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MONTEREY, CALIFORNIA

THESIS

THE INTEGRATION OF DECISION SUPPORT TECHNOLOGIES TO SUPPORT CONSISTENT GOVERNMENT EVALUATION OF CONTRACT PROPOSALS

by

Roy M. Garrison

March 2008

Thesis Advisor: Daniel R. Dolk
Second Reader: Albert Barreto

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   Within federal government contracting, contracting officers are empowered to evaluate proposals and determination which contractor should be awarded the contract. With multiple variables to consider, managing tradeoffs is an important aspect of the evaluation process. As such, there is room for a large amount of subjectivity in the evaluation process. Since multiple contracting officers can arrive at different conclusions when evaluating the same proposals, there are instances when the wrong contractor is awarded a contract, as only one contractor can offer the true best value. Thus, the subjectivity in the process needs to be reduced so the contractor offering the best value is awarded the contract a higher percentage of the time.

   This thesis examines how the application of existing decision support technologies can assist contracting personnel in determining which proposal offers the best value to the government. The intent is to establish a model that, when implemented, will ensure contracting officers evaluate proposals both consistently and fairly. The proposed system integrates several decision support technologies. The overall concept is designed using a weight-based ranking model, enabled by a multi-criteria decision analysis software system. Supporting decision support software packages include an expert system and a data warehouse.

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THE INTEGRATION OF DECISION SUPPORT TECHNOLOGIES TO SUPPORT CONSISTENT GOVERNMENT EVALUATION OF CONTRACT PROPOSALS

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Submitted in partial fulfillment of the
requirements for the degree of

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from the

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ABSTRACT

Within federal government contracting, contracting officers are empowered to evaluate proposals and determine which contractor should be awarded the contract. With multiple variables to consider, managing tradeoffs is an important aspect of the evaluation process. As such, there is room for a large amount of subjectivity in the evaluation process. That is, one contracting officer may award a particular contractor a contract based on his tradeoff analysis, however a different contracting officer, when examining the same set of proposals, may have awarded a different contractor the contract because his tradeoff analysis was performed differently. There is little consistency in the system, especially when proposals for the same contract are similar in the variables of interest. Since multiple contracting officers can arrive at different conclusions when evaluating the same proposals, there are instances when the wrong contractor is awarded a contract, as only one contractor can offer the true best value. Thus, the subjectivity in the process needs to be reduced so the contractor offering the best value is awarded the contract a high percentage of the time.

The purpose of this thesis is to examine how the application of existing decision support technologies can assist federal government contracting personnel in determining which vendor proposal offers the best overall value to the customer in competitive solicitations. The intent is to establish a model that, when implemented, will ensure contracting evaluate proposals both consistently and fairly. The proposed system integrates several decision support technologies. The overall concept is designed using a weight-based ranking model, enabled by a multi-criteria decision analysis software system. Supporting decision support software packages include an expert system and a data warehouse.

The outcome of this thesis is a proof of concept rather than a fully functional decision support application, although certain elements of the overall system will be constructed. The intent is to establish how the subjectivity involved in the contract award process can be reduced if existing decision support software systems are properly integrated in support of a single objective.

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I.   INTRODUCTION

A.   AREA OF RESEARCH

Within federal government contracting, there are multiple variables for contracting officers to consider in determining which contractor is awarded a particular contract. These include price, delivery date, and past performance to name a few. The contract award decision may not always be obvious, particularly if no contractor's proposal outshines the other proposals in all variables. For example, one contractor may offer the lowest price, but has a history of missing deadlines and delivering sub-standard products. Thus, managing tradeoffs is an important aspect of the evaluation process. That is, one contracting officer may award a particular contractor a contract based on his tradeoff analysis, however a different contracting officer, when examining the same set of proposals, may award a different contractor the contract because his tradeoff analysis is performed differently. There is little consistency in the system, especially when proposals for the same contract are similar in the variables of interest. Since multiple contracting officers can arrive at different conclusions when evaluating the same proposals, there are instances when the wrong contractor may be awarded a contract, as only one contractor can offer the true best value to the government. Thus, the inconsistency in the process needs to be reduced so the contractor offering the best value is awarded the contract *every* time.

Currently, this inconsistency is not an issue for contracts awarded under simplified acquisition procedures. Within federal government contracting, simplified acquisition procedures apply to contracts valued between $2,500 and $100,000. Simplified acquisition procedures require only three proposals for each solicitation, as opposed to full and open competition required for contracts that exceed $100,000 in value. Contracting officers are empowered to evaluate the three proposals and make a determination as to which contractor should be awarded the contract based on price alone, assuming all three bids meet the technical requirements of the solicitation. This avenue for the relaxation of the requirement for full and open competition and the

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simplification of the award deliberation process was created in order to streamline the acquisition process for low cost procurements, thereby reducing a portion of the administrative cost and burden associated with the federal acquisition system. But since the only variable required to be considered is price, there is a strong possibility that the contractor offering the true best value is not awarded the contract, even if that contractor's proposal was only marginally more costly than the winning bid in terms of price.

The purpose of this research is to examine how contracts can be consistently awarded to the contractor offering the overall best value to the government. Contracts awarded under simplified acquisition procedures will serve as the proof of concept, although there is strong potential for the principles and recommendations discussed herein to be applied to all government acquisition methods. Choosing simplified acquisition procedures as the domain for the proof of concept poses an additional challenge. That is, since variables in addition to price must be considered in the evaluation process, this research will also examine how this can be accomplished without contradicting the reforms achieved with the development of simplified acquisition procedures.

The application of existing decision support technologies can assist contracting officers in determining which contractor proposal offers the best overall value to the government. The intent is to establish a model that, when implemented, will ensure that contracting officers evaluate proposals both consistently and fairly. The proposed model will integrate several decision support technologies. The overall concept is designed using a weight-based ranking model, enabled by a multi-criteria decision analysis software system. A supporting decision support software package will be used for the expert system.

B.   RESEARCH OBJECTIVES

The primary research objective is to determine how existing decision support system technologies can be integrated and applied to solve business problems in the domain of acquisition. Accordingly, a proof of concept is developed to increase the level

of consistency in evaluating proposals for government contracts under simplified acquisition procedures. As a supporting objective, this thesis will explore how this proof of concept can be extended and generalized in terms of decision support theories, models, and design methodologies required for the subsequent system integration.

C. RESEARCH DESIGN AND METHODOLOGY

This research will use the qualitative approach for data collection and analysis and will begin with a literature review. The literature review will consist of a review of decision support system theory and software systems and federal acquisition regulations. Next, the decision support models will be developed. The weight-based ranking model and expert system element will be developed based on the outcome of the literature review and the author's knowledge of, and experience in, the Department of Defense's acquisition process. Finally, functional prototypes of both the weight-based ranking model and expert system element will be developed.

D. SCOPE

The scope of this thesis will focus on developing a model for evaluating proposals for government contracts using commercially available decision support software systems. Certain individual elements of the model will be constructed; however, other elements such as the integration of multiple technologies and the development of a user-friendly interface are beyond the scope of this thesis and will only be discussed in theoretical terms. Currently, integrating multiple decision support technologies into a system with a single user interface requires extensive programming expertise. The proposed decision support tool, however, does not require a single user interface to be functional. The weight-based ranking model and expert system element can exist as separate entities, although a single user interface is ultimately desirable in order to minimize human error, decrease the time needed to evaluate proposals, and make the entire process more user friendly. Finally, data mining and other decision support technologies, although not specifically incorporated into the model, will be discussed in terms of their possible contribution to the proposed solution

Chapter II of this thesis provides background information on the federal acquisition system and decision support system theory. The intent is not to make the reader an expert in either area. Rather, Chapter II is designed to give the reader sufficient knowledge to comprehend the federal acquisition domain and how decision support systems might be applied for positive results. Chapter III shifts focus to the actual model that will be employed in the proof of concept, structured around the five basic decision support system components. Chapter IV is devoted to presenting the system prototype and is organized in the same manner as Chapter III. Finally, Chapter V will offer concluding remarks as well as a discussion of future research opportunities.

II.   BACKGROUND

A.   FEDERAL GOVERNMENT ACQUISITION

The obvious primary objective of the federal government acquisition system is to procure and manage the life cycle of the various products and services the government needs in order to function. As such, the acquisition workforce is entrusted with billions of taxpayer dollars each year, making proper stewardship of government resources an equally important objective. While this suggests that the government should always award contracts to the bidder offering the lowest price (assuming that bidder is capable of fulfilling the requirements) in order to conserve taxpayer dollars, other public policy objectives the acquisition system is required to support suggest otherwise. For example, part of federal government acquisition policy is to promote small business concerns. Thus, even if larger corporations can offer a lower price for a particular contract, if there are small businesses capable of fulfilling the requirements, the contract will be set aside for a small business. In addition, protecting the environment is a public policy objective of the government's acquisition system. If a product can be supplied cheaper, but environmental laws and/or regulations would be violated in the process, the government is willing to pay a higher cost. Other acquisition objectives include providing for full and open competition (except in the case of set aside programs), procuring commercial products and services when possible, rewarding vendors with a history of superior performance on government contracts, keeping administrative operating costs at a minimum, and conducting business with integrity, fairness, and openness.[1] The group of individuals that ensure these objectives are met for each acquisition is known as the Acquisition Team.

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[1] Federal Acquisition Regulations Part 1.102(b) (U.S. Government Printing Office, Washington, D.C, 2008).

1. The Acquisition Team

The Acquisition Team is comprised of government representatives from the procurement, supply, and technical communities. Customer and contractor representatives augment these individuals as well. Every member of the acquisition team is tasked to apply individual initiative and proper business judgment in contributing to the acquisition of the best value product or service that meets customer demands in a timely fashion. Acquisition team members are not identified all at once. Rather, they are identified as their role in the acquisition process becomes relevant. Thus the first member of the acquisition team is the customer, who initiates the requirement. As the acquisition matures, new members are added to the team, culminating with the contractor selected to supply the product or service. Along the way, team members share information with each other to ensure the acquisition is the product of a team effort. The objective of this approach is to satisfy the customer's needs in a manner as economical and efficient as possible. In order to achieve maximum efficiency, acquisition team members are authorized to develop and incorporate innovative strategies and practices in performing their duties, provided it is in the best interest of the government to do so and the strategies and practices are not in violation of any law, executive order, or other regulation.[2]

2. Contracting Officer

One of the most important members of the acquisition team is the Contracting Officer. The contracting officer is the only member of the acquisition team authorized to enter the government into a contract. Similarly, only a contracting officer can administer and/or terminate contracts. A contracting officer gets his authority from a warrant, which is a written certification, normally issued by the head of a contracting activity, authorizing an individual to enter into contracts on behalf of the government up to a designated dollar amount. The dollar amount limitation is established based on the individual's experience, education, knowledge, etc.

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[2] Federal Acquisition Regulations Part 1.102(c) (U.S. Government Printing Office, Washington D.C., 2008).

The contracting officer has numerous responsibilities. First and foremost, the contracting officer must make sure that the actions required for successful contracting are completed, contract terms are adhered to by the government and the contractor, and that the government's interests are protected. Contracting officers are authorized to exercise individual business judgment with considerable leeway. It is also the contracting officer's responsibility to ensure that all relevant laws, regulations, and agency policies and procedures have been followed before entering into a contract. Other responsibilities include ensuring adequate funds are on hand for obligation, ensuring that contractors are treated impartially and equitably, and utilizing specialists in other fields (e.g., audit, engineering, transportation, law, etc.) as consultants as appropriate.[3]

3. Contract Fundamentals

A contract is a mutually binding legal relationship obligating the seller to furnish the supplies or services…and the buyer to pay for them.[4] In order for a contract to exist, there are certain elements that must be present. Naturally, there must be both an offer and an acceptance. For example, a contractor "offers" to produce and deliver a product to the federal government, who makes the decision to "accept" the offer. In exchange, the federal government compensates the contractor for the products rendered. This compensation is called "consideration"—another necessary element of every contract. In addition, both parties must be legally competent and there must be legality of purpose. That is, if the services to be performed or the products to be delivered are illegal, there is no contract, regardless if all of the other elements exist.

Within the federal government, the contracting process begins with procurement planning. Procurement planning is the act of determining what to purchase and when to purchase it. Once procurement planning is complete, the next step is to plan the solicitation. The primary tasks in this stage are to research, document, and refine the product or service requirements and to identify possible sources that can fulfill those

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[3] Federal Acquisition Regulations Part 1.102-4(a) (U.S. Government Printing Office, Washington, D.C., 2008).

[4] Federal Acquisition Regulations Part 2.101 (U.S. Government Printing Office, Washington, D.C., 2008).

requirements. Once the planning is complete, the solicitation is written and publicized. The government then obtains bids, offers, quotes, or proposals (depending on the type of procurement) in response to the solicitation. Once a specified amount of time has elapsed (the exact time is specified in the solicitation), the government proceeds to the Source Selection stage, where the proposals are evaluated against the requirements identified in the solicitation as well as each other to determine which proposal is chosen as the winner. The contract is then awarded to the contractor that submitted that proposal. The contract award also ushers in the contract administration stage. This stage involves managing the relationship between the government and the contractor throughout the life of the contract. The final stage is Contract Close-out, where the contract is completed and settled. Any open items are also resolved at this stage.

4. Acquisition Regulations

Federal government contracting is governed by several sources. Above all, government procurement actions must adhere to all relevant laws and statutes enacted by Congress, such as the Contract Disputes Act and the Competition in Contracting Act, two of the most significant pieces of legislation related to procurement. The Contract Disputes Act established the Board of Contract Appeals through which disputes between the contracting officer and the contractor can be resolved. Similarly, the Competition in Contracting Act authorized the Comptroller General to hear contractor protests to contracting actions and to establish case law relevant to procurement as a product of the hearing's results. Related to Congressional legislation is case law. With respect to government contracting, case law emerges as a result of the federal court system hearing contract disputes and issuing rulings accordingly. In addition to settling the claims between the litigious parties, the rulings also govern future procurement actions of a similar nature.

The actions of the federal government contracting community are also governed by the Federal Acquisition Regulation (FAR), a set of policies and procedures applicable to every organization within the federal government. Each agency may publish regulations in addition to the FAR, provided those regulations do not contradict any

element of the FAR. For example, the Department of Defense has created the Defense Federal Acquisition Regulation Supplement (DFARS) in order to publish FAR implementation guidance and to establish policies exclusive to Department of Defense acquisitions.   Even agencies within the Department of Defense have published supplemental acquisition regulations, such as the Department of the Navy's Navy Acquisition Procedures Supplement (NAPS).

