is a bar chart display of the contribution of each criteria to the decision. This display is compiled by level and shown in Figure 20 and Figure 21. The user selects the level, goal, level 2, etc. and displays the contribution to the goal or a particular criteria at that level. This gives the decision maker a view of the contribution at each level to the decision. With this information, the user can determine whether the contribution of a particular criteria has a reasonable magnitude. The graphics display at the goal level also shows the user which criteria have contributed most to the choice of the final alternative. This can be used to determine the source of any unreasonable information and would lead the user down the path of the hierarchy necessary to correct the model. The ability to select different levels allows the user to fine tune the model from level to level until the user discovers the source for the unreasonable behavior of the model.

3. Sensitivity Analysis

After the user has corrected the gross errors in the model using the contributions of various criteria and comparing the results to an ideal result, subtle errors will remain. These errors are the result of criteria in the mid-levels of the hierarchy that are sensitive to small changes in the previous level. In some cases, this may be an exact model of the decision process. In others, it may be a failure in setting the weights between various criteria. For the user to analyze these effects, the software provides a sensitivity analysis mechanism.

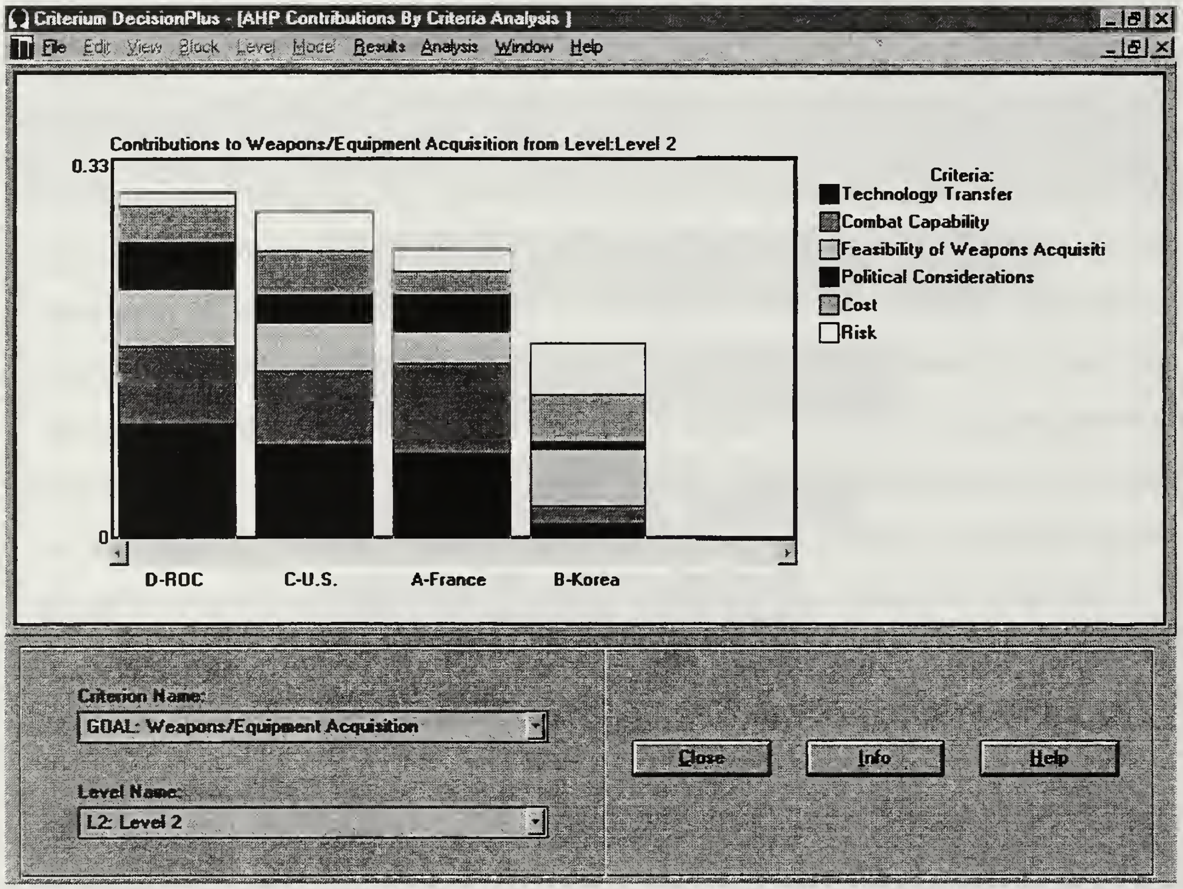


Figure 20. Contribution to Goal

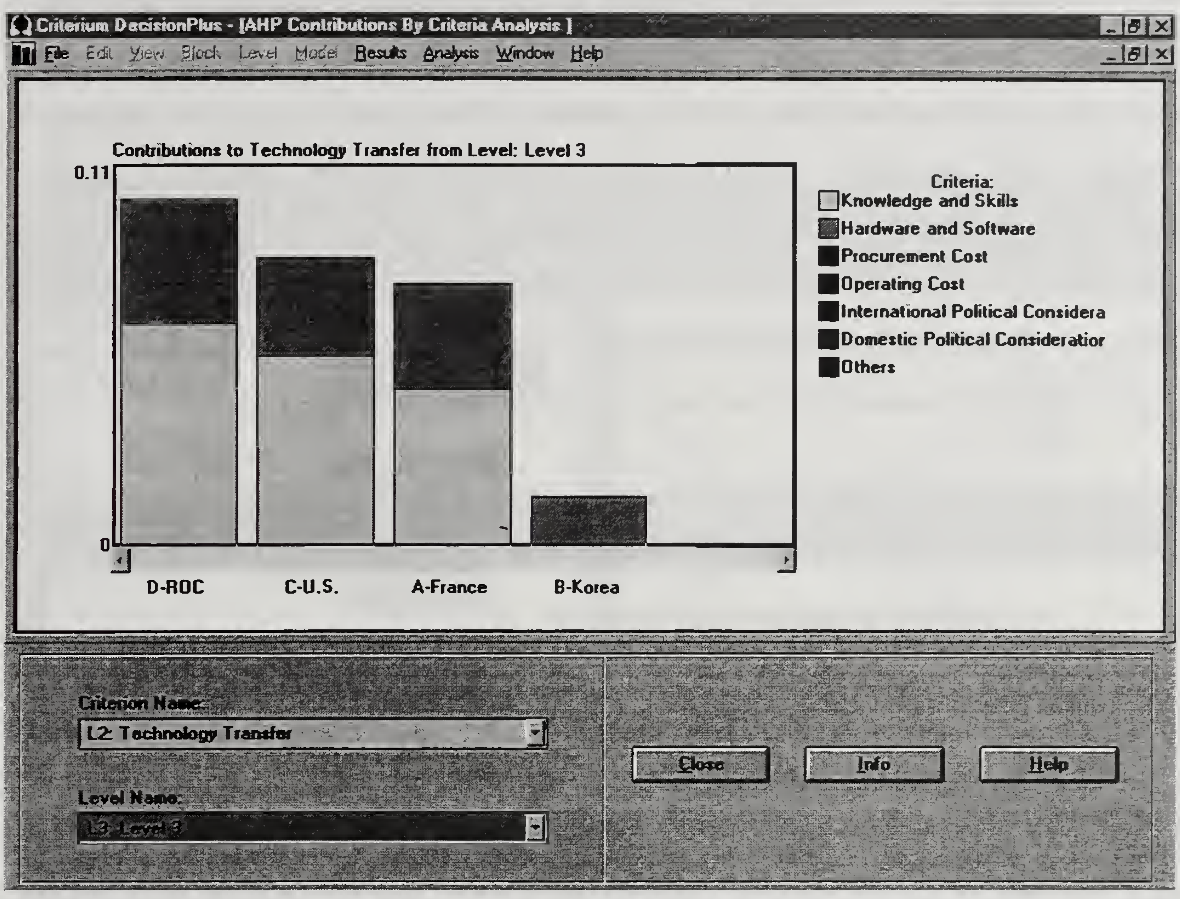


Figure 21. Contribution to Technology Transfer

Sensitivity analysis is defined as changes in the weights or ratings that change the preferred alternative. The software provides a simple mechanism for the sensitivity analysis. The user selects the bar chart which shows the results of the model. Then the user selects the sensitivity analysis display and places them in such a way that the user can see both displays. The sensitivity display provides a pointer which the user can move, and simultaneously, the result chart will change to reflect changes in the criteria that the user is manipulating.

The sensitivity display lists the criteria from most sensitive to least sensitive. This is shown in Figure 22. In the graphics portion of the display where ever the lines for each alternative cross, at that particular point, the criteria will lead to a change in the displayed alternative. This mechanism is much simpler to operate than, for example, a system where numeric quantities are displayed. Simplified operations of this kind are a requirement for a DSS in order to be used by higher level managers. Its immediate feedback to the user gives the user the ability to make rapid tests to determine whether the model is a good representation of the decision process.