5.   Types of Procurements

There are three major methods of procurement utilized by the federal government: contracting by negotiation, sealed bidding, and simplified acquisition procedures. The contracting officer is responsible for choosing which type of procurement is used, using guidance provided in the FAR.   The FAR, however, does not provide specific information on when to use each method. Rather, the contracting officer must fully understand the requirements of each solicitation, weigh the pros and cons of each procurement method, and make a judgment-based determination on which method to use to ensure the adherence to the guiding principles of the FAR.

a.   *Sealed Bidding*

Sealed bidding involves evaluating bids on a competitive basis, the public opening of bids, and awarding the contract to the bidder offering the lowest price, assuming that contractor's bid is both responsive (fully meets the requirements of the solicitation) and responsible (the contractor has the technical and financial ability to fulfill the requirements of the solicitation). Sealed bidding is usually employed for the purchase of supplies and services that can be specifically described and where competition is based only on price and price-related variables. The use of the sealed bidding method is contingent on four conditions that must be satisfied. First, there must be enough time to allow the solicitation, submission, and evaluation of the sealed bids. Secondly, price and price-related variables must serve as the basis on which the contract will be awarded. Next, discussions with contractors who submitted bids must not be required. Finally, there must be a reasonable expectation that more than one sealed bid

will be submitted. In sealed bidding, the solicitation takes the form of an Invitation for Bids (IFB). The IFB does not constitute a government offer to procure goods and services. Rather, the bids submitted by contractors constitute the offers while the government's contract award serves as the acceptance.[5]

Two-step sealed bidding is a special type of sealed bidding, which combines negotiation with elements of the traditional sealed bidding method. The intent of this method is to realize the advantages of sealed bidding, even when sufficient specifications are not on hand. Under two-step sealed bidding procedures, the government requests, evaluates, and discusses, as needed, technical proposals from all interested contractors. At this point, pricing is not a factor for consideration. The intent is to determine which technical proposals are acceptable. After this determination, those contractors that submitted acceptable technical proposals submit sealed price bids. After publicly opening the bids, the government evaluates them and proceeds to award the contract to the lowest bidder, assuming that bidder is both responsive and responsible.

b. Contracting by Negotiation

With the contracting by negotiation method, the government and the competing contractors exchange information. These information exchanges occur both before and after the contractors submit proposals. This method also allows the government to award the contract based on criteria other than price. That is, other variables such as past performance, technical excellence, management capability and cost feasibleness may be incorporated into the source selection criteria. The solicitation takes the form of a request for proposal (RFP) in contracting by negotiation. As its name implies, the RFP requests interested contractors to submit offers, one of which the government may accept and thereby enter into a binding contract with that contractor. The government may also choose to enter into negotiations with those contractors whose bids fall within the competitive range before choosing which contractor is awarded the contract. The competitive range is comprised of the highest rated proposals as measured

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[5] Federal Acquisition Regulations Part 14 (U.S. Government Printing Office, Washington, D.C., 2008).

against the evaluation criteria. Before employing the contracting by negotiation method, contracting officers must document which of the four conditions required for sealed bidding was not met.[6]

c.   Simplified Acquisition Procedures

The final major procurement method is Simplified Acquisition Procedures (SAP). SAP was established as an effort to streamline the procurement process through the reduction of administrative costs. SAP also serves to increase the opportunities for small and disadvantaged contractors to be competitive for government contracts. There are certain restrictions to using SAP as a procurement method however. The most important restriction is that SAP is limited to procurements with an estimated value less than or equal to $100,000. But for procurements not expected to exceed that monetary threshold, SAP is the preferred method.[7]

Under SAP, solicitations take the form of Requests for Quotations (RFQ). As with other types of solicitations, a RFQ is a formal advertisement of a requirement by the government. Contractors then respond to the government with a quotation, which provides information on price, availability, and other meaningful product information. The government evaluates the proposals and then issues an order, or offer, to the contractor deemed most qualified to fulfill the requirement. Once the chosen contractor accepts the government's offer, the agreement becomes legally binding.

SAP can be further broken down into procurements that do not exceed $2,500 in value and those that do (i.e., purchases greater than $2,500 and less than or equal to $100,000). Purchases less than or equal to $2,500 are called micro-purchases. The micro-purchase method further streamlines the administrative cost and burden associated with government acquisition through the use of the government-wide commercial purchase card or International Merchant Purchase Authorization Card

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[6] Federal Acquisition Regulations Part 15 (U.S. Government Printing Office, Washington, D.C., 2008).

[7] Federal Acquisition Regulations Part 13 (U.S. Government Printing Office, Washington, D.C., 2008).

(IMPAC). Essentially, authorized government personnel purchase items for government use using a credit card, thus no solicitation is issued.

6. Source Selection

Source selection is the process in which one contractor is chosen to receive the contract award. Source selection begins with an evaluation of the proposals that have been received in response to a particular solicitation. Source selection goals include maximizing competition, minimizing the complexity of solicitation, evaluation, and selection decisions, ensuring impartial evaluation, and ensuring selection of the proposal with the highest degree of realism. Simplified Acquisition Procedures are an exception to the goal of maximizing competition, since contracting officers are required to obtain only three bids for each procurement, as opposed to the full and open competition requirement for sealed bidding and contracting by negotiation.

There are numerous evaluation factors that may be considered when selecting a source. Obviously, cost is to be considered in every procurement. Other factors may be included provided they are relevant to the acquisition, such as past performance, or support of public policy objectives. Under Simplified Acquisition Procedures, the contracting officer is only required to consider price. As such, contracts awarded using SAP are often awarded to the bidder offering the lowest price. Contracting officers are not forbidden from considering other evaluation factors when using SAP. In fact, the FAR encourages innovative approaches to contracting. Yet most contracting officers choose not to do so because it is time consuming to do so and view it as an unduly burdensome process, particularly since SAP was established to eliminate such burdens.

In the federal acquisition system, there are certain circumstances where competition is limited in order to support various socio-economic public policy objectives. One such set of circumstances is classified as small business "set-asides". A small business set-aside is where a contract is reserved for small businesses, thus excluding large businesses from consideration. In general, whenever there are two or more small businesses capable of fulfilling a government requirement (not to exceed $100,000) at a reasonable price, the contract will be set aside accordingly. As with every

rule, there are exceptions, however the acquisition objective remains that small businesses are to receive any contract where it is determined to be in the interest of ensuring that a fair proportion of government contracts for property or services in each industrial capacity are placed with small businesses.[8] The disadvantaged business set aside program is similar in its nature to the small business set-aside program. The disadvantaged business program is designed to grant special consideration to businesses owned by socially disadvantaged groups such as racial minority groups.[9]

Another special consideration impacting full and open competition is the Historically Underutilized Business (HUB) Zone program. The HUB Zone program seeks to increase government investment/employment in areas of high unemployment and underdevelopment. To qualify for this program, the company must be a small business, be owned and controlled by United States citizens, have its principal office located in the HUB Zone, and have at least 35 percent of its employees residing in the HUB Zone.[10]

To summarize, the source selection process can be viewed as a burdensome process or a streamlined procedure, depending on the type of procurement, the evaluation factors, the nature of the item being purchased, and numerous other considerations. No matter the situation, the goal will always be to obtain the best value for the government, subject to public policy and acquisition streamlining objectives. Thus, if there are tools available that can decrease the complexity of the source selection process without a corresponding increase in evaluation and selection time and cost, it makes sense to incorporate those tools into the process. A prime candidate for such inclusion is a decision support system.

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[8] Federal Acquisition Regulations Subpart 19.5 (U.S. Government Printing Office, Washington, D.C., 2008).

[9] Federal Acquisition Regulations Subpart 19.12 (U.S. Government Printing Office, Washington, D.C., 2008).

[10] Federal Acquisition Regulations Subpart 19.13 (U.S. Government Printing Office, Washington, D.C., 2008).

B.   DECISION SUPPORT SYSTEM FUNDAMENTALS

A Decision Support System (DSS) can be defined in numerous ways, depending on an individual's frame of reference and the context in which the term is used. All definitions fundamentally convey the same basic idea, that is, a DSS is simply an information system that assists in the act of making decisions.[11]   A DSS can accommodate multiple types of inputs and incorporate multiple tools to accomplish its mission, ranging from data and documents to optimization models and simulations. There are multiple types of DSS and the problem areas in which they can be applied vary considerably. For example, a DSS can be applied to a problem as simple as determining the optimal driving route from a place of origin to a place of destination given different scenarios with respect to variables such as traffic congestion, weather, and fuel consumption rates. On the other end of the complexity scale, a DSS that employs simulation can be used to predict human behavior for use in complex command and control decisions. Regardless of how they are applied, however, all DSS function to assist decision-makers in recognizing and resolving problems, completing decision process activities, and ultimately arriving at decisions.

1.   Characteristics of a Decision Support System

In addition to sharing a common purpose, all DSS possess certain principles and characteristics. There are three main characteristics common to all DSS. As previously mentioned, the first major characteristic of DSS is that they are developed exclusively to aid in decision processes. Secondly, DSS are not intended to replace managerial judgment. Rather, they are designed to support the decision-maker by providing information that can be used in the exercise of managerial judgment. Finally, DSS should also be able to react swiftly to the requirements of decision-makers, which can be continually dynamic. That is, a DSS should be able to provide managers with the right information in the right format at the right time at the right cost.[12]

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[11] P. N. Finlay, Introducing decision support systems (Cambridge: Blackwell, 1994) 3.

[12] D.J. Power, Decision Support Systems Hyperbook, Fall 2000, 15 Jan. 2008 <http://dssresources.com/dssbook/>.

These three major concepts are augmented by a number of other characteristics. For example, a DSS contains a knowledge element that depicts certain elements of the decision-maker's environment, identifies how to complete various activities, and distinguishes what conclusions are legitimate in different scenarios. A DSS also has the capability to obtain and preserve various types of knowledge, such as procedure keeping, rule keeping and descriptive knowledge (through record keeping). In addition, a DSS can present knowledge in various forms. That is, knowledge can be customizable and provided on an ad hoc basis or it can be presented in a more formalized manner, such as through standardized reports.[13] A DSS can provide support to decision-makers in all levels of the managerial hierarchy in an organization, to both groups and individuals, and to isolated decisions as well as several interdependent and/or sequential decisions. Finally, a DSS should be user friendly and easy to build.[14]

2. Decision Support System Components

A typical DSS is comprised of five basic components: Data Management, Model Management, Knowledge Management, a Graphical User Interface, and the User. The interactions between these components are illustrated in Figure 1. While the interactions between these five components are useful in illustrating a general DSS framework, not all DSS contain all components. For example, a DSS may contain a Model component but not a Knowledge component, or vice versa. The data management component of a DSS is responsible for managing the numerous tasks required to retrieve, store, and organize the meaningful data for the circumstances surrounding the specific decision. The data management system's other responsibilities include managing the system's security features, maintaining and executing data integrity procedures as required, and various data administration activities associated with using the DSS. Subsystems such as

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[13] Clyde Holsapple and Andrew Whinston, Decision Support Systems: A Knowledge-Based Approach (New York: West Group, 1996) 144-5.

[14] Efraim Turban, Decision Support and Expert Systems: Management Support Systems (New York: Macmillan, 1990) 110.

database(s), a database management system, a data repository, and data query facility manage these tasks within the data management component.[15]
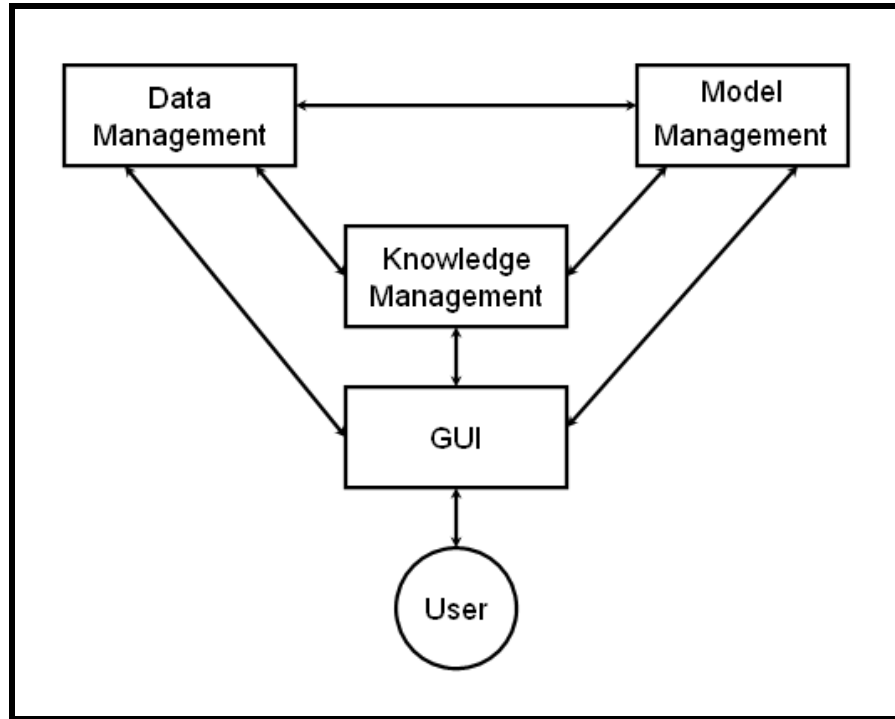
Figure 1.   Decision Support System Components

The model management component performs functions similar to those of the data management component. That is, the model management component carries out retrieval, storage, and organizational tasks associated with any mathematical models that serve as the DSS's analytical capability. The model management component is comprised of several elements: a model base, model base management system, model directory, and model execution, integration, and command. The model base contains the actual models that provide the analytical capability. The model base management system creates, updates, and changes models, creates and manages reports, and manipulates data as needed. The model directory catalogs the entire set of models within a DSS, to include model definitions that can be employed by the user when attempting to determine model

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[15] D.J. Power, Decision Support Systems Hyperbook, Fall 2000, 15 Jan. 2008
<http://dssresources.com/dssbook/>.

availability and capability. Finally, model execution, integration, and command manages the actual use of the model and combines models as needed.[16]

The primary function of the knowledge management component is to perform the activities associated with managing the problem-solving process. These include tasks related to recognizing the problem and developing solutions. The knowledge management component synthesizes the data and the models and offers the decision-maker an effective application that supports the decision environment in question.