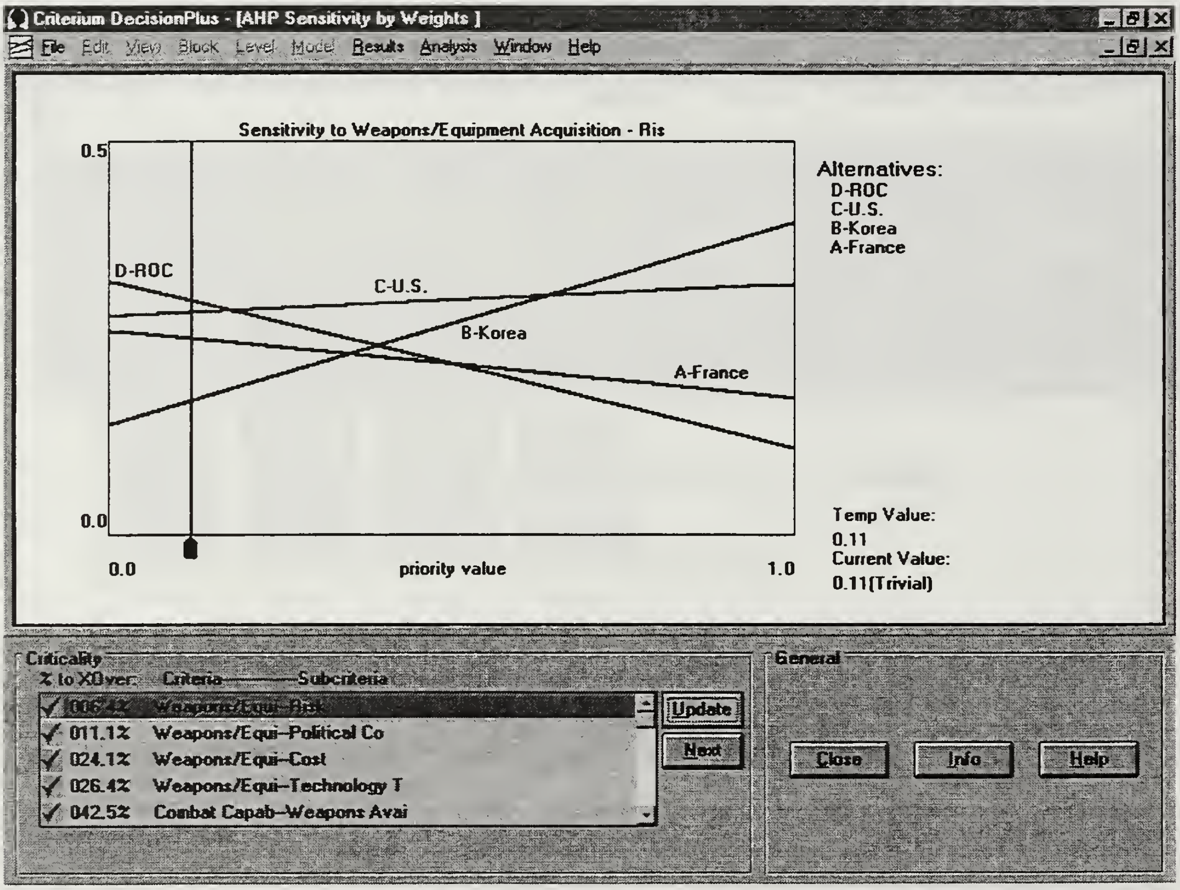


Figure 22. Sensitivity Analysis Window

Figure 23 shows two windows for sensitivity analysis and the results display. With the display setup in this manner, it is possible to see the effects of moving a particular criteria to a critical point and a change of the recommended alternative to the

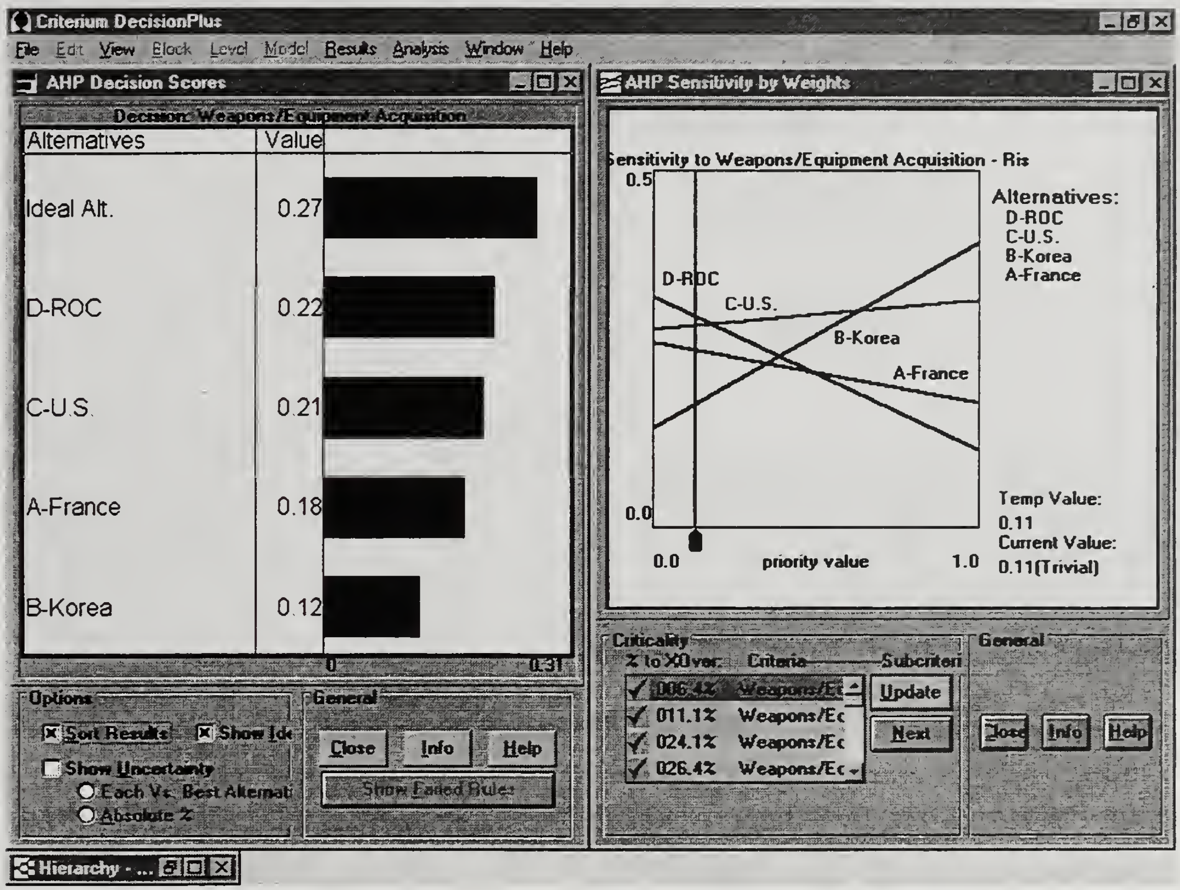


Figure 23. Sensitivity Analysis and Results Window

decision. The graphics would indicate when more than one alternative is involved in the change of the criteria's value. This may indicate in the model that some criteria should not in fact be modeled because the range of this criteria is narrow for each alternative. This can normally be done by inspection. When the graph is displayed many of the alternative lines will cross the best alternative very near to the current value indicated by the cursor for that criteria. Any single alternative line crossing the best alternative may indicate that these alternatives are close together in value or it may indicate that one of the alternatives has been weighted incorrectly. Figure 24 shows the effect of moving the

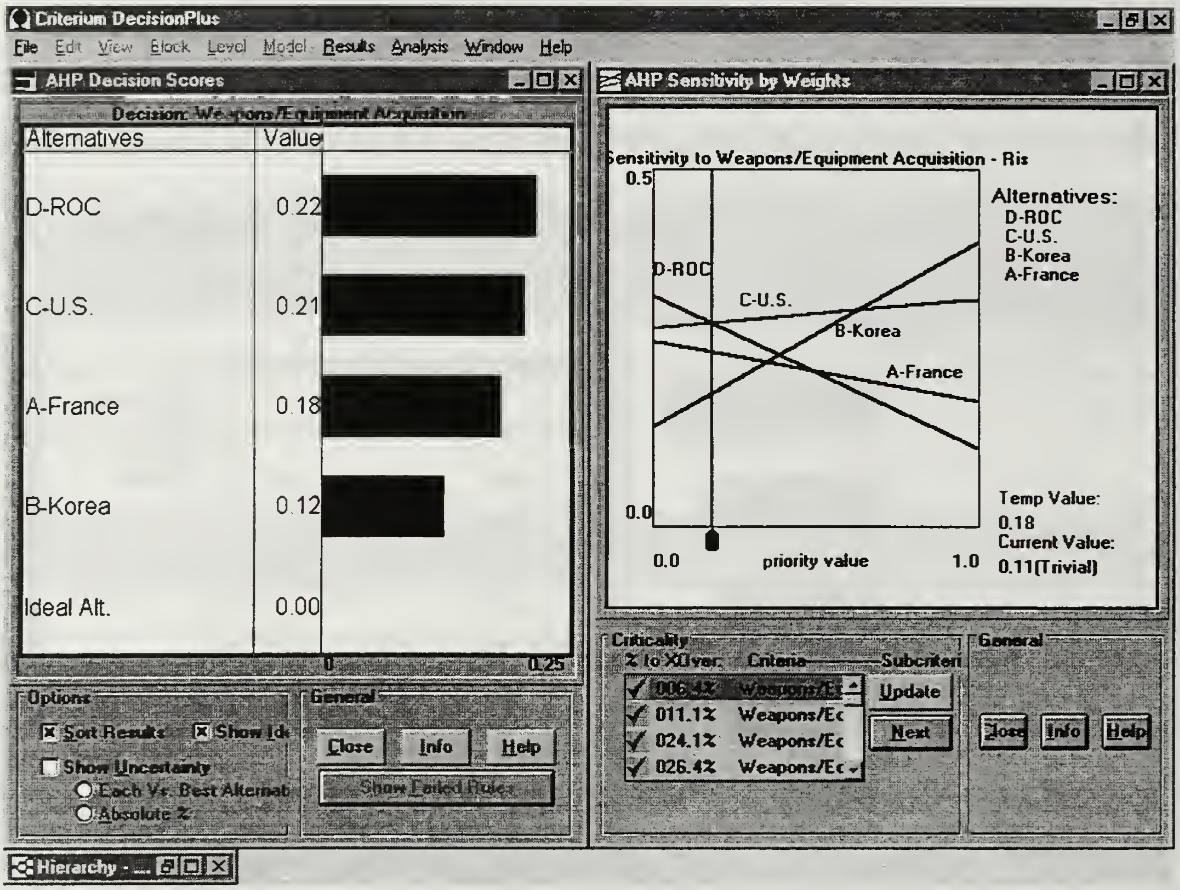
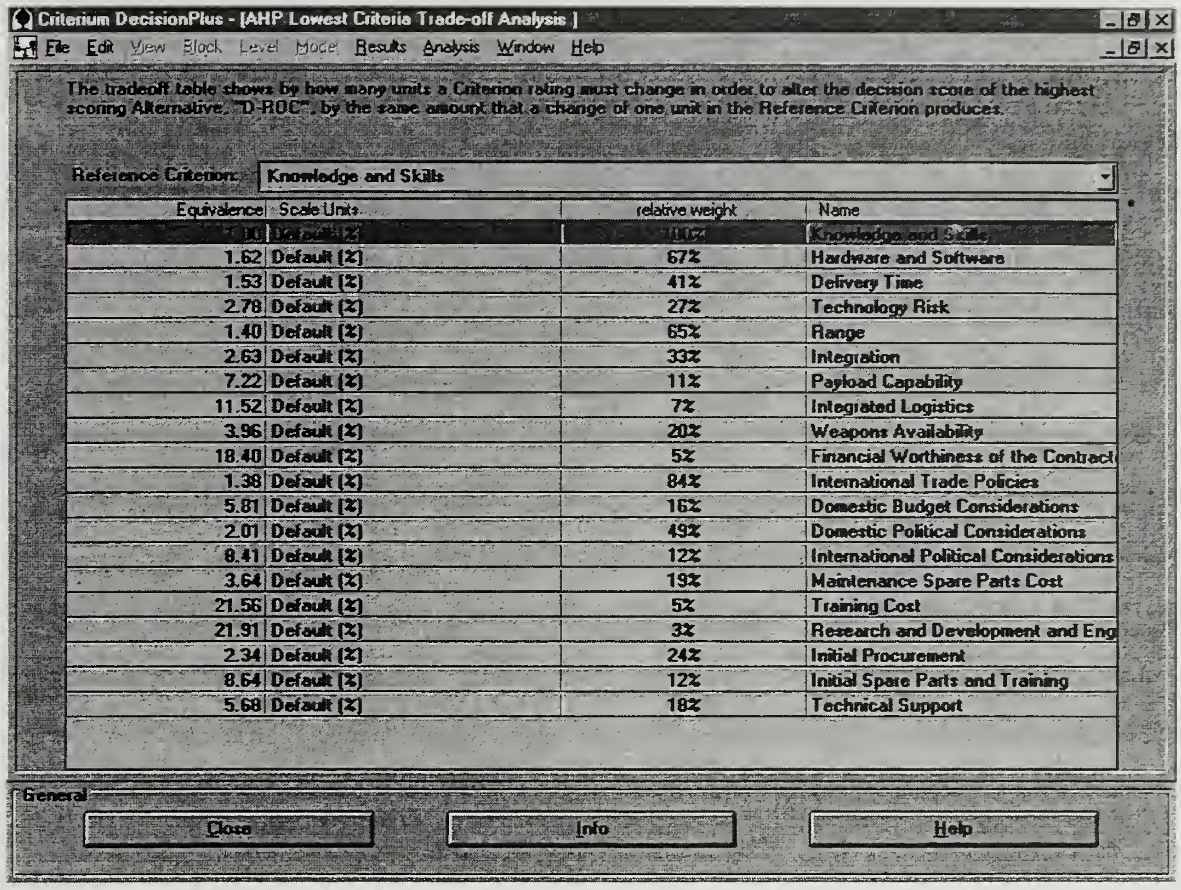


Figure 24. Critical Point

line for knowledge and skills for the ROC alternative up to the critical point where the alternative choice changes from ROC to US.

4. Tradeoffs

This function of the Criterium software displays the criteria at the lowest level of the hierarchy as a ratio to a selected criteria. For example, if the user selects the criteria in the model of "Knowledge And Skills" as a reference, it shows a list where one unit of Knowledge And Skills equals X units of all the other lowest level criteria. This allows the decision maker to directly observe the reasonableness of the model by weighing the lowest level criteria against each other to insure that they have the proper relationship. This is the most difficult to grasp because it's numerical in nature and is presented as a simple list. The Tradeoff of Display is shown in Figure 25.



Equivalence	Scale Units	relative weight	Name
1.00	Default (%)	100%	Knowledge and Skills
1.62	Default (%)	67%	Hardware and Software
1.53	Default (%)	41%	Delivery Time
2.78	Default (%)	27%	Technology Risk
1.40	Default (%)	65%	Range
2.63	Default (%)	33%	Integration
7.22	Default (%)	11%	Payload Capability
11.52	Default (%)	7%	Integrated Logistics
3.96	Default (%)	20%	Weapons Availability
18.40	Default (%)	5%	Financial Worthiness of the Contract
1.38	Default (%)	84%	International Trade Policies
5.81	Default (%)	16%	Domestic Budget Considerations
2.01	Default (%)	49%	Domestic Political Considerations
8.41	Default (%)	12%	International Political Considerations
3.64	Default (%)	19%	Maintenance Spare Parts Cost
21.56	Default (%)	5%	Training Cost
21.91	Default (%)	3%	Research and Development and Eng
2.34	Default (%)	24%	Initial Procurement
8.64	Default (%)	12%	Initial Spare Parts and Training
5.68	Default (%)	18%	Technical Support

Figure 25. Tradeoffs

B. MODIFICATION OF THE HIERARCHY MODEL

Modification of the model is most easily performed by displaying the model hierarchy and double clicking on the block which represents the criteria the user is interested in modifying. This will bring up the window where original weights were entered. These weights are relative values between the criteria at the lowest level. These weights represent the relative worthiness of each weapons system in that criteria. The software automatically normalizes these numbers for the point in the level that the user is modifying.

1. Model Reasonableness

The simplest way to determine whether the model is producing reasonable results is to examine the contribution by each criteria to the results. In Figure 20 is a display of the results from the current model.

An examination of these results indicate that the largest factor contributing to the alternative of the ROC being selected over others, is technology transfer. This reflects the results of this survey which rated technology transfer and combat capability as equal importance and the two most important criteria in the model. This is also a reasonable assertion for the ROC in that technical capabilities gained by the ROC are important as they are important for any country that wishes to maintain a strong defense. Since this is the largest contributor to the selection of the ROC as the best alternative and the other alternatives appear graphically to represent the amount of technology transfer that will take place to the ROC, this would appear to be reasonable and unlikely to require modification.

The next largest contributor to the selection of the ROC is combat capability. Combat capability appears to be equally distributed between the four alternatives with the exception of France which has a better combat capability. This is a reasonable result in line with my experiences in the procurement of weapons systems.

All other criteria with the exception of risk contribute equally to the alternatives. Cost in the case of the Korean option is an advantage, however, the Korean option is the least likely because of its effects on technology transfer. This leaves the risk criteria to be considered. Each option has a different degree of risk associated with it. But this is unlikely to be modified because the ROC has the most risk associated with the selection and if the risk were moved to the highest value, it would still win out over the US option. A sensitivity analysis of risk indicates that this is the most likely factor to result in the US option being selected, but moving the ROC to a value of 0 (maximum risk) will only bring the ROC option equal to the US option.