The design and implementation of the user interface is a critical factor with respect to the functionality of the DSS. Users must be able to access and manipulate the data, model, and processing components of the DSS without undue difficulty in order for the system to offer the required support to the decision environment without interfering with the task in question. An effective user interface allows the user to communicate with the DSS with relative ease, regardless of the purpose of the communication.

In order to maximize the effectiveness of the user interface, it is important to consider the role and viewpoint of the user. The user plays a critical role in both the design and implementation of the system. In considering the user, elements such as skill set, motivations, knowledge domain, usage patterns, and organizational roles and how they relate to the decision environment should be examined.[17]

3.   Types of Decision Support Systems

There are different approaches to classifying decision support systems, but a commonly accepted taxonomy developed by D.J. Power enumerates five major categories of DSS: Data-Driven, Model-Driven, Knowledge-Driven, Document-Driven, and Communications-Driven.[18]

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[16] Efraim Turban, <u>Decision Support and Expert Systems: Management Support Systems</u> (New York: Macmillan, 1990) 118-23.

[17] George M. Marakas, <u>Decision Support Systems in the Twenty-First Century</u> (Upper Saddle River: Prentice-Hall, 1999) 9-11.

[18] D.J. Power, <u>Decision Support Systems Hyperbook</u>, Fall 2000, 15 Jan. 2008 <http://dssresources.com/dssbook/>.

a.   *Data-Driven DSS*

Data-Driven DSS stress retrieving and manipulating sizeable databases of data. That is, a Data-Driven DSS is frequently a compilation of data, both historical and current, from multiple sources that have been stored for trouble-free access and examination. Logically, the level of functionality is dependent on the complexity of the system. Systems accessed by basic database functions such as query and retrieval offer limited, but often inadequate, functionality whereas Data-Driven DSS that employ Online Analytical Processing (OLAP) offer a much greater functionality. A Data-Driven DSS is capable of providing an organization with both internal data and data concerning the organization's external environment. In addition, the data can be either specific to a particular transaction or a summary of multiple transactions. Data-Driven DSS enable managers to process data in order to ascertain facts and arrive at conclusions based on the patterns or trends they see. The obvious advantages of Data-Driven DSS include the fact that they not only supply managers with desired information, but that they do it whenever managers need it (and as often as they need it) and in a useable format. Data-Driven DSS does have a clear disadvantage in terms of cost. A large investment is often required to implement large Data-Driven systems, not to mention updating and maintaining them.[19]

b.   *Model-Driven DSS*

The second major category of DSS is Model-Driven DSS. As the name implies, Model-Driven DSS stress access to and manipulation of one or more models, as opposed to databases. As in the case with Data-Driven systems, functionality levels vary depending on the nature and complexity of the decision in question. For example, the use of simple statistical models offer basic level functionality whereas other systems may employ complex models that combine data analysis with sophisticated modeling tools. Large databases are typically not required for Model-Driven DSS, as the data and parameters needed to run the models are supplied by the decision-maker and are pertinent only to the situation in question. Notwithstanding this fact, the ability of Model-Driven

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[19] D.J. Power, Decision Support Systems Hyperbook, Fall 2000, 15 Jan. 2008
<http://dssresources.com/dssbook/>.

DSS to access existing data stores, especially in the form of data warehouses and/or Web-resident databases, is a desirable situation, particular when the model requires historical data as inputs. Thus, regardless of complexity, mathematical and analytical models remain the primary element of a Model-Driven DSS. The models generate output that decision-makers can examine and consider before deciding on a particular course of action. Every Model-Driven DSS is unique in purpose, precisely designed with a particular set of objectives in mind. As such, the models employed are unique as well, making the choice of model to use an important fact to consider when planning the system. Another characteristic of Model-Driven DSS is the fact that the values of important input variables as well as key constraints are dynamic. In fact, they may change frequently, depending on the stability of the various environmental and internal forces affecting the situation. As with DSS in general, models can take many forms. Indeed, modeling techniques can range from simple decision trees and influence diagrams to complex simulation and optimization programs.[20]

One of the more common modeling techniques is multi-criteria decision analysis. Multi-criteria decision analysis models are often developed using a four-step technique known as the Analytical Hierarchy Process (AHP). In comparing the overall value of various alternatives available to a decision-maker, AHP considers both quantitative and qualitative variables. AHP's initial task involves diagramming the problem in a hierarchal manner. Working from top to bottom, the diagram starts with the ultimate objective of the system (e.g., maximize profitability, minimize costs, etc.), expands into the relevant variables or selection criteria that must be considered by the decision-maker, and ends with the available alternative courses of action. For example, a decision-maker seeking to minimize total transportation time when traveling from point A to point B might construct a hierarchal representation of the problem similar to the diagram shown in Figure 2.

[20] D.J. Power, Decision Support Systems Hyperbook, Fall 2000, 15 Jan. 2008 <http://dssresources.com/dssbook/>.
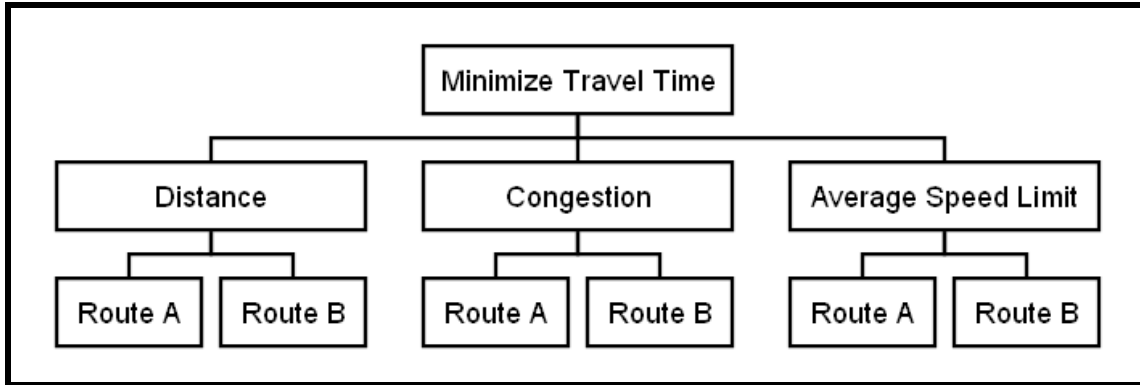
Figure 2.   The Analytical Hierarchy Process

The next step involves evaluating and comparing the alternatives based on available data. The goal of this step is to establish how each alternative compares to every other alternative with respect to each variable. The relative importance, or weight, of each variable is determined in step three. Finally, step four involves determining the ranking of the alternatives based on the results of the previous steps. Essentially, AHP is a structured approach to ranking alternatives based on multiple variables and is a useful tool in managing tradeoffs. Although the AHP diagram suggests that alternatives can be evaluated using simple pairwise comparisons, this approach is rendered less feasible as the number of decision alternatives becomes larger. There are several commercially-available software systems featuring multi-criteria decision analysis such as Logical Decisions for Windows, Expert Choice, and Decision Plus.

c.   Knowledge-Driven DSS

Knowledge-Driven DSS are interactive computer systems that specialize in providing problem-solving capabilities to decision-makers. This problem-solving knowledge is drawn from the system's familiarity and understanding of a specific problem domain, comprehension of different types of problems that fall inside that domain, and requisite expertise at generating solutions for those problems. All Knowledge-Driven DSS share certain characteristics. As stated, the first common trait is that all Knowledge-Driven DSS share the same ultimate objective, which is to assist

managers in arriving at solutions to problems. Next, this type of DSS relies on data structures such as rules, frames, or likelihood information for representing knowledge in computer executable form. Finally, the foundation for Knowledge-Driven DSS recommendations is human knowledge. That is, Knowledge-Driven DSS do not typically think on their own. Rather, they rely on knowledge entered by system designers and maintainers in generating recommendations.[21]

As with other DSS categories, Knowledge-Driven DSS can take several forms, including World Wide Web sites such as www.wikipedia.com, concepts such as Communities of Practice, and expert system technologies. The object of an expert system is to mirror the human reasoning process as much as technology will allow. Although similar in theory to Model-Driven DSS, expert systems differ in one fundamental aspect. That is, Model-Driven DSS revolves around following a series of pre-established commands for reacting to a scenario whereas a Knowledge-Driven DSS that incorporates an expert system generates a response based on its knowledge base of the decision environment and the logical rules that are built into the system to assist in solving problems. Additionally, some knowledge/expert systems use inference techniques to derive new facts from an existing fact base. In short, whereas Model-Driven DSS use a mathematical and/or statistical approach to problem solving, Knowledge-Driven DSS relies heavily upon heuristic techniques in arriving at recommendations.

For example, the knowledge base for many expert systems is built using a set of rules. Most rules are structured as logical IF-THEN statements, often nested several layers deep. Rules formally specify a recommended solution, structured with the IF signifying the premise(s) while the THEN portion of the statement constitutes the conclusion(s). Thus, the nature of rules revolves around the relationships between premise and conclusion as opposed to providing instructions, which is how IF-THEN statements are used by many computer programming languages.

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[21] D.J. Power, <u>Decision Support Systems Hyperbook</u>, Fall 2000, 15 Jan. 2008 <http://dssresources.com/dssbook/>.

Using rule-based Knowledge-Driven DSS has both advantages and limitations. One of the biggest advantages of rules is that they are easy to comprehend. Thus, knowledge stored as structured rules allows easy explanations with respect to recommendations and the logic the system employed to arrive at those recommendations. Also, from the system designer viewpoint, rules are easily adjusted to address changes in the decision environment. These advantages of rules are offset to a certain degree by several limitations. Namely, rules cannot always be developed to capture knowledge that has a high degree of complexity. Additionally, knowledge represented by rules often has the tendency to be superficial. Yet despite these limitations, Knowledge-Driven DSS designers and builders often favor rule-based systems whenever possible, with the understanding that some applications are just too complex to render a rules-based approach feasible.

d. *Document-Driven DSS*

Document-Driven DSS is relatively new, and is still evolving. Also known as Knowledge Management Systems, a Document-Driven DSS combines multiple and diverse storage and processing technological capabilities in order to offer total document retrieval and analysis. The World Wide Web is the most commonly recognized Document-Driven DSS, in that the web enables access to enormous databases of documents, images, audio files, and video files. Common uses of Document-Driven databases include accessing and managing policies and procedures, product information, catalogs, as well as internal organizational documents of interest such as important records, electronic correspondence, and meeting notes. Document-Driven DSS often use search engine technology as the primary tool for user interface.[22]

e. *Communications-Driven and Group DSS*

Communications-Driven and Group DSS is the final major category of DSS. These DSS stress communications, collaboration, and shared decision-making

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[22] D.J. Power, Decision Support Systems Hyperbook, Fall 2000, 15 Jan. 2008 <http://dssresources.com/dssbook/>.

assistance. Examples of this type of DSS include technologies as simple as video tele-conferencing, threaded email or web-based community forums. The distinguishing feature of a Communications-Driven DSS is that it allows multiple individuals to correspond with each other, share information and knowledge, and coordinate their tasks. As the name implies, Group DSS enable numerous users to collaborate via software tools that are model-driven. This category of DSS is perhaps the fastest growing one in concert with the contemporary emphasis on knowledge sharing and knowledge flow within organizations.[23]

4.   Decision Support System Limitations

Decision support systems do have certain limitations. For example, DSS are currently unable to possess uniquely human decision-making elements such as creativity, imaginativeness, or instinct. In addition, DSS are constrained by the computer systems upon which they are operating, their design, and the level of knowledge they contain at the moment they are run. A third limitation lies in the fact that language and command interfaces currently lack the sophistication necessary to enable natural language comprehension of user commands (although this is improving). Finally, DSS typically are often designed to be limited in scope of application. In turn, this inhibits their utility in broader decision-making contexts.[24] Also, user acceptance of DSS is sometimes slow in forthcoming because of users' perception of the system challenging their human judgment.

5.   Applications in the Government Procurement Domain

As shown in Figure 3, there are six main stages in the federal government's procurement process: procurement planning, solicitation planning, solicitation, source selection, contract administration, and contract close out or termination. Various decision

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[23] D.J. Power, <u>Decision Support Systems Hyperbook</u>, Fall 2000, 15 Jan. 2008 <http://dssresources.com/dssbook/>.

[24] Marakas 5.

concepts and technologies can be employed throughout several stages of the overall process to assist contracting officers and other government acquisition professionals.
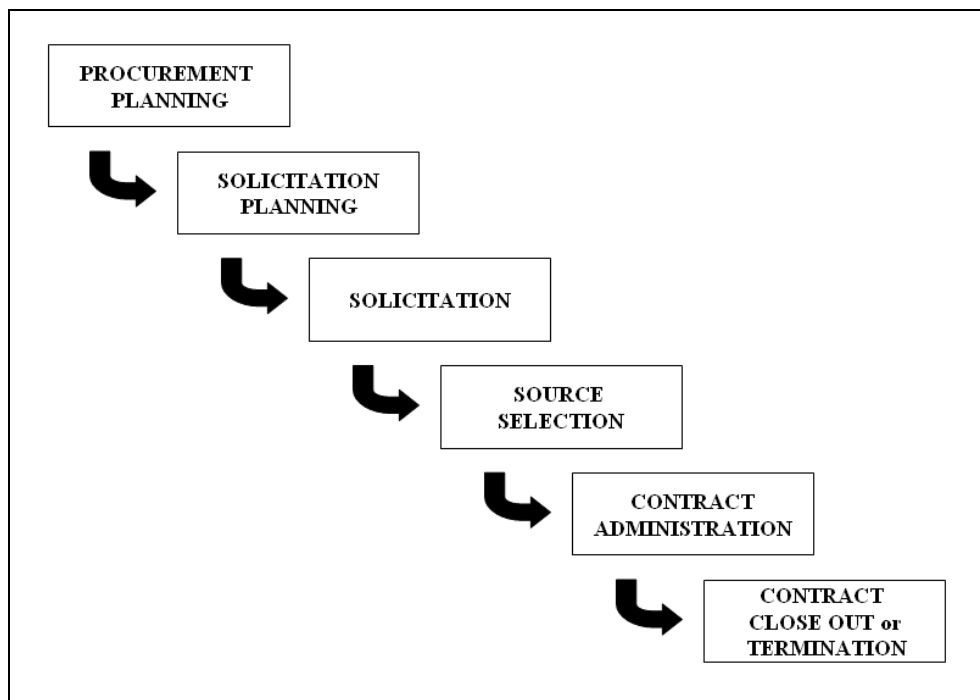
Figure 3.   The Government Procurement Process

For example, both data mining and multi-criteria decision analysis can assist with procurement planning. Procurement planning is the process of determining what to procure and when to procure it. For example, data mining tools can be used to determine what item, among several alternatives, has historically had the smallest rate of failure. Similarly, data mining tools can be used to analyze historical relationships between cost and quality attributes for previously procured goods and services in preparation for current or future procurements. Additionally, in a budget constrained environment, this often results in tradeoffs, as the government simply cannot afford to procure everything it wants. As such, multi-criteria decision analysis, in concert with expert judgment, can be used to manage those tradeoffs. Further, simple decision support tools such as decision trees and influence diagrams can be used in this regard as well.