The above analysis can be performed by selecting one display (contribution by criteria) and would assure the user that the results do indeed reflect a reasonable option. As an exercise I investigated the contributions to technology transfer from the next level of the hierarchy (Level 2). At this level the numbers used for weighting were generated by my experience and research into regulations and past procurements of these types of systems.

Level 2 is shown in Figure 21. The contributions to technology transfer are two items, Knowledge and Skill and the Transfer of the Hardware and Software. Obviously, if you buy a weapons system, you will receive the physical aspects of it (hardware and software) but more important to the ROC is the technical knowledge and skills used to develop and maintain this equipment. This diagram again shows a realistic view of technology transfer. At this point, we cannot find anything to modify in the model that would make a significant difference in the selection of alternatives. A key attribute of a DSS is that its purpose is to assist in making a decision. Changes made to the model below a certain threshold would be counterproductive in that they could only serve in an attempt to make the model produce a decision. The real purpose of a DSS is to present the alternatives to the decision maker not to make the decision for him.

If we had found some relationship displayed to us graphically which would appear unrealistic, the process of modifying it would be as follows:

- Select the block in the hierarchy which represents the criteria that you wish to modify.
- Modify the weighting for that criteria to a better representation of the model.
- Display the results of the model and analyze it for reasonableness.
- If the results are reasonable, the software has presented the user with a prioritized list of the alternatives. This list is shown graphically and a glance at it will show the user the best alternative to the worse alternative. A glance will also show the user the relative worth of each alternative.

- If the results are not reasonable or require investigation, then analyze the most significant contributors to those results in an attempt to discover the error in the model. Then return to the first step.

C. SUMMARY

The Criterium software meets the majority of user interface requirements for a DSS. Graphics displays, simple input devices and easily interpreted output are a requirement for a DSS to function at a high level of management. Without these attributes, the system would probably go unused or its output would acquire a poor reputation.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The preceding chapters have demonstrated the utility of a DSS for military procurement. Large scale intricate decisions in procurement require detailed and nearly unlimited quantities of information to make the best possible decision. It is impossible for the decision maker to simplify, enumerate and analyze this information. Any decision maker must be able to champion his decisions to his superiors. To do this, he must, of course believe that he has made a prudent and reasonable decision. If he is overwhelmed with information that he cannot quantify, it will be difficult for him to believe that he is has covered every reasonable alternative. A DSS would assist the decision maker in quantifying the information coming to him. A DSS would also provide support to the decision maker in his belief that he has made the correct decision. Table 1 shows the differences between decisions made with the assistance of a DSS and more traditional methods.

Non-DSS	DSS Method
Complex problems, dissimilar criteria, large amounts of data	Reduce complexity, use dissimilar criteria comparison methods, automate data processing
Time-consuming, laborious staff work	Fast automated analysis
No time or data for analysis	Automated sensitivity analysis
Inflexible response to changing requirements	New insights, flexible data manipulation, system re-use, continuous process improvement
Expensive acquisition process and weapons	Improved control and cost performance
Subjective, inconsistent decisions based solely on human judgment; subject to critics	Consistent, objective decisions, open decision process; focus on process, not person
"Fighting fires"; crisis management	Quality analysis, planning, implementation

Table 1. Benefits of DSS

Table 1 demonstrates the advantages of using a DSS for complex decisions. The decision maker not only makes a more reliable decision but receives a better understanding of the factors leading to that decision.

A computer cannot replace human judgment or experience. The primary purpose of the DSS is to present the decision maker with information and analysis to augment these human qualities. The DSS will provide the user with analysis and probable results which will allow the decision maker to make a well-informed decision.

From the survey, we found that the higher officer's rank the less they tended to know about computers. But most of the officers surveyed believed that a working knowledge of computer systems would be necessary in the future.

We found that 60% of the people responding believed there were problems with the present procurement system and over 75% of the respondents thought that the procurement system should be standardized. These respondents also thought that there should be a systematic approach to weapons system selection. Seventy-eight percent of the respondents believe that a DSS would help decision makers, improve efficiency and save money. They also believed that DSS would lead to a more objective decision. Of the respondents 49% responded that they did not understand what a DSS is. Of this 49%, 60% were high ranking officers. This would point to a possible problem in the organization accepting DSS solutions for procurement. Further research and a much more detailed survey would be required to reach a conclusion relating to education and training for people at various levels in the procurement system.

The Criterium software lacks some mechanisms that would make it more usable in large organizations. The most significant problem is its inability to communicate with other software, for example, database queries or an electronic mail system. Without these, the software would have difficulty in being accepted as an organizational tool. This could easily be overcome by simply modifying the software to work with another organizational tool which has these capabilities. For example, modern spreadsheets have all of these capabilities and are commonly used throughout most large organizations.

These modifications to work with other software used by the organization would also give the Criterium software the ability to query databases.

The fact that the software lacks some mechanisms does not mean that it could not be used to introduce a pilot system and ultimately sell an organization on a larger DSS. The software will feed data to an Excel spreadsheet or text output to any other program; however, it only accepts data from other versions of itself. It would be possible for an organization to set up a hierarchy of DSS' each feeding a file to the one at the next higher level in the organization resulting at the highest level in a final decision. The only mechanism that could successfully do this would be a network of computers that share files. This would be problematic in a military situation because of problems with classified material and information.

B. RECOMMENDATIONS

- The ROC should complete its efforts to standardize the military procurement system as soon as possible. In doing this, they should attempt to establish a DSS to support the decision making in the military procurement process.

- The ROC should perform a broad and detailed survey to establish the factors that contribute to a decision of military procurement. This survey would establish a case for a DSS assisted decision making rather than the current practices.

- Computers have an increasing presence at all management levels. The ROC should insure that every management level has a working understanding of computers and computer assisted decision making.

- The ROC should try to move the procurement process from an individual decision to an organizational decision supported by analysis and computer assisted solutions.

C. FUTURE DEVELOPMENTS

In this thesis, has emphasized a DSS as a solution to military procurement problems. The ROC Navy's procurement problems obviously cannot be solved by the implementation of one system. In order to meet its future needs, the Navy requires long-range planning to provide database and networking support for a DSS. These database and networking systems must meet the needs of future support systems.

APPENDIX A. SURVEY

1. Current procurement regulation are sufficient to prevent misconduct. (Circle one response)

Strongly Disagree Disagree Do Not Know Agree Strongly Agree

2. We should have a standardize, systematic approach to the weapons/equipment selection and acquisition.

Strongly Disagree Disagree Do Not Know Agree Strongly Agree

3. Should the following factors relating to weapons selection be included ?

A. Feasibility of weapons/equipment acquisition (for instance the policy of the export country, export license; etc..)

Strongly Disagree Disagree Do Not Know Agree Strongly Agree

B. Cost

Strongly Disagree Disagree Do Not Know Agree Strongly Agree

C. Delivery Schedule

Strongly Disagree Disagree Do Not Know Agree Strongly Agree

D. Technology Transfer

Strongly Disagree Disagree Do Not Know Agree Strongly Agree

E. General Specifications of Weapons/Equipment
Weapons Performance
Integrated Logistics (ILS)
Risk

Strongly Disagree Disagree Do Not Know Agree Strongly Agree

F. Political Reasons

Strongly Disagree | Disagree | Do Not Know | Agree | Strongly Agree

G. Other (List Additional Factors)

____

____

____

4. What would the distribution of each factor as a weighted value that would achieve the best possible results for a selection process? Please allocate the appropriate percentage relative to each factor, all percentages will sum to 100%.

A. Feasibility of weapons/equipment acquisition (for instance the policy of the export country, export license; etc.)

____

B. Cost

____

C. Delivery Schedule

____

D. Technology Transfer

____

E. General Specifications of Weapons/Equipment ____________

Weapons Performance ________

Integrated Logistics (ILS) ________

Risk ________

Total = 100%

F. Political Reasons ____________

G. Other (List Additional Factors)

____________________ ____________

____________________ ____________

____________________ ____________

Total = 100%

5. Would a decision support system (DSS) assist the decision maker to make the right choice

Strongly Disagree | Disagree | Do Not Know | Agree | Strongly Agree

6. If a DSS is adopted, will it help the process of weapons equipment acquisition to meet the following objectives: (Please circle all that apply)