The solicitation planning stage objectives are to produce the procurement documents (e.g., request for proposal, statement of work, etc.) and determine the

evaluation criteria if required. There is a prescribed uniform contract format to assist acquisition personnel in preparing the procurement documents; however, no similar tool exists to assist in determining the evaluation criteria. For this task, an expert system that incorporates the collective knowledge of the acquisition workforce can be used to create a tool to assist contractors in determining the appropriate evaluation criteria.

Source selection is the stage in which decision support systems most suitably apply. In selecting a contractor, decision support technologies such as multi-criteria decision analysis can be used to determine which contractor offers the overall best value for the government for a particular procurement action.

The contract administration phase includes the management of contract changes and the monitoring of contractor performance. Contractor performance is a critical function, as it may be used to influence future contract award decisions involving that contractor. In certain contract types, contractor performance may also impact how much profit the contractor earns on that contract. Once again, multi-criteria decision analysis can be used to assist acquisition personnel. Contractors can be evaluated on specific performance criteria (cost control, schedule management, etc.) in order to make overall past performance determinations.

As the purpose of this thesis is to examine how DSS can be applied to the Source Selection stage, the following chapter will focus on a proposed multi-criteria decision analysis model. The proposed model will integrate several decision technologies and will assist contracting personnel by ranking alternative contractors against multiple weight-based variables en route to arriving at a recommendation as to which contractor should be awarded the contract.

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III.   SOURCE SELECTION SUPPORT SYSTEM MODEL

This thesis proposes the development of a Source Selection Support System—a decision support tool that integrates several commercially available decision support software technologies.   Specifically, the system integrates a multi-criteria decision analysis tool with an expert system and a data warehouse through a common user interface.   While these components technically need not be integrated in order for the overall concept of the system to be realized, developing an integrated decision technology environment can provide a richer portfolio of DSS generation capabilities. Most standalone DSS focus on providing just one of the basic components (Model Management, Knowledge Management, etc.).   Applications which require several or all of these components are better served by an integrated environment that allows users to access various independent components as needed.

The primary purpose of the Source Selection Support System is to compare three separate proposals for government solicitations against established criteria to determine the best source in a consistent manner, which in turn can be documented.   This decision support system is comprised of all five basic DSS components: Model Management, Data Management, Knowledge Management, a Graphical User Interface, and the User. The user runs the expert system component to determine decision variable weights, as influenced by the circumstances of the procurement in question.   The user then enters contractor and proposal data associated with that solicitation.   Scores for each decision variable are then calculated for each contractor, at which point a weight-based ranking system takes over to ultimately arrive at a recommendation.   As the Source Selection Support System integrates several commercially available software systems (expert system, ranking model, etc.), each of these sub-systems has its own user interface.   A universal interface is proposed, however, to link all components in order to provide a more user-friendly master system.   A more thorough discussion of each component follows.

A.   MODEL MANAGEMENT

The backbone of the Source Selection Support System is a weight-based ranking model that follows the principles of the Analytical Hierarchy Process (AHP). As such, the model is composed of a series of variables that when weighed accordingly, provide the contracting officer with a recommendation as to which contractor offers the best overall value to the government for a particular solicitation. The AHP model for the Source Selection Support System is shown in Figure 4. Since the ultimate objective of the model is to provide the contracting officer with a recommendation, that becomes the top tier of the AHP diagram, followed by the variables to be considered and the competing contractors serving as the alternatives.
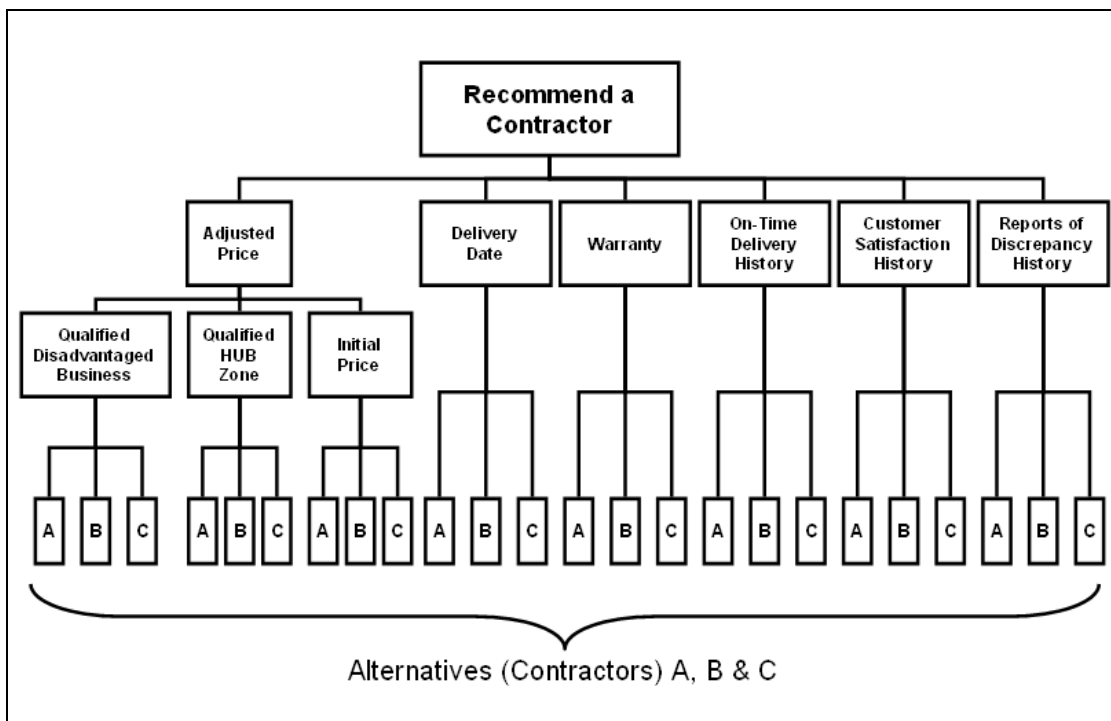

Figure 4.   The Source Selection Support System AHP diagram

The independent variables of interest include price, delivery date, warranty, customer satisfaction history, on-time delivery history, and report of discrepancy (ROD)

history. Other variables may be incorporated into the model, but for the purpose of this thesis, the aforementioned six variables will suffice.

1. Decision Variable

a. *Contractor*

Entry/selection of a particular contractor and respective bid initiates the model. Thus, selection of an alternative constitutes a decision variable. Contractors that conduct business with the federal government are uniquely identified by a five digit code known as the cage code. If the contractor is already recorded in the database, the cage code is used to retrieve that contractor's relevant information. If the contractor is not yet in the database, there is an option to insert the contractor.

2. Independent Variables

a. *Qualified Disadvantaged Business*

The federal government offers special consideration to businesses owned by women, racial minorities, and United States military veterans. Government contracting officers are authorized to award contracts to businesses that qualify for this program even if it results in an increase in cost to the government, provided the business's net worth does not exceed $750,000. The intent is to satisfy public policy objectives by awarding government contracts to socially disadvantaged businesses that otherwise may not be able to realistically compete for government work. Despite this objective, contracting officers will not award a contract to a disadvantaged contractor if the price difference is too great. Thus, the Source Selection Support System applies a percentage-based price adjustment on the quoted price from disadvantaged businesses in order to account for the price difference limitation. For example, the contracting officer may use ten percent as the acceptable difference between a disadvantaged contractor's quoted price and a non-disadvantaged contractor's quoted price. The price adjustment percentage can change, depending on factors such as individual contracting activity policy, the nature of the procurement, etc.

The model gets disadvantaged business status (yes or no) for each contractor from the data warehouse. As for the value of the percentage-based price adjustment, this is directly entered by the user, as it could vary depending on command policy and the characteristics of the procurement. If a contractor does not qualify for this price adjustment, its quoted price is unchanged. If a contractor does qualify for this price adjustment, its quoted price is reduced by the following amount (PA_{DIS}):

$$PA_{DIS} = P_I * (AP_{DIS})$$

Where:

PA_{DIS} = Disadvantaged business price adjustment

P_I = Initial Proposal Price

AP_{DIS} = Disadvantaged business price adjustment percentage

An example disadvantaged business price adjustment calculation is shown in Table 1.

Price Adjustment (AP_{DIS}) = 10 %				
Company	P_I	Disadvantaged Business?	$P_I * (AP_{DIS})$	Revised Price
A	$1,000	Yes	$1,000 * 10% = $100	$900
B	$950	No	N/A	$950
C	$975	No	N/A	$975

Table 1. Example Disadvantaged Business Price Adjustment Calculation

The price adjustment is applied to all qualifying contractors, regardless of how much difference there is between prices. If the revised price is still higher than the non-qualifying contractors, the proposal from the disadvantaged contractor will still be considered, as the remaining variables used by the model may still result in the disadvantaged contractor offering the best overall value despite the higher price.

b. Qualified HUB Zone

In an effort to spread federal government work across a wider geographic area and support businesses in local economies that may be suffering, the government gives special consideration to contractors located in Historically Underutilized Business (HUB) Zones. In order to qualify for HUB Zone status, the business must be owned and controlled by United States citizens, have its principal office physically located in the HUB Zone, and have a minimum of 35 percent of its employees residing in the HUB Zone. Once again, a percentage-based price adjustment is applied to HUB Zone contractors bidding on a solicitation. Similar to the Disadvantaged Business variable, the model obtains a contractor's HUB Zone status (yes or no) from the data warehouse. The value of the percentage-based price adjustment is directly entered by the user, as it could vary for the same reasons as the Disadvantaged Business variable. Once again, if a contractor does not qualify for this price adjustment its quoted price is unchanged. If a contractor does qualify for this price adjustment, its quoted price is reduced by the following amount (PA_{HUB}):

$$PA_{HUB} = P_I * (AP_{HUB})$$

Where:

PA_{HUB} = HUB Zone price adjustment ($)

P_I = Initial Proposal Price

AP_{HUB} = HUB Zone price adjustment percentage

An example HUB Zone business price adjustment calculation is shown in Table 2.

Price Adjustment (AP_{HUB}) = 10 %				
Company	P_I	Qualified HUB Zone?	$P_I * (AP_{HUB})$	Revised Price
A	$1,000	Yes	$1,000 * 10% = $100	$900
B	$950	Yes	$950 * 10% = $95	$855
C	$975	No	N/A	$975

<div align="center">Table 2.   Example HUB Zone business price adjustment</div>

The rules for application of the Disadvantaged Business price adjustment apply for this variable as well. That is, the HUB Zone price adjustment is applied to all qualifying contractors, regardless of how much difference there is between price. If the revised price is still higher than the non-qualifying contractors, the proposal from the HUB Zone contractor will still be considered, as the remaining variables used by the model may still result in the HUB Zone contractor offering the best overall value despite the higher price.

c.   *Delivery Date Score*

This variable rewards the contractor offering the earliest promised delivery date. The contractor with the earliest promised delivery date as indicated on the proposals receives a score of 100 percent. The other two contractors receive scores proportionate to the deviation (in days) of their delivery dates from the earliest delivery date. The model gets delivery date information via direct data entry, with the information source being the contractor's proposal. The Delivery Date Score is calculated as follows:

$$S_{DD} = 1 - \left(\frac{D_{IND} - D_{LOW}}{D_{LOW}} \right)$$

Where:

S_{DD} =   Delivery Date score

D_{LOW} = The number of days from expected contract award date to the

earliest promised delivery date

D_{IND} = The number of days from expected contract award date to this

individual contractor's promised delivery date

An example delivery date score calculation is shown in Table 3.

Company	Delivery Date	D_{IND}	$1-\left(\dfrac{D_{IND}-D_{LOW}}{D_{LOW}}\right)$	S_{DD}
Expected Contract Award Date: 7/1/2008				
A	8/01/2008	31	1, since $31 = D_{LOW}$	100 %
B	9/15/2008	76	1-[(76-31)/31]= -0.4516	- 45 %
C	8/14/2008	44	1-[(44-31)/31]= 0.5806	58 %

Table 3.   Example delivery date score calculation

Note that the calculation can result in a negative score. Due to a software limitation that does not allow negative values for scores, negative scores must be reset to zero. Thus, the Delivery Date Score for Contractor B is zero percent.

d.   *Warranty Score*

The warranty score is calculated based on the length (in months) of the warranty. The company with the warranty covering the longest period is assessed a score of 100 percent. The other two companies are assessed scores proportionate to the deviation of the lengths of their warranties to the length of the warranty covering the longest period. The model gets warranty information via direct data entry, with the information source being the contractor's proposal. The warranty score is calculated as follows:

$$S_W = 1 + \left(\frac{W_{IND} - W_{HIGH}}{W_{HIGH}} \right)$$

Where:

S_W =   Warranty score

W_{HIGH} =   The number of months of coverage the longest warranty offers

W_{IND} =   The number of months of warranty coverage offered by this

      individual contractor

An example warranty score calculation is shown in Table 4.

Company	W_{IND}	$1 + \left(\dfrac{W_{IND} - W_{HIGH}}{W_{HIGH}} \right)$	S_W
A	0 (no warranty)	1+[(0-48)/48] = 0	0 %
B	42	1+[(42-48)/48] = 0.875	87.5 %
C	48	1+[(48-48)/48] = 1	100 %

Table 4.   Example warranty score calculation

e.   *Customer Satisfaction Score*

The value of this variable is the average percentage score for the contractor on a uniform customer satisfaction survey. The survey is issued to customers of this contractor on government contracts, with the data recorded in the data warehouse. The survey uses a likert scale, enabling customers to evaluate contractors on various criteria using a numerical scale from 0 to 10. The Customer Satisfaction Score is calculated as follows:

$$S_{CS} = \left(\frac{\sum S_{IS}}{n}\right) for\ all\ S_{IS}$$

Where:

S_{CS} = Customer Satisfaction score

S_{IS} = The average score for each individual survey filled out for this

contractor

n = The number of contracts for this contractor for which a customer

satisfaction survey has been submitted

An example customer satisfaction score calculation is shown in Table 5.

Contractor A	
Contract Number	Average Individual Customer Satisfaction Score
N38259-06-C-5839	82 %
N86938-07-D-2358	91 %
N38259-07-D-3321	98 %
Overall Customer Satisfaction Score = (82 + 91 + 98)/3 = 90.33	

Table 5.   Example customer satisfaction score calculation

f.   *On-time Delivery Percentage*

This variable measures the percentage of government contracts the contractor has won where the promised delivery date was met. The intent of this variable is to penalize contractors who have failed to meet the delivery terms of their contracts. The more missed delivery dates a contractor has on its record, the lower the on-time delivery percentage. The On-Time Delivery Percentage score is fed data from the data warehouse and is calculated as follows:

$$S_{OT} = \frac{N_{OT}}{n}$$

Where:

S_{OT} = On-time Delivery Percentage score

n = The number of government contracts this contractor has been

awarded

N_{OT} = The number of government contracts this contractor has fulfilled

on time.

g.   *Report of Discrepancy (ROD) Percentage*

Reports of Discrepancy are complaints against a contractor, filed by a customer, on a federal government contract. They can be either as a result of the wrong product received or the wrong service performed or as a result of poor product/service quality. A contractor's score for this variable is the percentage of federal government contracts the contractor has been awarded for which no ROD was filed. ROD data is obtained from the data warehouse with the ROD percentage score calculated as follows:

$$S_{ROD} = 1 - \left(\frac{N_{ROD}}{n} \right)$$

Where:

S_{ROD} = ROD percentage score

n = The number of government contracts this contractor has been

awarded

N_{ROD} = The number of government contracts this contractor has been

awarded for which a ROD was submitted.

An example ROD percentage score calculation is shown in Table 6.

Company	n	N_{ROD}	S_{ROD}
A	211	4	98 %
B	57	11	81 %
C	163	6	96 %

Table 6.   Example ROD percentage score calculation

3.   Dependent Variables

a.   *Price Score*

A contractor's price score begins with the contractor's revised bid. The revised bid is the quoted price after applying any appropriate price adjustments (e.g., disadvantaged business). The contractor that offers the lowest price after the price adjustments are applied is awarded a score of 100 percent. The contractors who do not offer the lowest price after price adjustments are applied are assigned scores proportionate to the deviation between their revised bids and the lowest revised bid. This variable gets its information from the independent variables Price, Qualified Disadvantaged Business, and Qualified HUB Zone. The Price Score is calculated as follows:

$$S_P = 1 - \left(\frac{(B_I - AP) - RB_{LOW}}{RB_{LOW}} \right)$$

Where:

$S_P =$ Price score

$B_I =$ Initial bid amount

$RB_{LOW} =$ Lowest revised bid (i.e., after application of price adjustments)

$AP =$ Total price adjustment

An example price score calculation is shown in Table 7.

Company	B_I	AP	B_I - AP	$1 - \left(\dfrac{(B_I - AP) - RB_{LOW}}{RB_{LOW}} \right)$	S_P
A	$1,100	$0	$1,100	1-[(1,100-1,035)/1,035] = 0.9372	93.72 %
B	$1,150	$115	$1,035	1, since $1,035 = RB_{LOW}	100 %
C	$1,250	$125	$1,125	1-[(1,125-1,035)/1,035] = 0.913	91.3 %

Table 7.   Example price score calculation

b.   *Overall Acceptance Score*

The sum of the scores of all other variables, multiplied by their respective weights. The value of this variable for a contractor is compared to the value for the other contractors that submitted proposals. Whichever contractor achieves the highest score for this variable is recommended for contract award. The overall acceptance score is calculated as follows:

$$S_{TOT} = (W_P * S_P) + (W_W * S_W) + (W_{DD} * S_{DD}) + (W_{CS} * S_{CS}) + (W_{OT} * S_{OT}) + (W_{ROD} * S_{ROD})$$

Where:

S_{TOT} = Overall acceptance score for a particular contractor's bid

W_X =   Percentage weight assigned to variable X

4.   Influence Diagram

The influence diagram goes into effect once the three bids required under simplified acquisition procedures are in hand. The influence diagram shown in Figure 5

depicts how the Source Selection Support System model is structured. The model is applied three times for each contract, since it applies separately to each contractor bid being evaluated.
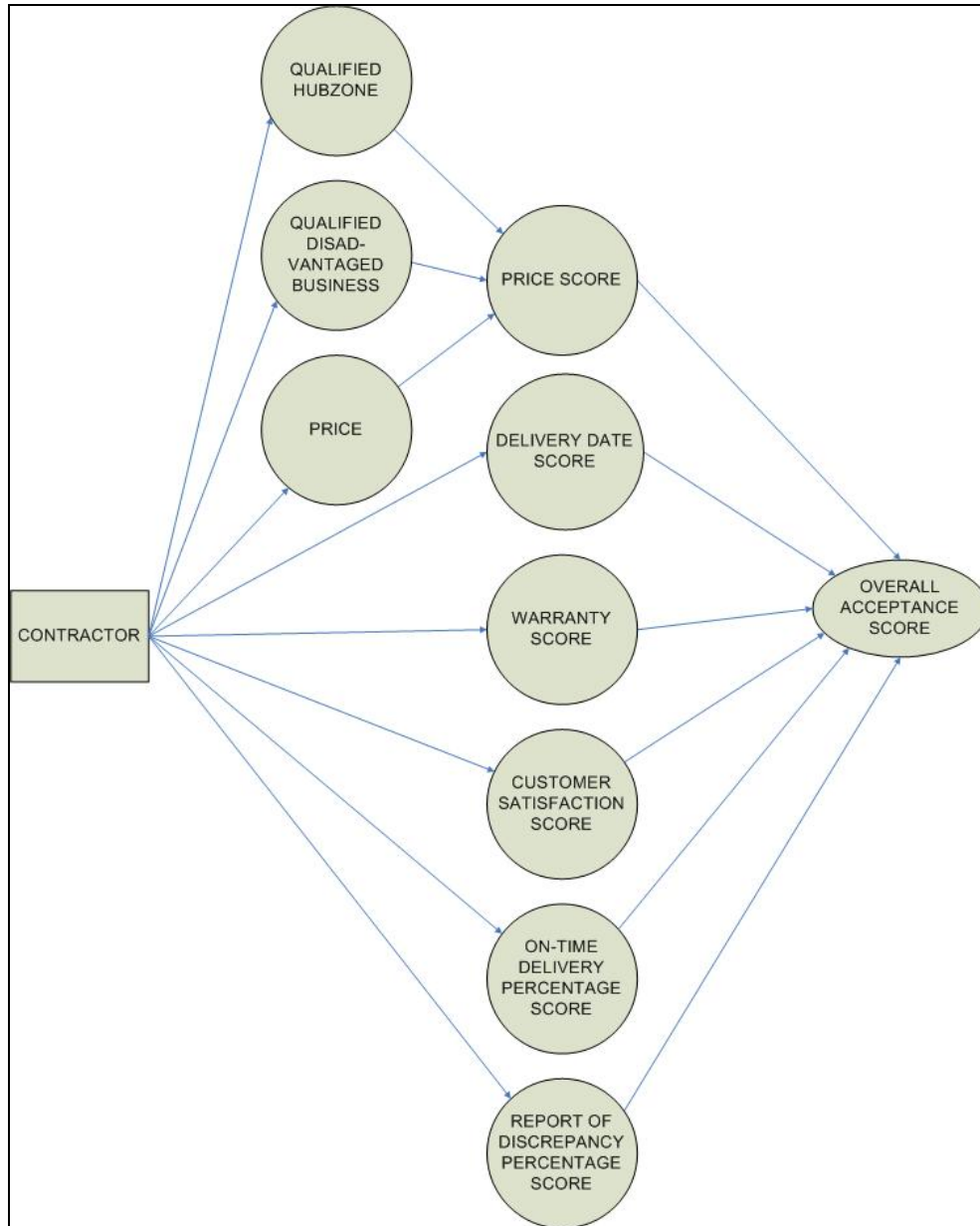

Figure 5.   Source Selection Support System influence diagram

5.   Constraints

Most of the constraints for this model are addressed in the request for proposal. For example, a variable such as delivery date would naturally have some kind of constraint. Realistically, customers are only going to wait a certain amount of time to receive the product/service called for in the contract. Yet in theory the model appears to allow for a contractor to have what the customer might consider an unreasonable amount of time to pass from contract award to delivery date and still achieve the highest overall acceptance score, depending on the weights assigned to each variable. The proceeding example illustrates this possibility.

Three proposals are received for a government contract. The delivery date score is calculated in Table 8 (note that the lower limit for delivery date score is zero).

Expected Contract Award Date: 7/1/2008				
Contractor	Delivery Date	D_{IND}	$1-\left(\dfrac{D_{IND}-D_{LOW}}{D_{LOW}}\right)$	S_{DD}
A	8/01/2009	397	1, since $397 = D_{LOW}$	100 %
B	8/13/2009	409	1-[(409-397)/397]= 0.9698	97 %
C	8/14/2012	1,505	1-[(1,505-397)/397]= -1.7909	0%

Table 8.   Delivery date scores for example scenario

The scores on all variables for each contractor are listed in the Table 9.

Variable	Weight	Contractor A		Contractor B		Contractor C	
		Score	Adjusted	Score	Adjusted	Score	Adjusted
Price Score	40 %	33 %	13.2 %	37 %	14.8 %	100 %	40 %
Delivery Date Score	*20 %*	*100 %*	*20 %*	*97 %*	*19.4 %*	*0 %*	*0 %*
Warranty Score	10 %	80 %	8 %	80 %	8 %	100 %	10 %
Customer Satisfaction	10 %	90 %	9 %	92 %	9.2 %	95 %	9.5 %
On-time Delivery %	10 %	100 %	10 %	100 %	10 %	100 %	10 %
ROD Percentage	10 %	100 %	10 %	97 %	9.7 %	92 %	9.2 %
Overall Acceptance			70.2 %		71.1 %		78.7 %

Table 9.   Example scenario variable scores for all contractors

Despite a delivery date three years after the other two contractors, Contractor C wins the contract because it is much better on the Price Score variable, which is weighted two times as heavily as Delivery Date Score and four times as heavily as any other variable.   Contractor C's delivery date, however, may be outside the realm of reasonableness for the customer.   In this situation, a constraint seems to be necessary. Fortunately, the model does not need to account for constraints like this because the request for proposal identifies the constraints long before the model is ever applied.   In other words, if a contractor's proposal does not satisfy the constraints in the request for proposal, such as required delivery date, the proposal is thrown out before applying the model.   There are no variables to which a constraint logically applies where that constraint cannot be incorporated into the request for proposal.

B.   KNOWLEDGE MANAGEMENT

Even when the competing proposals are in hand, there is still a critical knowledge component that must be in place before the model can be applied. Recall that the model follows the principles of the analytical hierarchy process. That is, it employs weight-based ranking to arrive at its recommendation. As such, the model is still missing the weight for each variable.

Determining the appropriate amount for the variable weights is not a simple task. One possible approach to this challenge is to assemble a team of experienced subject matter experts within the individual contracting activity who can collectively determine the appropriate relative weights for each variable. Realistically there is no single weight distribution plan that is appropriate to every scenario a contracting officer is likely to face. Consider the following two situations. In situation one, the customer is running low on funds due to other necessary purchases. This customer will be able to afford the product being procured under contract, but would like to do so at the lowest cost possible (assuming the product satisfies required performance parameters). Furthermore, the customer does not require the product any sooner than the required delivery date indicated on the request for proposal. In this situation, it would be appropriate for the contracting officer to weigh the price score variable more heavily than usual and weigh the remaining variables less in order to compensate. As such, the contracting officer may elect to use a set of weights similar to those listed in Table 10.

Variable	Weight
Price Score	70 %
Delivery Date Score	10 %
Warranty Score	5 %
Customer Satisfaction Score	5 %
On-Time Delivery Percentage	5 %
ROD Percentage	5 %

Table 10.   Sample price-intensive variable weight-distribution plan

Alternatively, situation two involves a customer requesting the procurement of a product critical to a primary mission area. Although there is a required delivery date indicated on the request for proposal, since the customer is deploying in several weeks, the earlier the item is delivered the better. An earlier delivery will allow more time for contractor technical support should onsite training be required. As such, the customer is willing to pay a premium if it means getting the product sooner. Clearly in this situation

delivery date should be weighed heavier than it is under normal circumstances. The contracting officer may elect to use a set of weights similar to those listed in Table 11.

Variable	Weight
Price Score	50 %
Delivery Date Score	30 %
Warranty Score	5 %
Customer Satisfaction Score	5 %
On-Time Delivery Percentage	5 %
ROD Percentage	5 %

Table 11.   Sample delivery date-intensive variable weight-distribution plan

Note that just because a particular variable's relative importance increases, it does not necessarily mean that it becomes the most heavily weighted variable. Logically, price will always be the most important variable because a contractor's performance on every other variable will always be ultimately acceptable. Otherwise, the contractor would have been suspended (or debarred entirely) from federal government work or have its proposal rejected. For example, if a contractor's ROD percentage score is so low that it is unacceptable, than that contractor would not be permitted to continue bidding on government work (i.e., suspension or debarment). Similarly, if a contractor's delivery date is unacceptable (i.e., it does not satisfy the required delivery date indicated on the request for proposal), its proposal will be rejected long before the model is applied. Price Score is the only variable where there is no constraint that prohibits it from being considered.   That is, the model accepts proposals from contractors offering a comparatively low price while at the same time accepting proposals from contractors offering a much higher price. Since the price range among the alternative proposals may vary widely, and since every contractor is technically acceptable with respect to the other variables, price score should always be the primary discriminator.