A. Efficiency related to time constraints

B. Efficiency related to cost

C. Efficiency related to combat effectiveness

D. Objective

E. Other (Please List)

____

____

____

7. On which of the following factors would the effectiveness of a DSS rely ? (Please circle all that apply)

A. The accuracy of budget estimates

B. Pre-implementation preparatory staff work

C. Implementation of contract

D. Other (Please List)

____

____

____

8. You are familiar with DSS

Strongly Disagree Disagree Do Not Know Agree Strongly Agree

APPENDIX B. RESULTS OF SURVEY

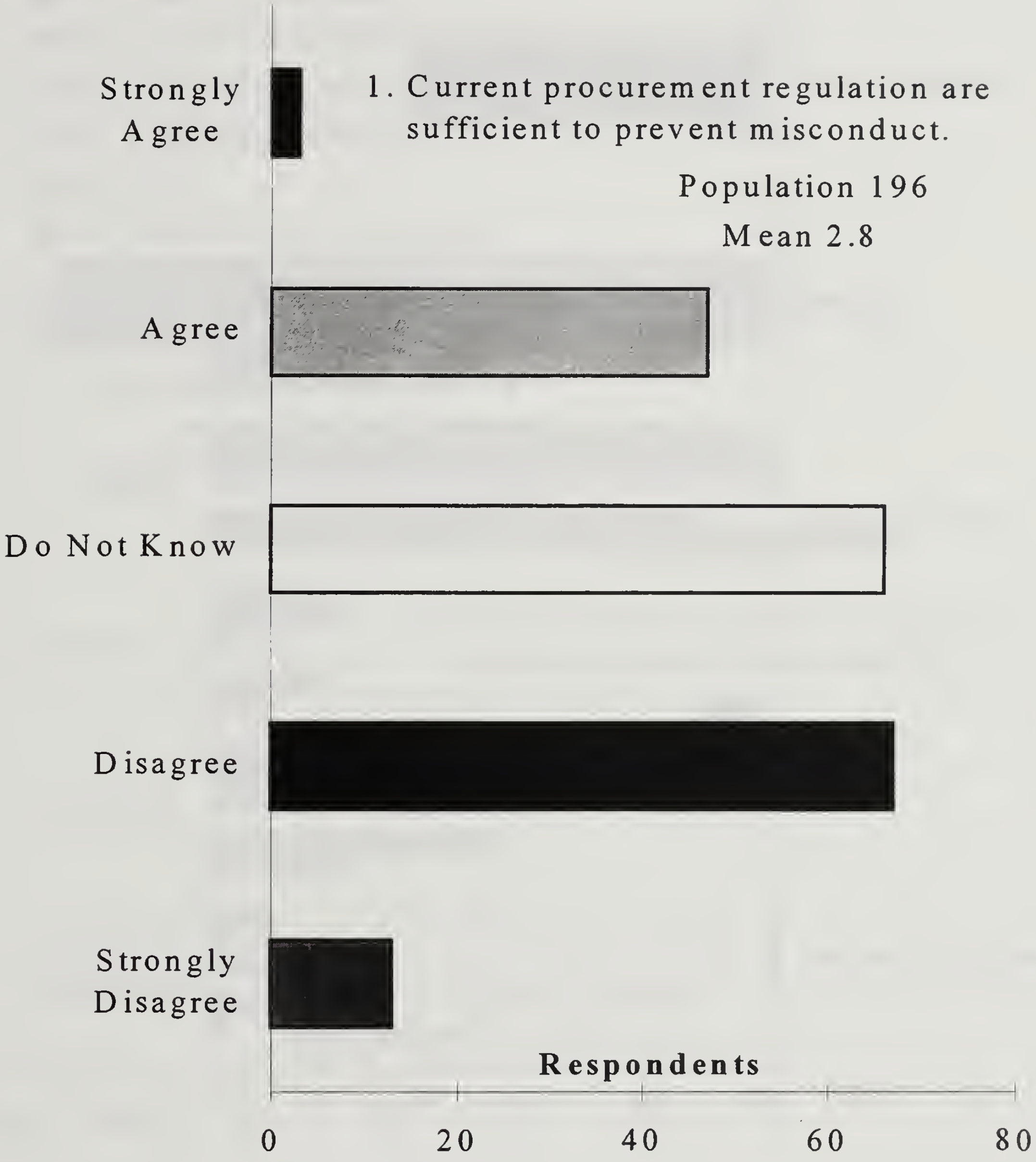


Figure 26. Question 1.

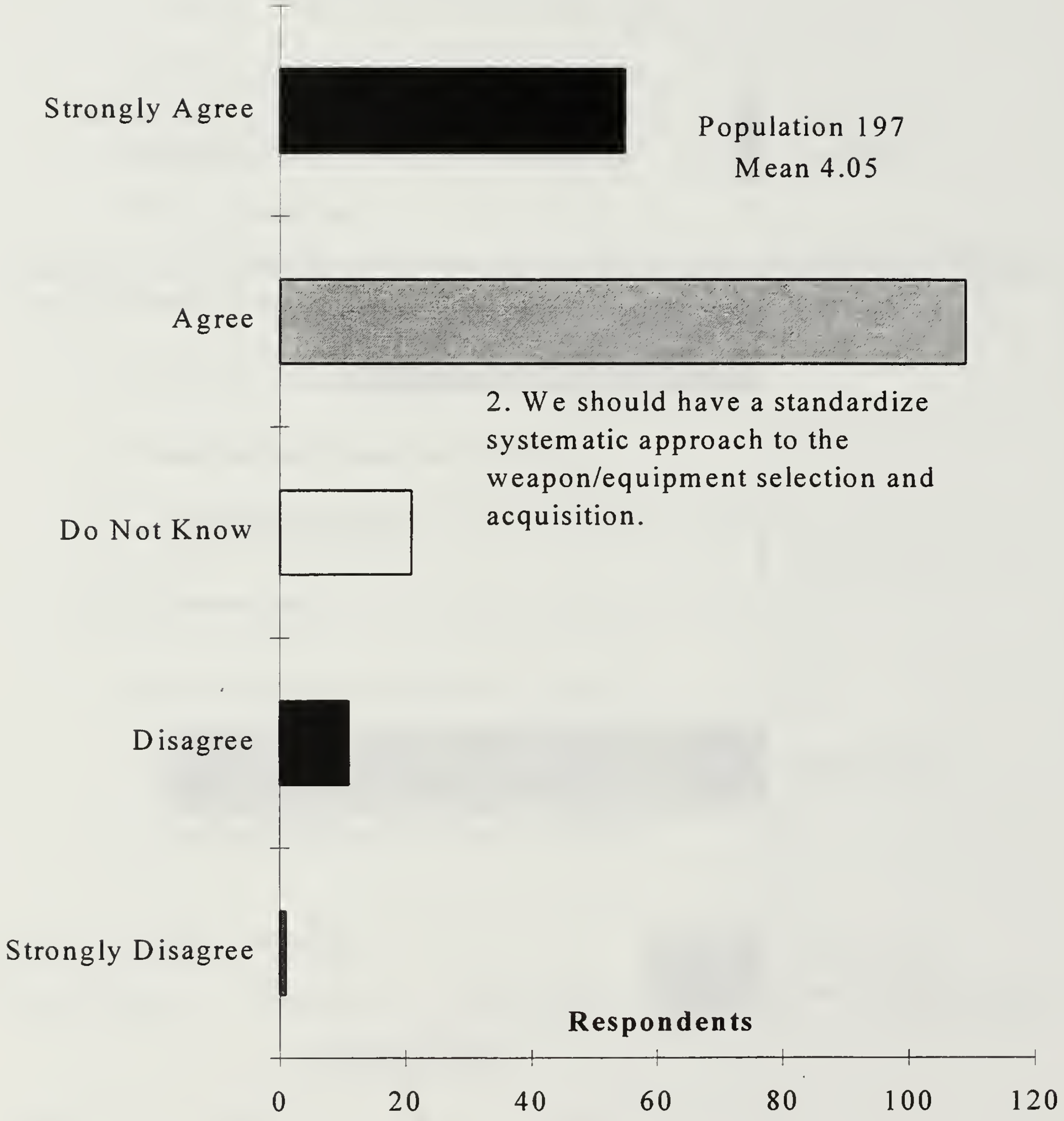


Figure 27. Question 2.