It therefore becomes necessary to develop a series of likely scenarios a contracting officer is likely to encounter and determine a specific weight distribution plan for each of those scenarios. A simple decision tree can be used to model the scenarios

and record the weights for each variable within those scenarios. Figure 6 depicts a portion of one such decision tree. Although this sample decision tree only includes three variables, it can be expanded in order to accommodate other variables.
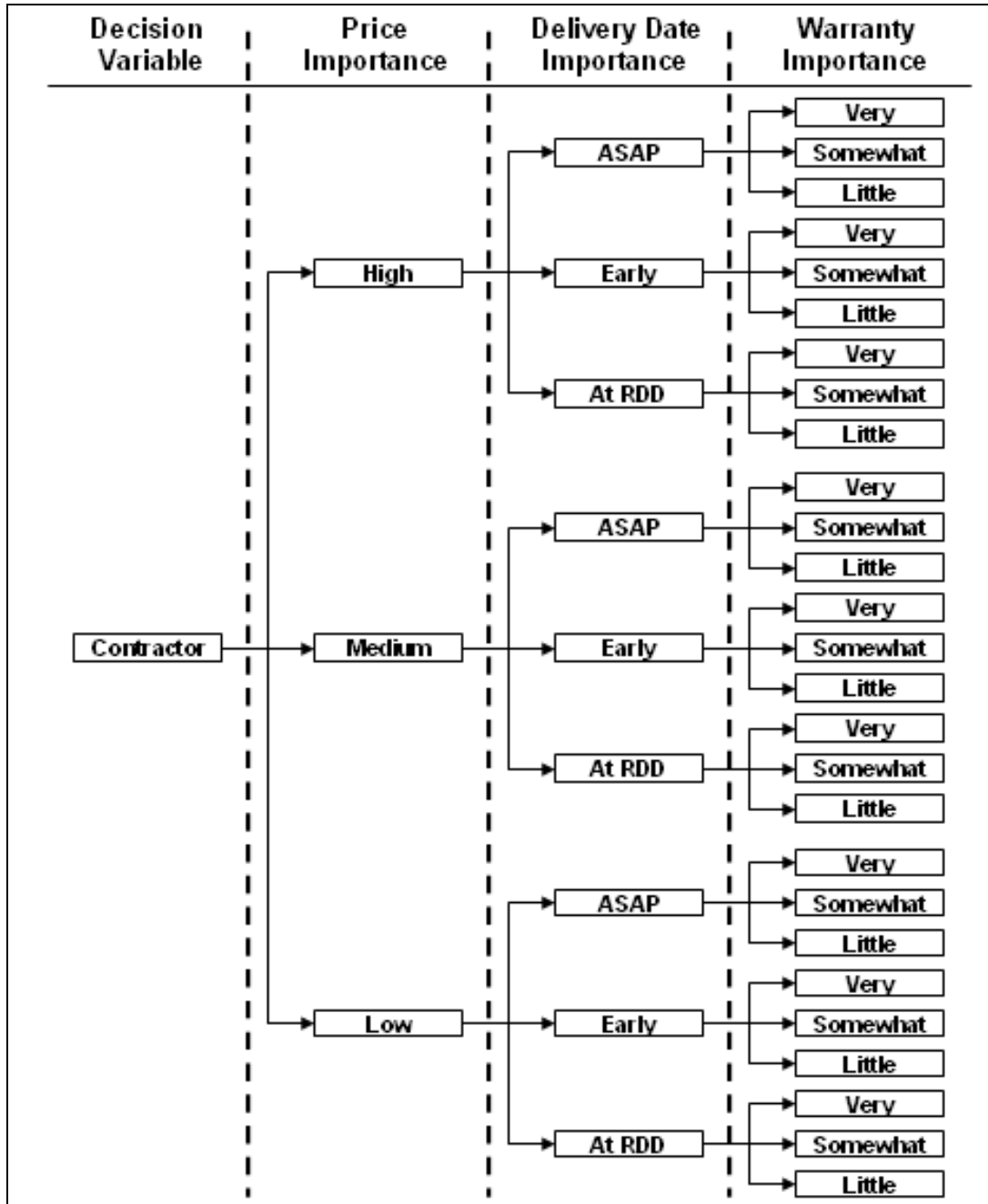

Figure 6.   Portion of sample decision tree

Note that the user must select one of four price ranges within which the contract is expected to fall. The lower the expected price range, the lower the weight for this variable will be. Conversely, if the contract is expected to cost the customer a high dollar amount, the weight for this variable will be higher. This is due to the budget limitations most, if not all, customers face. The more money spent on the contract, the less money available for other purchases. Thus, as the contract value increases and requires more financial resources from the customer, minimizing costs becomes even more important due to the need to fund other requirements. Once the user determines in what range the contracts expected price will fall, he then proceeds to the next variable, Delivery Date. In this decision tree, there are three scenarios for Delivery Date:

1. If the item being procured is a mission critical item, the weight for Delivery Date score is increased.

2. If the item being procured is not mission critical, but is requested by the customer to be delivered as soon as possible, the weight is increased above normal levels, but not to the point where it matches the Delivery Date score weight for a mission critical item.

3. If there is not a compelling need for the product and the customer can wait until the required delivery date (as indicated on the request for proposal) to receive the item, the weight for Delivery Date score is comparatively lower than the weight under the other two scenarios.

After the weight for Delivery Date score is determined, the system performs similar functions for the remaining variables.

The problem still remains, however, as to the best way to determine the appropriate weight for each variable in each scenario. Unlike most situations in government work, there is no statute or regulation that prescribes either the answer or the way in which to arrive at the answer. Fortunately, contracting personnel are uniquely qualified to develop a reasonable solution due to the need for them to exercise judgment in managing tradeoffs and their ability to rely on experience when awarding contracts. Accordingly, the most effective way to determine the proper weight distribution plans for

each scenario (after modeling the scenarios using a decision tree) may still be to assemble a team of experienced contracting personnel at each activity, who in turn can reach a consensus for each scenario through discussion and negotiation—two skills at which contracting personnel excel.

Once the scenarios are identified and the corresponding weights are determined, they must then be integrated into the Source Selection Support System. The system uses an expert system to do so. Note that the decision tree (including weights) graphically represents the collective knowledge of a group of contracting experts. The function of the expert system is to transform the tacit knowledge possessed by those experts (captured in the decision tree) into explicit knowledge that benefits all contracting personnel, including those not nearly as experienced. Thus, the overall system model combines information from the proposals and information retrieved from the data warehouse with the output of the expert system in order to determine the overall acceptance score.

C.   DATA MANAGEMENT

The data management component is comprised of the data warehouse and built-in data mining capability.

1.   Data Warehouse

The data warehouse for the Source Selection Support System will store information required to perform the calculations needed to evaluate the alternatives in accordance with the model structure. Recall that certain variables (price, delivery date, warranty) are entered via direct data entry once proposals are received. The remaining variables (disadvantaged business status, HUB Zone status, customer satisfaction, report of discrepancy, an on-time delivery history) require an evaluation of a contractor's past performance information. As such, the data warehouse will store information pertinent to the relevant past performance variables for each contractor. At a minimum, the data warehouse must include the following data for each contractor in order to produce the information necessary to fully apply the model:

- Disadvantaged business status (Yes/No)

- HUB Zone status (Yes/No)

For every contract awarded to and completed by this contractor:

- Report of Discrepancy record (Yes/No)

- On-Time Delivery record (Yes/No)

- Customer Satisfaction Survey Information (as scored by each customer)

Prior to the initial deployment of the system, the data warehouse must be populated with past contract data in order to establish a past performance baseline. Logically there will be limits to the amount of data that will be entered due to the large amount of data that exists. Rather, the amount of past performance data necessary to establish the baseline should be sufficient to form a reasonable representation of what the baseline would be if all data were entered. For example, entering past performance data from the past five years may be enough to establish a baseline that would mirror the baseline if all data had been entered. Inputting the entire history of data is not feasible due to the time and money required. Additionally, data may not be as readily available for older contracts and even if it is, the older the data, the less its relevance. That is, a contractor's poor performance 25 years ago becomes less relevant if the same contractor's performance over the last five years is stellar. Once the database is current, new contractors will be added as they appear and new contracts will be added as they are awarded. The data warehouse will be structured in a manner similar to the entity-relationship diagram depicted in Figure 7.
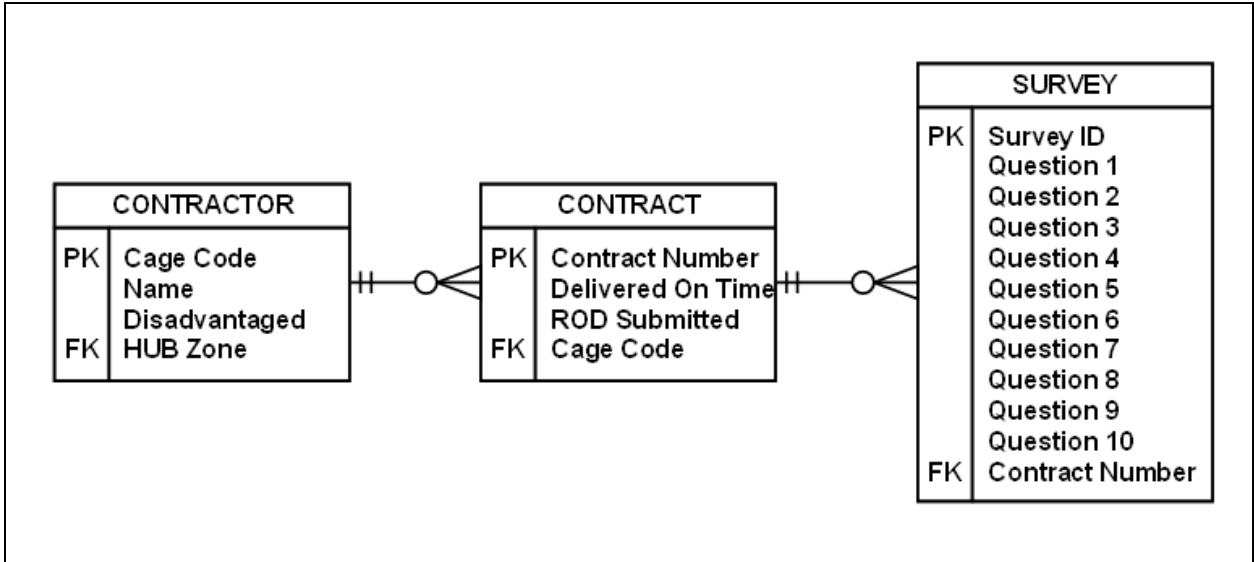
Figure 7.   Data Warehouse entity-relationship diagram

The Contractor table records the data the model requires for each contractor. Since each contractor has a unique cage code, this serves as the primary key. The contractor name is also recorded for descriptive and verification purposes. The "Disadvantaged" and "HUB Zone" attributes have values of either "Yes" or "No" for each contractor. Each contractor may have won multiple contracts, hence the one-to-many relationship. The Contract table records relevant data for each contract. The primary key is Contract Number (another unique identifier) while "Delivered On Time" and "ROD Submitted" are Yes/No attributes. Finally, the survey table records customer response data on ten questions from a standardized Likert survey distributed after contract completion. Since one contractor may serve more than one customer on the same contract (i.e., multiple end users), it is a one-to-many relationship.

Data quality and integrity is maintained through the near instantaneous saving of the contract to the database once the decision is reached, assuming the contracting officer concurs with the recommendation. Because the data warehouse is integrated into the system, the output of the model (i.e., the recommended contractor) can be easily saved to the database without adding much additional data. The main challenge will be to keep the database updated with subsequent data after the contract has been awarded. It is easy to save the contract award when the contracting officer is already looking at it on his

screen, but to log back in to record delivery date, customer satisfaction data, etc. is another story. To address this problem, the Source Selection Support System will have a feature that lists all contracts with incomplete data when prompted by the user.

Data processing is required for certain variables. That is, some variables do not get their values directly from a particular attribute in a table in the data warehouse. The data must first be processed into a new form. For example, the model requires a contractor's customer satisfaction score as an input. Yet there is no attribute in any table that provides this information. That is, the data warehouse only records numerical responses to individual questions for each survey that is completed. This data must be processed in order for the model to accept it. As indicated in the model management section, the average score for each survey must be calculated based on the responses to each individual question. From there, the average of all survey averages for a contractor must be computed to get the information in its proper form.

The data administration will be based on server administration and database standard operating procedures. For example, security will be maintained through standard authentication and authorization practices while back-up procedures will include regular back-ups kept for a designated period of time at multiple locations to minimize the risk of destruction and/or failure.

2. Data Mining

Data mining capability will be embedded in the system to serve as a feedback enabler. Data mining is "a process that uses a variety of data analysis tools to discover patterns and relationships in data that may be used to make valid predictions."[25] Essentially, data mining serves to identify patterns and relationships in data, which can then be used by managers in decision making.

Within the context of the Source Selection Support System, data mining can be employed to validate the model and update it as needed. For example, recall that one of

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[25] Two Crows Corporation. "Introduction to Data Mining and Knowledge Discovery." Third Edition. 2005.

the initial steps to implement the system is to establish a set of variable weights for each possible scenario a contracting officer is likely to encounter. After these weight sets are input to the system, contracting officers use them to execute the model. This arrangement works well, assuming that the contractor ultimately recommended by the contract performs well. If the contractor does not perform well, however, it might be an indication that the variable weight mix for the scenario under which the contractor was awarded the contract is not optimal. That is, the model may have selected a poor alternative and awarded the contract to a contractor who did not offer the overall true best value to the government. Alternatively, it may also indicate nothing of consequence. Perhaps it was a simple isolated incident, which would not contradict the validity of the model. Without further analysis, the true indication cannot be determined.