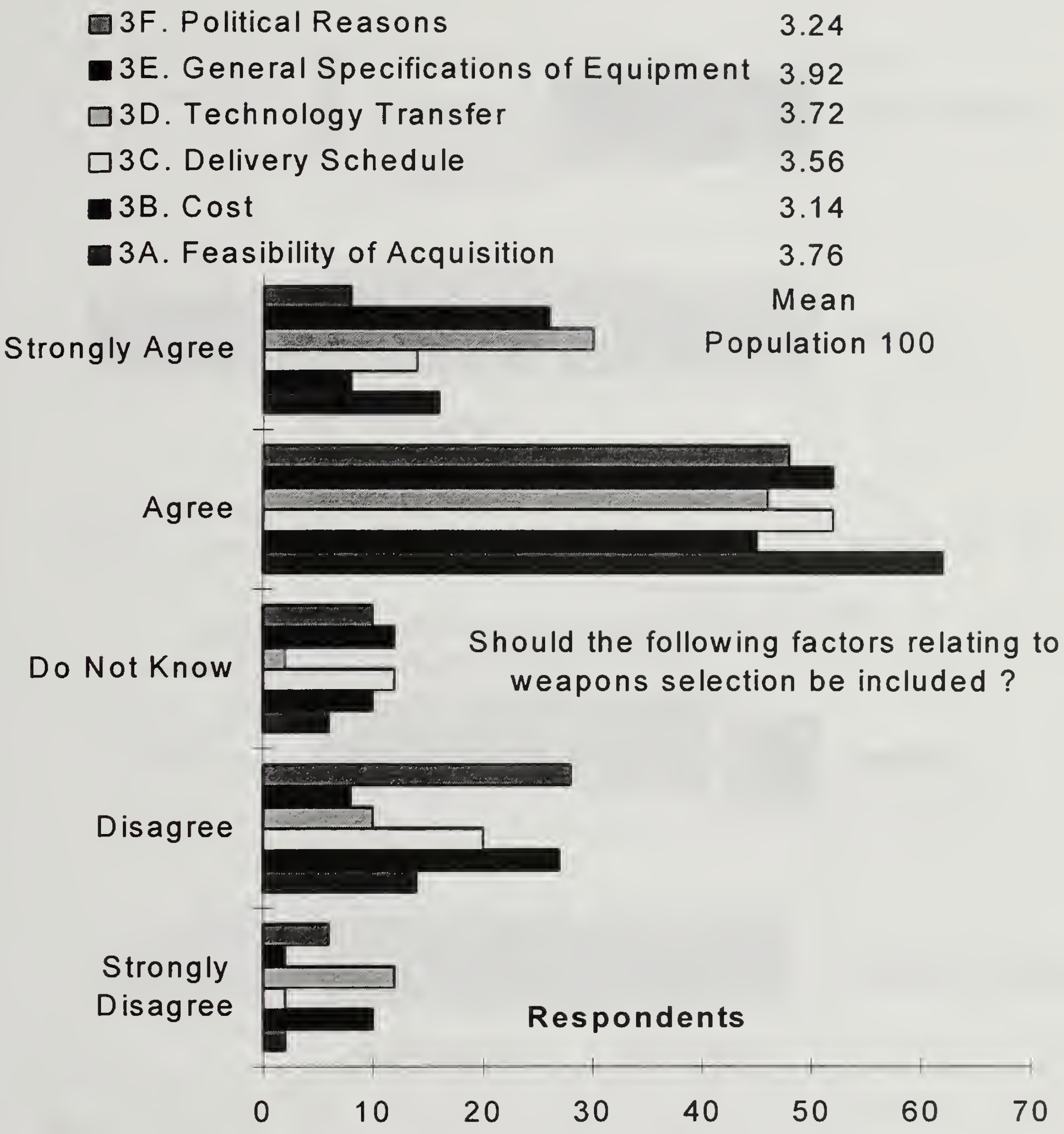


Figure 28. Question 3.

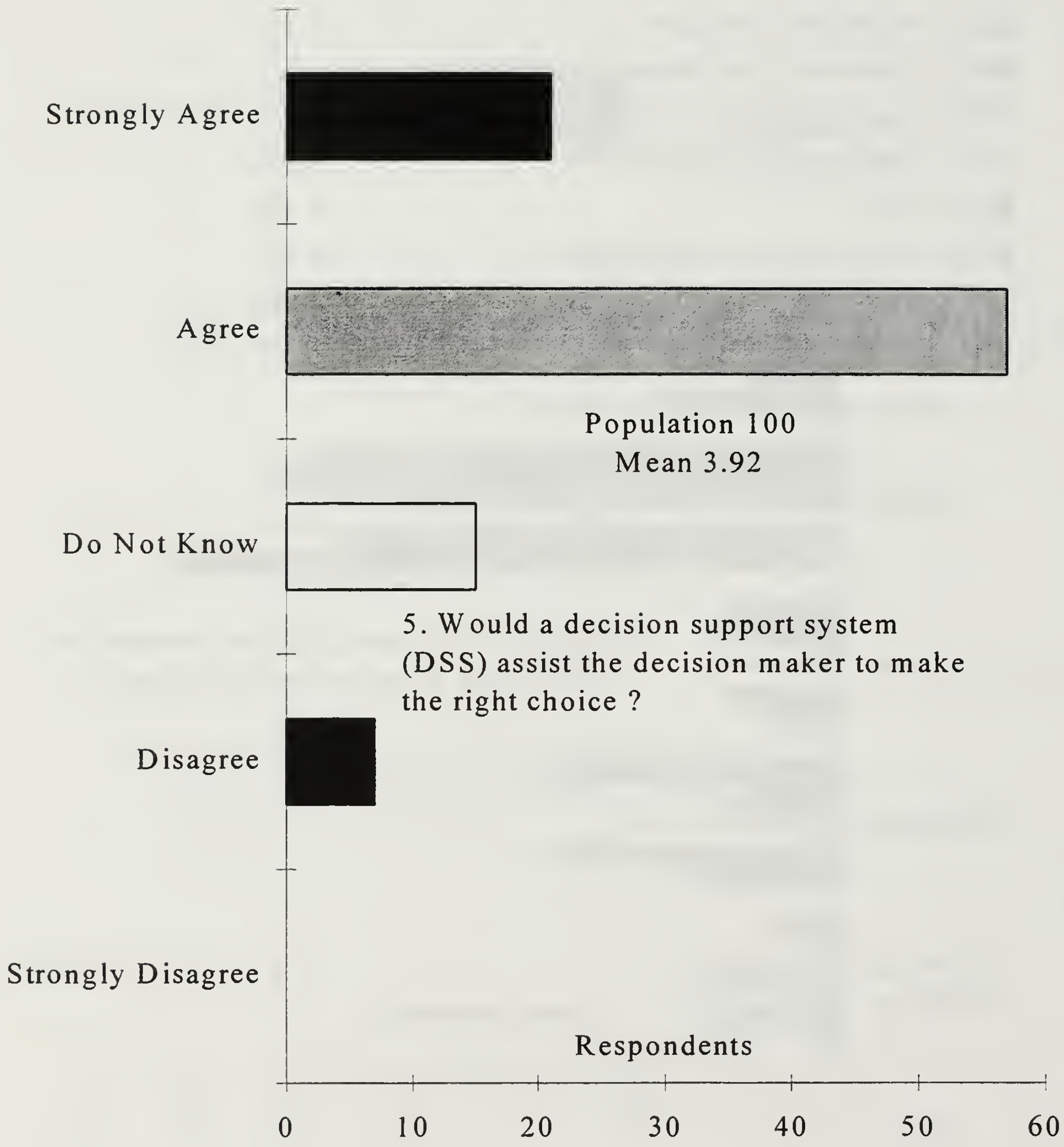


Figure 29. Question 5.

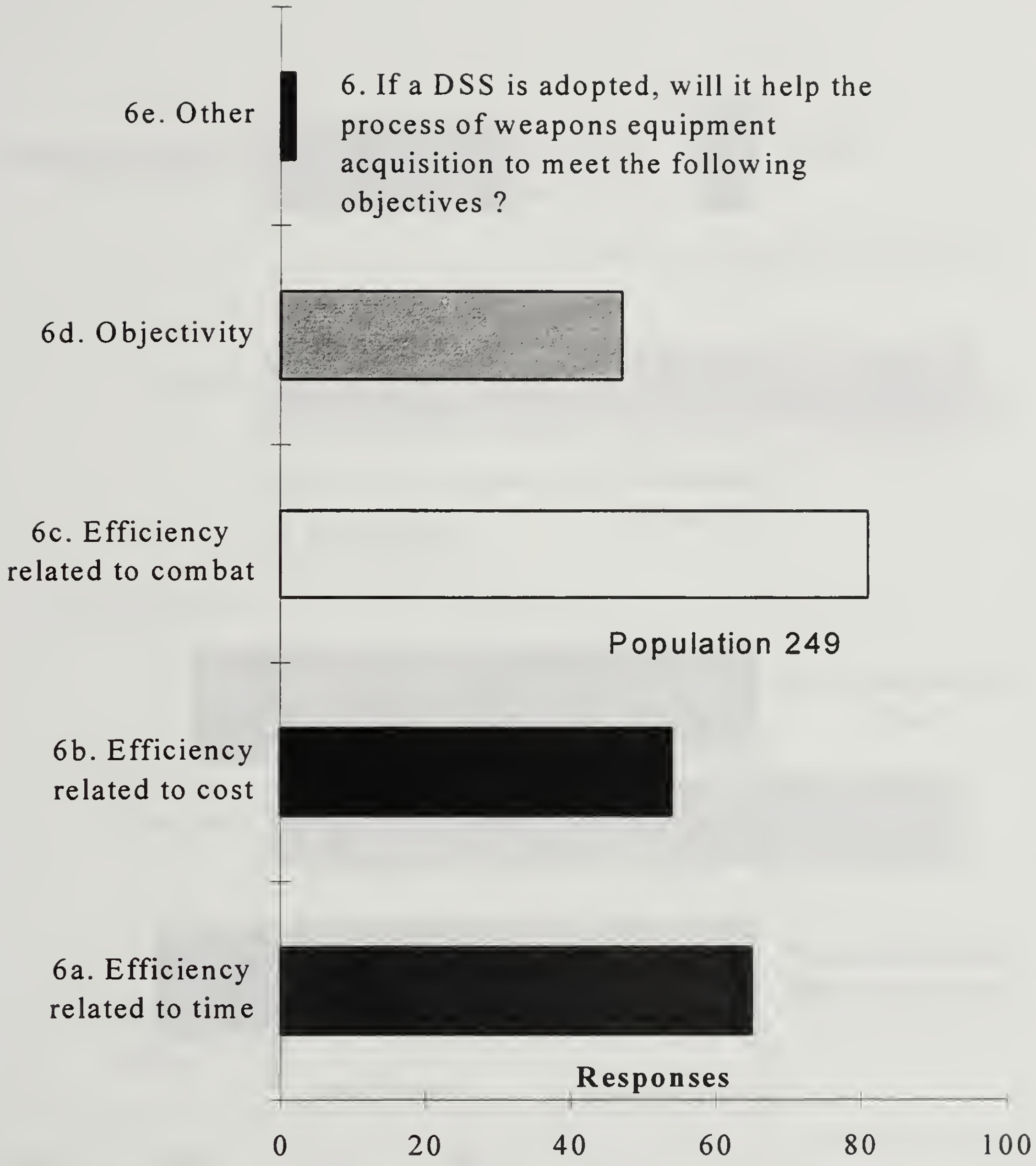


Figure 30. Question 6.