Data mining can be used to determine whether patterns of failure are occurring for specific variable weight distribution plans. For example, for a particular scenario, delivery date score may carry a weight of 15 percent. Subsequent data shows that contractors are failing to meet promised delivery dates on a regular basis under this scenario. Thus, it may be necessary to modify the weight distribution plan in order to increase the weight for another variable such as price at the expense of the delivery date score variable, since the delivery date score variable weight is not producing the desired effect anyway. Thus, data mining closes the loop in the process by providing feedback to the model, as shown in Figure 8.
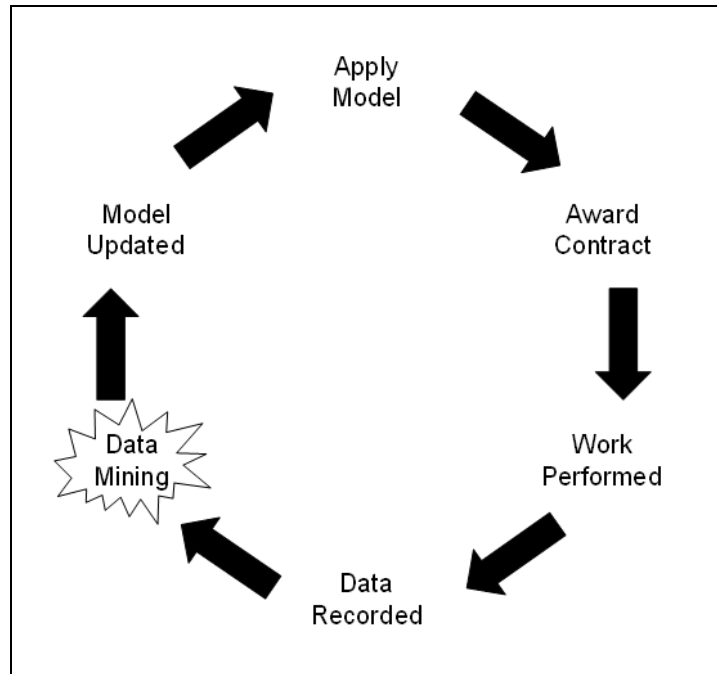
Figure 8.   System feedback loop

D.   USER INTERFACE

The discussion of the user interface will encompass two broad areas: the manner in which users access the system, and the navigation schema once users are inside the system.

1.   System Access Using a Virtualization Environment

One possible disadvantage of implementing the Source Selection Support System is the procurement cost associated with the various commercially available decision technologies. As the proposed system is intended to be an individual tool that can be accessed by acquisition personnel via their desktop computers, the license costs for the software packages that serve as the system components could be prohibitive. Accordingly, a cost effective solution to this constraint would be to allow personnel access to the system from their individual workstations without having to install the system on each of those workstations. Creating a virtualization environment will do just that.

Within the context of information technology, virtualization "is a technique for hiding the physical characteristics of computing resources from the way in which other systems, applications, or end-users interact with those resources."[26]   Essentially, virtualization allows multiple individual workstations to access the same resource housed by a single physical resource. This virtual relationship is shown in Figure 9. Within the context of the Source Selection Support System, the system can be installed on a central server and accessed by multiple workstations with no physical connection or workstation specific software necessary.

Figure 9.   Virtualization environment for the Source Selection Support System

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[26] Andi Mann, "The Pros and Cons of Virtualization." www.btquarterly.com. Last accessed 12 Feb. 2008.

Virtualization offers multiple advantages. As discussed, there are significant cost savings to be realized in the form of reduced software license fees and system administration costs. In addition, system maintenance and upgrades are accomplished more easily with virtualization. That is, upgrades need only be installed and system maintenance need only be performed on the hardware actually hosting the system. Corresponding upgrades and maintenance are not necessary on the virtual machines accessing the application. Other benefits from virtualization can include better security, reduced downtime, increased ability to achieve service levels, the capability to accommodate legacy systems on new hardware without major upgrades, and better conduciveness to location and staff mobility issues.[27]

Another option for configuring the virtualization environment for the Source Selection Support System is to establish a single physical server capable of hosting multiple virtual servers. Within the context of DSS, the major benefit of this configuration is that it allows for decision support systems which require unique configurations to have dedicated virtual hardware as opposed to competing for system resources on a shared physical server. Furthermore, this strategy allows virtual servers utilizing different operating systems to function without interfering with each other. Finally, this configuration enables a data center of smaller size, with corresponding savings in server cooling costs.

2.   Navigation Schema

The user interface provides the portal through which the user accesses the other components of the system. Specifically, the interface allows users to input information used by the model component, save/retrieve data to/from the data warehouse, and access the knowledge captured in the expert system. All of these tasks can be grouped into two main system functions: evaluating proposals and database management. The user

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[27] Andi Mann, "The Pros and Cons of Virtualization." www.btquarterly.com. Last accessed 12 Feb. 2008.

navigates through the system via point-and-click. And since the scope of the Source Selection Support System is narrow with sequential steps, there is little chance of a user getting "lost".

If the user wishes to evaluate a set of proposals, he selects this option from the main menu. The next step is to calculate the variable weights. In determining the weights for the variables, the user will be prompted to answer a series of multiple choice questions which will ultimately determine the right mix based on the circumstances surrounding the procurement and the business rules that are built into the expert system. After the weights are determined, the user searches the data warehouse for the contractors from who proposals were accepted. If the contractors are already in the data warehouse, the corresponding data for those contractors is retrieved. If a contractor is new and has not yet been recorded in the data warehouse, the user will be prompted to do so at that time. The user then enters the remaining required data directly after reviewing each contractor's proposal. For each proposal, the user will have to input the price, delivery date, and warranty length.

If the user wishes to perform any database management tasks, he selects this option from the main menu. The user has access to all three tables of the database and can insert or modify records as necessary. That is, with respect to the Contractor table, the user will be able to add new contractors or modify a contractor's status (disadvantaged business and/or HUB Zone). The user will also be able to update records in the Contract table. Although the system records a new contract once the user accepts the recommendation (assuming the recommendation is accepted), the user will still need to update the contract record with on-time delivery and ROD data. A user may also need to insert a new contract in the table in the event he does not accept the recommendation of the decision support system, thus this capability will be included as well. Finally, the user will be able to record customer survey data to the Survey table. Users will not be permitted to delete records from any table in order to prevent accidental deletion of relevant data. The navigation schema is shown in Figure 10. There are branches from the main menu for the two primary activities.
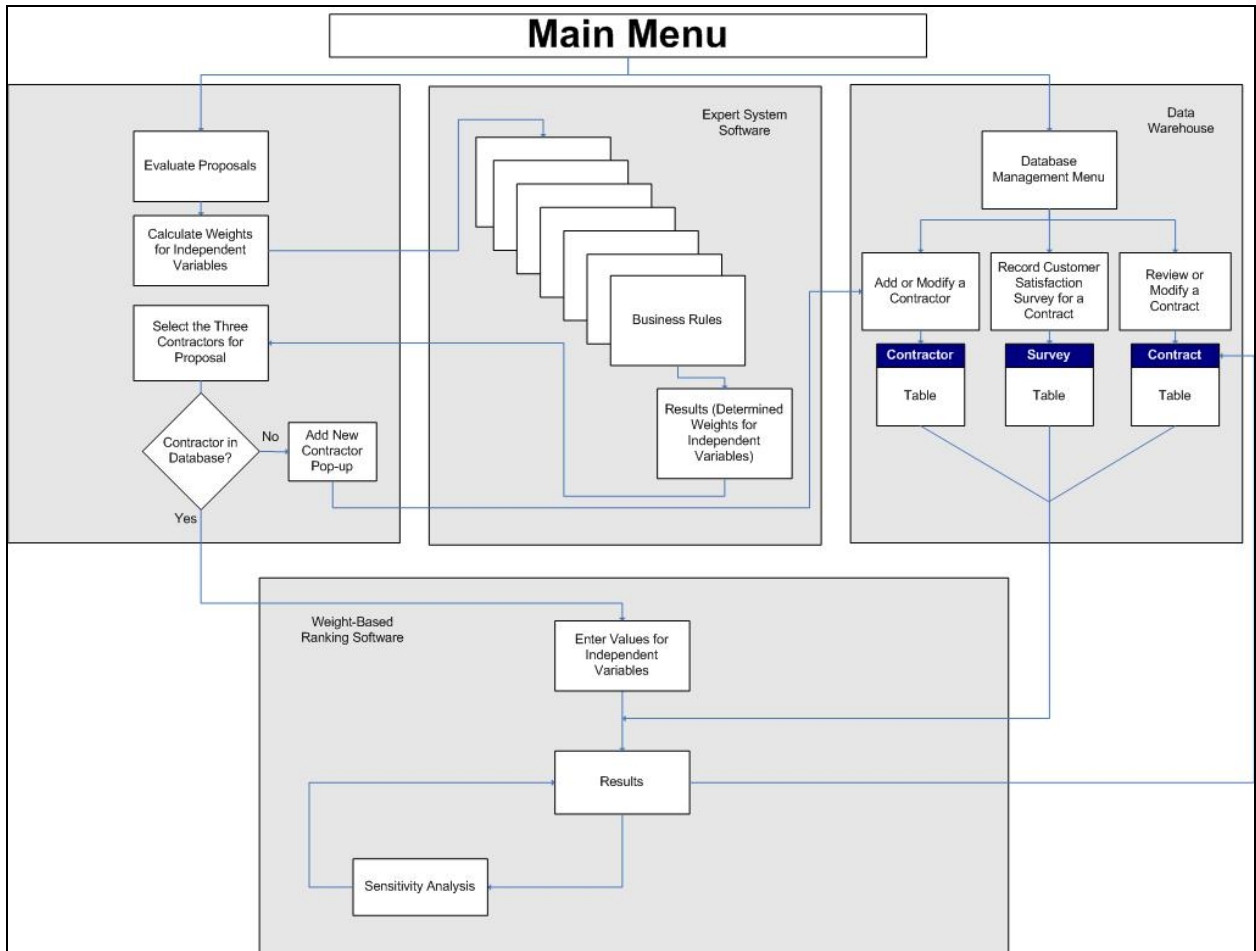
54

Figure 10.   User interface navigation schema

E.   USER

The primary users of the Source Selection Support System are federal government contracting personnel. These personnel may vary in experience and knowledge, as both seasoned contracting officers and brand new contracting support staff are potential users. A possible secondary group of users may be the customers on whose behalf the contracts are awarded. That is, if the system is upgraded to include a web-enabled capability, customers will be able to input their own survey data as opposed to contracting personnel performing that task.

The preceding discussion of the proposed system discussed the structure of the model in largely conceptual terms, without identifying any particular decision technologies to be used. As such, the next step is to take the model and research what commercially available decision technologies most appropriately align with the objectives of the system. After determining which decision technologies to incorporate into the overall system, the individual elements of the system (weight-based ranking model, expert system, data warehouse) can be constructed.

IV.   SYSTEM PROTOTYPE

The Source Selection Support System links commercially-available decision support software systems with a database using a custom designed user interface. Specifically, the prototype uses Infoharvest Corporation's Criterium Decision Plus for the weight-based ranking system, Informavore Corporation's Firefly Designer for the expert system, and Microsoft Access for the database. These systems interact in the manner depicted in Figure 11. The proceeding scenario will be used to illustrate how these individual software systems function to support the overall system.
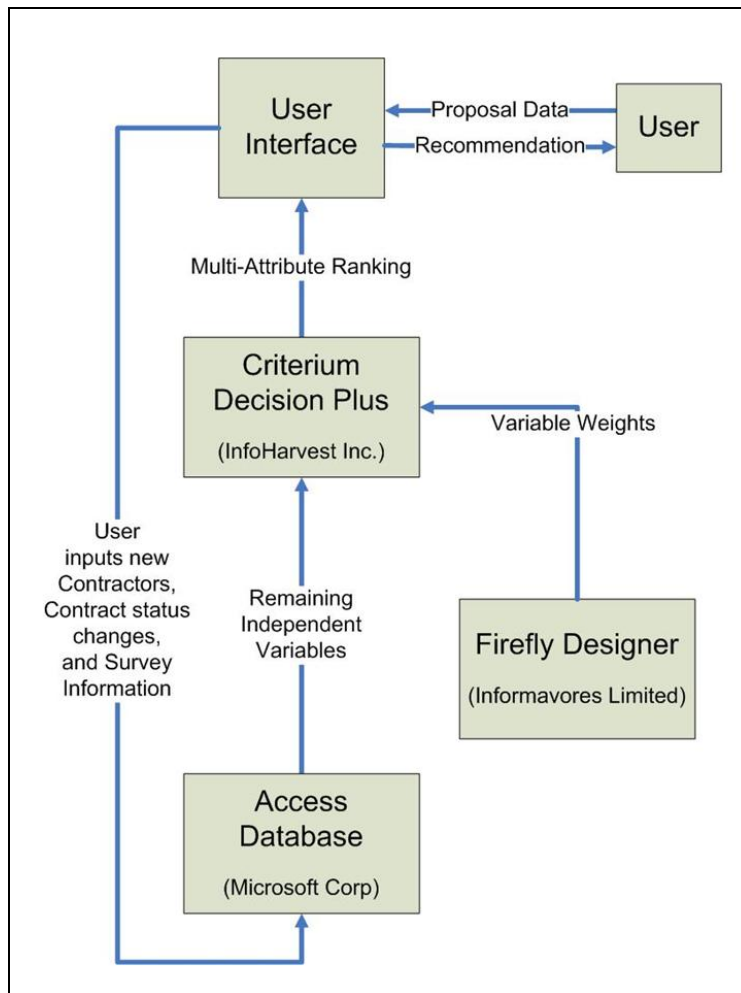

Figure 11.   System prototype software interrelationships

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A.   SCENARIO

USS Neversail, a guided-missile destroyer homeported in San Diego, CA requires 24 new tactical combat vests for boarding team members. The ship deploys in four weeks and these are mission critical items. And since team members may depend on these vests to save their lives, a strong warranty is highly desirable. The total cost is expected to be between $30,000 and $35,000. Since the job will exceed the micro-purchase threshold of $2,500, the ship submits the requirement to the local contracting activity at the Fleet Industrial Supply Center. The contracting officer has received the request, issued a solicitation, and received the three proposals required under simplified acquisition procedures. All proposals meet technical requirements. Additionally, the contracting officer expects to award the contract on January 14, 2008. As expected, the proposals are slightly different when it comes to price, but the contracting officer is not convinced that the lowest price is the best decision for the government. He examines the proposals more closely and collects the data shown in Table 12.

	Davis Army Supply	International Security	Shipboard Solutions
Delivery Date	6/5/2008	5/11/2008	6/15/2008
Price	$32,500	$31,300	$30,475
Warranty	0	42	48

Table 12.   Proposal data for USS Neversail scenario

Davis Army Supply is a disadvantaged business, and therefore qualifies for a ten percent price adjustment to its initial bid. The other two contractors do not qualify for any price adjustments. The contracting officer logs on to the Source Selection Support System in order to help him arrive at an award decision.

B.   EXPERT SYSTEM

Following the system navigation schema in Figure 10, the first step is to determine the appropriate weights for the independent variables given the characteristics of the scenario. This is accomplished through the Firefly expert system. Figure 12 shows the expert system structure.