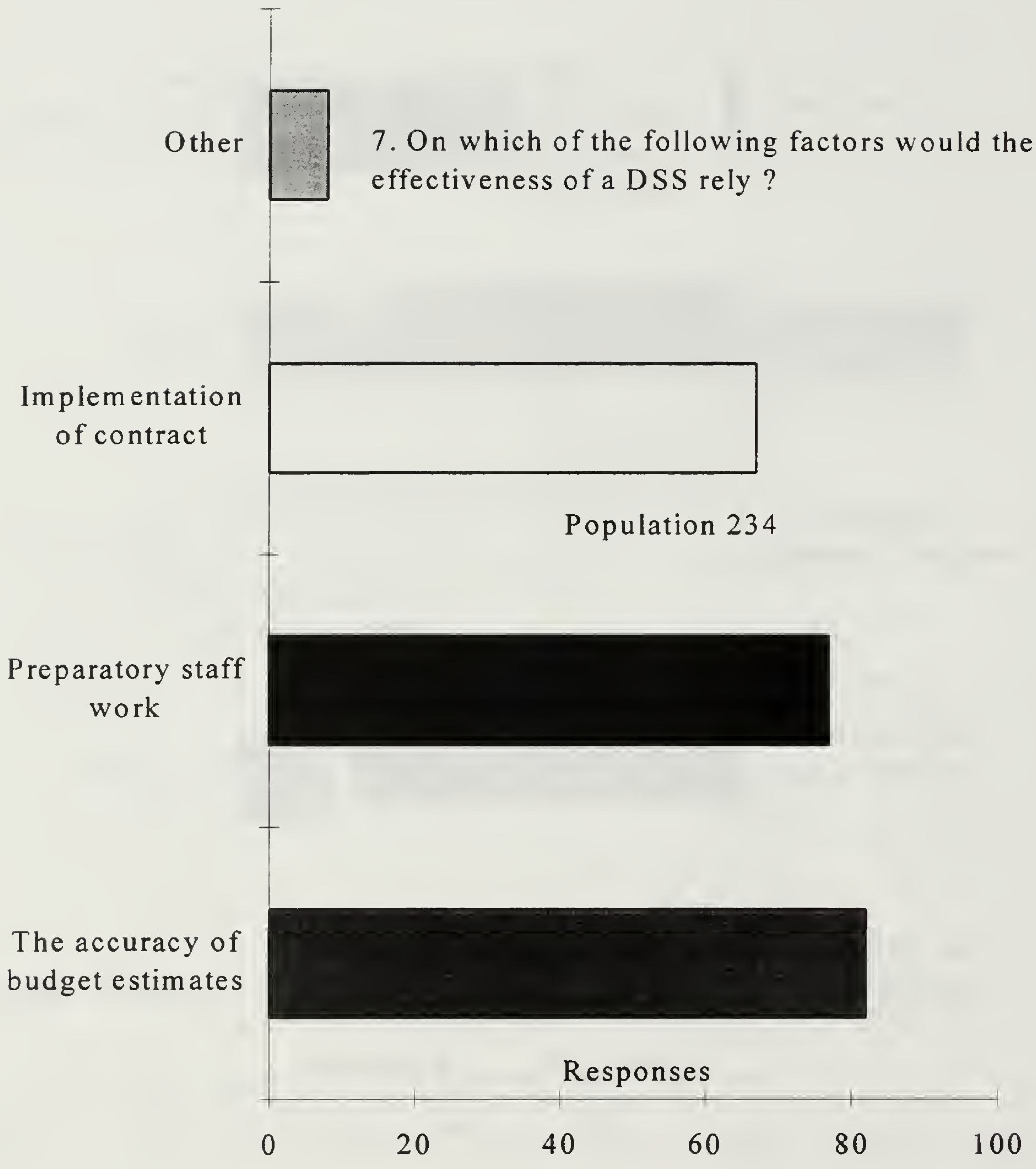


Figure 31. Question 7.

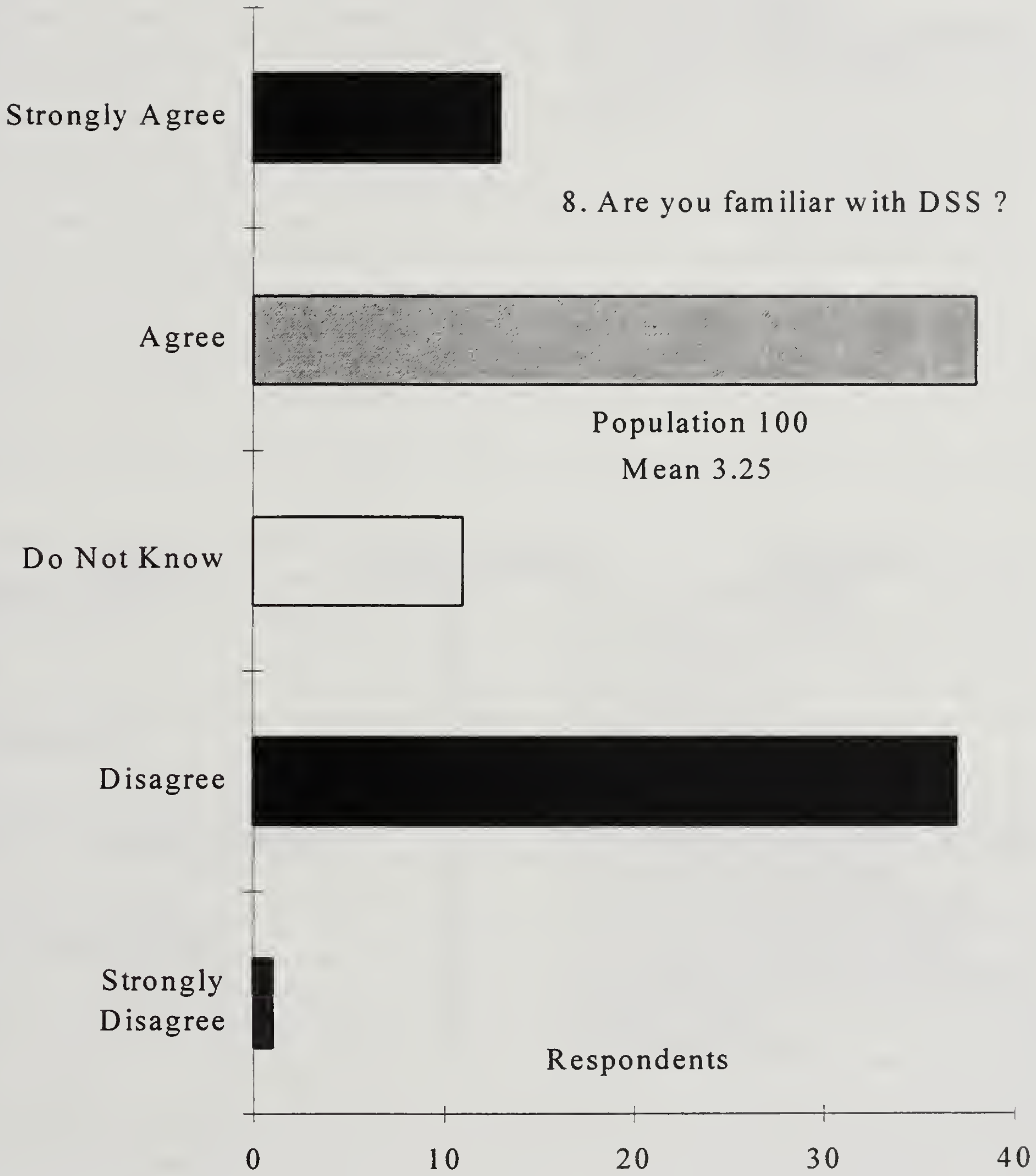


Figure 32. Question 8.

APPENDIX C. CRITERIA

Goal Level	Weights	Priorities	Rating Set
Weapons/Equipment Acquisition	27	0.27	Technology Transfer
	11	0.11	Risk
	22	0.22	Combat Capability
	17	0.17	Feasibility of Weapons Acquisition
	10	0.1	Political Considerations
	13	0.13	Cost

Level 2	Weights	Priorities	Rating Set
Technology Transfer	60	0.6	Knowledge and Skills
	40	0.4	Hardware and Software
Risk	60	0.6	Delivery Time
	40	0.4	Technology Risk
Combat Capability	80	0.8	Mission Effectiveness
	5	0.05	Integrated Logistics
	15	0.15	Weapons Availability
Feasibility of Weapons Acquisition	5	0.05	Financial Worthiness of the Contractor
	80	0.8	International Trade Policies
	15	0.15	Domestic Budget Considerations
Political Considerations	80	0.8	Domestic Political Considerations
	20	0.2	International Political Considerations
Cost	30	0.3	Operating Cost
	70	0.7	Procurement Cost

Level 3	Weights	Priorities	Rating Set
Knowledge and Skills			Alternatives
Hardware and Software			Alternatives
Delivery Time			Alternatives
Technology Risk			Alternatives
Mission Effectiveness	60	0.6	Range
	30	0.3	Integration
	10	0.1	Payload Capability
Integrated Logistics			Alternatives
Weapons Availability			Alternatives
Financial Worthiness of the Contractor			Alternatives
International Trade Policies			Alternatives
Domestic Budget Considerations			Alternatives
Domestic Political Considerations			Alternatives
International Political Considerations			Alternatives
Operating Cost	80	0.8	Maintenance Spare Parts Cost
	20	0.2	Training Cost
Procurement Cost	10	0.05	Research and Development and Engineering Cost
	80	0.42	Initial Procurement
	40	0.21	Initial Spare Parts and Training
	60	0.32	Technical Support

Lowest Criteria	A-France Rating	A-France Priority
Knowledge and Skills	70	0.27
Hardware and Software	85	0.28
Delivery Time	40	0.17
Technology Risk	50	0.19
Range	100	0.37
Integration	100	0.42
Payload Capability	90	0.36
Integrated Logistics	30	0.16
Weapons Availability	50	0.21
Financial Worthiness of the Contractor	60	0.22
International Trade Policies	60	0.17
Domestic Budget Considerations	30	0.11
Domestic Political Considerations	80	0.32
International Political Considerations	80	0.29
Maintenance Spare Parts Cost	30	0.13
Training Cost	30	0.11
Research and Development and Engineering Cost	40	0.16
Initial Procurement	30	0.14
Initial Spare Parts and Training	30	0.11
Technical Support	60	0.23

Lowest Criteria	B-Korea Rating	B-Korea Priority
Knowledge and Skills	0	0
Hardware and Software	40	0.13
Delivery Time	100	0.42
Technology Risk	100	0.37
Range	20	0.07
Integration	0	0
Payload Capability	30	0.12
Integrated Logistics	30	0.16
Weapons Availability	20	0.08
Financial Worthiness of the Contractor	40	0.15
International Trade Policies	100	0.29
Domestic Budget Considerations	100	0.37
Domestic Political Considerations	10	0.04
International Political Considerations	30	0.11
Maintenance Spare Parts Cost	90	0.39
Training Cost	80	0.29
Research and Development and Engineering Cost	100	0.4
Initial Procurement	100	0.48
Initial Spare Parts and Training	60	0.22
Technical Support	20	0.08

Lowest Criteria	C-U.S. Rating	C-U.S. Priority
Knowledge and Skills	85	0.33
Hardware and Software	80	0.26
Delivery Time	80	0.33
Technology Risk	80	0.3
Range	70	0.26
Integration	60	0.25
Payload Capability	70	0.28
Integrated Logistics	50	0.26
Weapons Availability	100	0.42
Financial Worthiness of the Contractor	80	0.3
International Trade Policies	85	0.25
Domestic Budget Considerations	60	0.22
Domestic Political Considerations	60	0.24
International Political Considerations	70	0.25
Maintenance Spare Parts Cost	60	0.26
Training Cost	70	0.25
Research and Development and Engineering Cost	90	0.36
Initial Procurement	60	0.29
Initial Spare Parts and Training	80	0.3
Technical Support	80	0.31

Lowest Criteria	D-ROC Rating	D-ROC Priority
Knowledge and Skills	100	0.39
Hardware and Software	100	0.33
Delivery Time	20	0.08
Technology Risk	40	0.15
Range	80	0.3
Integration	80	0.33
Payload Capability	60	0.24
Integrated Logistics	80	0.42
Weapons Availability	70	0.29
Financial Worthiness of the Contractor	90	0.33
International Trade Policies	100	0.29
Domestic Budget Considerations	80	0.3
Domestic Political Considerations	100	0.4
International Political Considerations	100	0.36
Maintenance Spare Parts Cost	50	0.22
Training Cost	100	0.36
Research and Development and Engineering Cost	20	0.08
Initial Procurement	20	0.1
Initial Spare Parts and Training	100	0.37
Technical Support	100	0.38

APPENDIX D. MODEL DEFINITION

MODEL: Weapons System Selection

Model Methodology: Analytical Hierarchy Process

GOAL LEVEL:

Weapons/Equipment Acquisition

Notes:

In choosing a weapons system source, our objective is to maximize the total utility of the weapons system and minimize the total cost.

LEVEL 2:

Technology Transfer

Notes:

This criterion indicates the technical capacity which will exist domestically after the procurement of the weapons system. The greatest advantage is represented by a purely domestic development and research followed by the relative willingness of the source country to supply technical expertise and information.

Risk

Notes:

This criterion is used to show the risk of cost overruns, schedule slippage, or the failure to meet operational requirements, or possibly non-delivery.

Combat Capability

Notes:

A figure that represents the performance characteristics of the weapons system evaluated on the same numeric scale as the other criteria. This is a composite of the capabilities of the weapons system.

Feasibility of Weapons Acquisition

Notes:

The feasibility of acquiring weapons system, this factor involves trade restrictions, international embargoes, and domestic budget considerations.

Political Considerations

Notes:

This is the sum of all political considerations both domestic and international.

Cost

Notes:

This is the cost of both purchasing the system and operating it.

LEVEL 3:

Knowledge and Skills

Notes:

These are intangible skills and knowledge gained with the use and employment of advanced or new technologies.

Hardware and Software

Notes:

This is the actual equipment or software gained and the ability to maintain and operate gained by the ROC.

Delivery Time

Notes:

Represents the time required to deliver an operational system, and possibly the time to train personnel in operation and maintenance of the system.

Technology Risk

Notes:

This represents whether the weapon's system is a finished technology or a leading edge technology. This points to the risk that the weapon may in fact, be ineffective since it is untested in combat.

Mission Effectiveness

Notes:

This is a reflection of the effectiveness of the weapons system.

Integrated Logistics

Notes:

This represents whether the technology of the weapons system fits well into the existing systems used by the armed forces of the ROC. A weapons which uses unique spares or supplies would require unique logistics to maintain and use.

Weapons Availability

Notes:

This is a reflection of the reliability and maintainability of the weapons system

Financial Worthiness of the Contractor

Notes:

This is the ability of the company producing the weapons system to produce the system even though it may not be to their financial advantage to do so. It also indicates the companies technology expertise to research and complete the project.

International Trade Policies

Notes:

Some countries may have restrictions on the export of a particular type of weapons system, or they maybe an internationally recognized embargo on the country that is the source for the weapon.

Domestic Budget Considerations

Notes:

Whether or not the legislative branch of government will budget money for this particular weapons system.

Domestic Political Considerations

Notes:

Political considerations include domestic politics involved with government contracting. .

International Political Considerations

Notes:

International politics involved with embargoes to outlawed countries or sources of supply which are not politically aligned with the ROC

Operating Cost

Notes:

Operating costs are the costs associated with the use of the equipment for example, steaming time required to train with the equipment, the cost resulting from a training exercise which expends ammunition, missiles, etc.

Procurement Cost

Notes:

This is a cost of the equipment at initial purchase including the initial maintenance of the equipment and the initial parts support for the equipment.

LEVEL 4:

Range

Notes:

The range of the weapon

Integration

Notes:

This reflects whether the weapons system is well integrated with the ship's existing weapons system. Does it provide extra capability or duplicate existing weapons systems.

Payload Capability

Notes:

Does the weapon contain the capability of multiple types of warheads. Is the carrying capacity of the weapon suitable for the target.

Maintenance Spare Parts Cost

Notes:

This is the cost of the parts to maintain the equipment and the cost of preventative maintenance spares to keep the equipment at readiness.

Training Cost

Notes:

The costs of training maintenance personnel and operations personnel.

Research and Development and Engineering Cost

Notes:

This is the cost of the development of the weapons system and the cost of its production.

Initial Procurement

Notes:

This is the minimum cost of acquiring a production run of the equipment.

Initial Spare Parts and Training

Notes:

This is the cost of initial parts support and the initial training of personnel to operate and maintain the system.

Technical Support

Notes:

This is the cost of technical personnel to support the weapons system while ROC personnel are being trained.

ALTERNATIVES:

A-France

B-Korea

C-U.S.

D-ROC

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