The user has four alternatives for price importance:

- Less than $25,000

- Between $25,000 and $50,000

- Between $51,000 and $75,000

- Between $75,000 and $100,000

Three alternatives for delivery date importance:

- Mission critical

- Delivery requested as soon as possible but not mission critical

- Delivery at required delivery date sufficient

And three alternatives for warranty importance:

- Warranty very important

- Warranty somewhat important

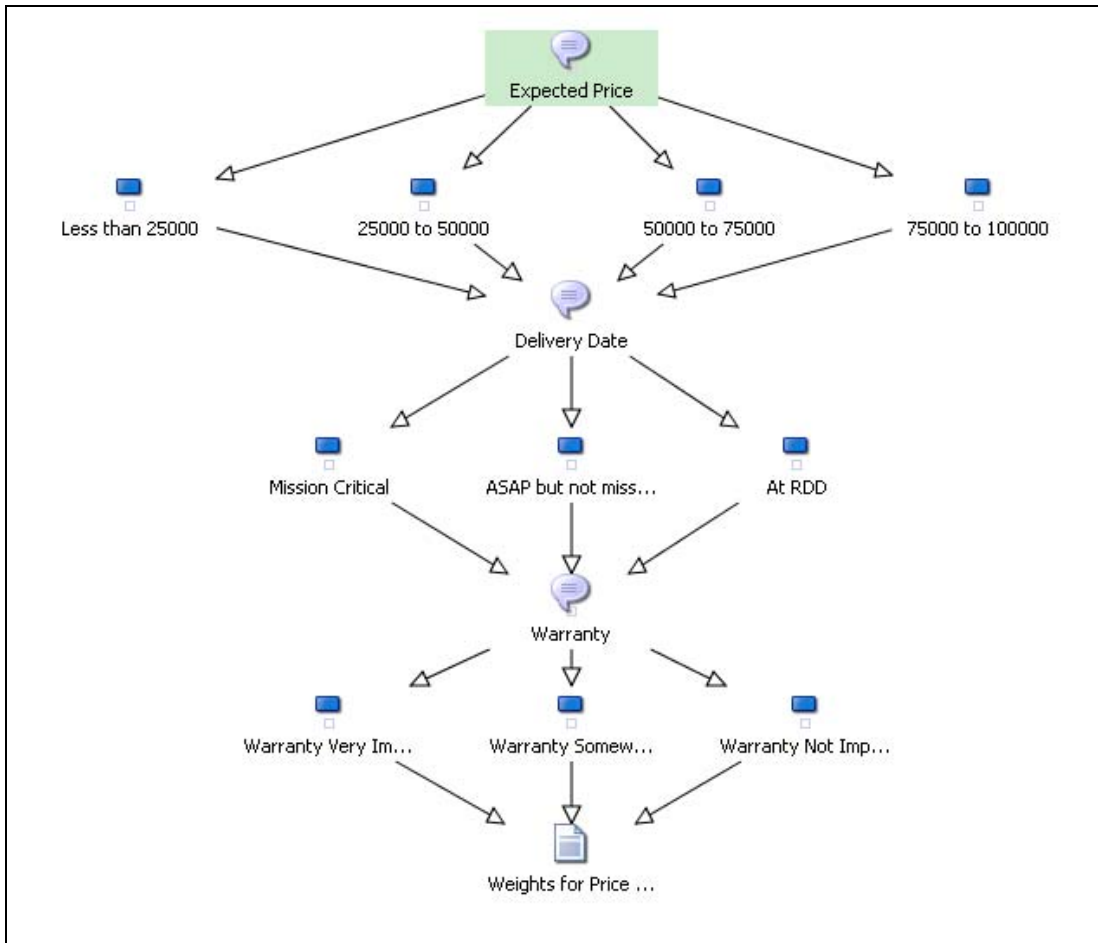- Warranty not important

Figure 12.   Source Selection Support System expert system component structure

For the purposes of this prototype, the remaining three variables (on-time delivery score, ROD score, and customer satisfaction score) represent equal portions of the remaining weight percentage available. For example, if the combined weight of the price, delivery date, and warranty variables is 70 percent, then the weight for each of the remaining three variables is 10 percent [(100-70)/30]. Firefly includes a feature that allows the user to proceed through each of the three multiple-choice variables in order to arrive at the pre-determined weight distribution. The user is prompted to answer questions similar to the one displayed in Figure 13.

Figure 13.   Sample Firefly question

As shown in Figure 14, after the user has answered all required questions, Firefly provides a results screen that displays the resultant variable weights.

Figure 14.   Firefly results screen

Now that the variable weights have been determined, it is time to calculate the scores for each variable.

C.   DATA WAREHOUSE

The system prototype uses a Microsoft Access database as the data warehouse. Recall that the system retrieves scores for the On-Time Delivery, ROD, and Customer Satisfaction variables from the data warehouse. The Access schema is shown in Figure 15.
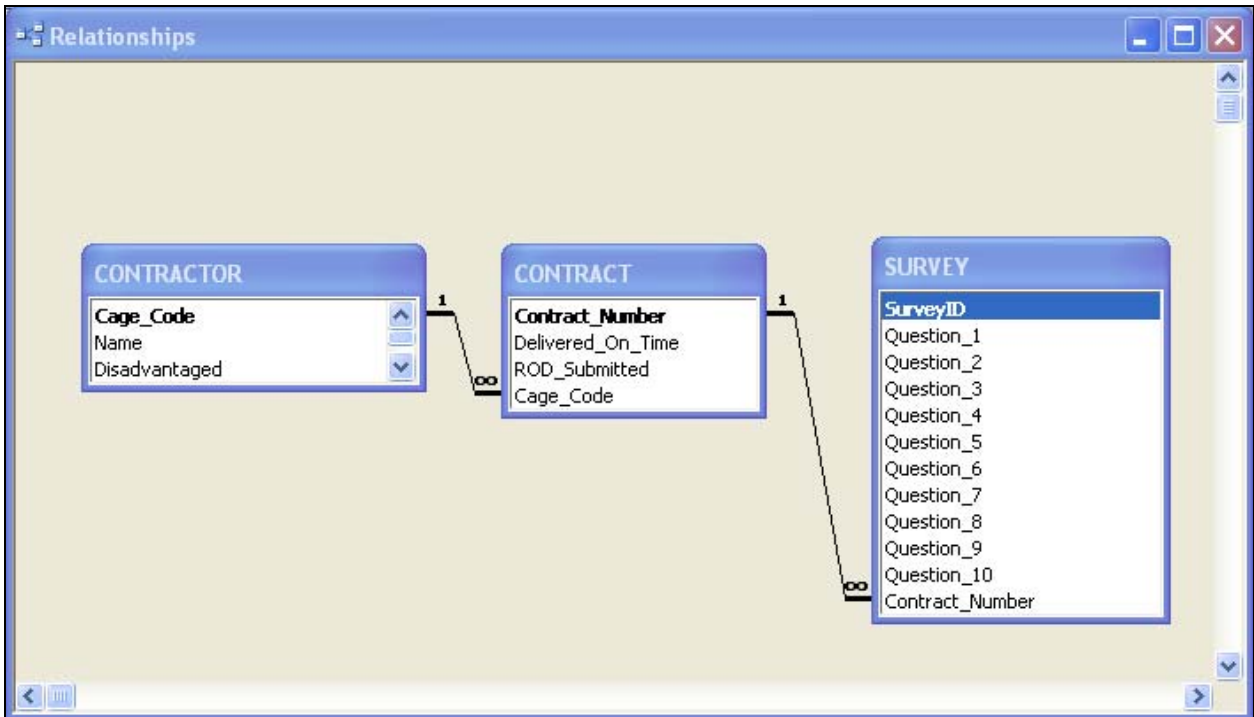
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Figure 15.   Microsoft Access schema

Queries are used to convert the data recorded in the tables into the scores needed by the weight-based ranking model. For example, if a contracted item was delivered late, a "No" is recorded in the Delivered_On_Time attribute of the Contract table. A query retrieves all contract records for a particular contractor and calculates the overall On-Time Delivery score for that contractor through various structured query language statements. Once the system has retrieved the On-Time Delivery, ROD, and Customer Satisfaction scores, it stores them in the weight-based ranking model built in Decision Plus.

The data warehouse provided the data shown in Table 13 for the three contractors in this scenario.

	Davis Army Supply	International Security	Shipboard Solutions
ROD Score	94 %	90 %	48 %
Customer Satisfaction Score	94 %	100 %	48 %
On-Time Delivery Score	79 %	78 %	79 %

Table 13.   Additional Information From Data Warehouse

D.   WEIGHT-BASED RANKING MODEL

The first step in creating a model in Decision Plus is to create a goal hierarchy. For the Source Selection Support System, the ultimate goal is to select a contractor to recommend to the contracting officer for contract award. Thus, "Select a Contractor" is the Goal level in the hierarchy. The variables that play a role in determining the outcome of the goal level are listed in the next level of the hierarchy, Level 2. Finally, since each contractor will be scored against these variables, they are all modeled in the hierarchy as well in the form of alternatives. The completed hierarchy for the Source Selection Support System is shown in Figure 16.
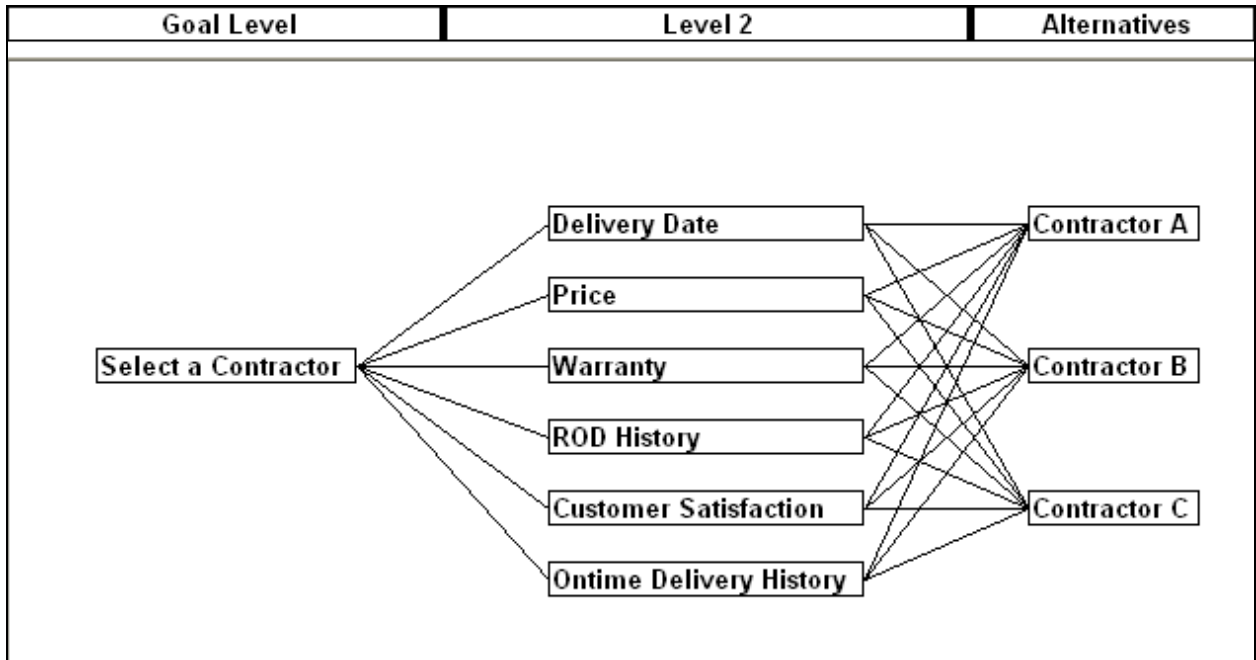
Figure 16.   Decision Plus hierarchy

After modeling the hierarchy, the next step is to transfer the weights calculated in Firefly into the Decision Plus module. Recall from Figure 13 that the variable weights for this scenario are as follows:

- Cost: 55 percent

- Delivery Date: 15 percent

- Warranty: 10 percent

- Customer Satisfaction: 6.67 percent

- ROD History: 6.67 percent

- On Time Delivery Percentage: 6.67 percent

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The Decision Plus screen used to enter the variable weights is shown in Figure 17.
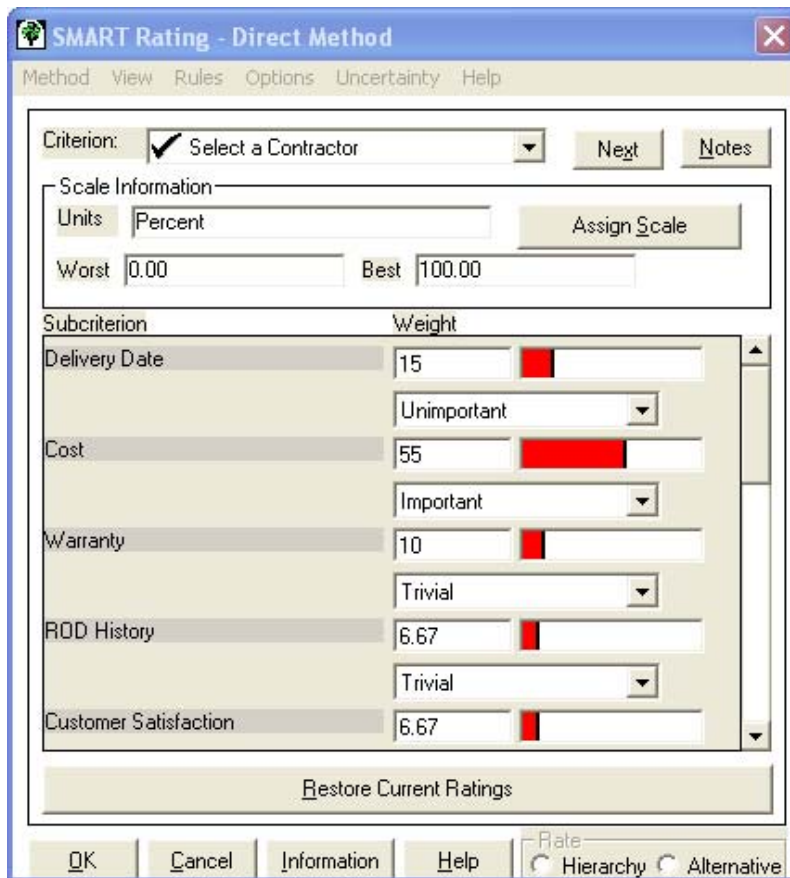

Figure 17.   Decision Plus variable weight entry screen

Decision Plus offers three ways in which to enter variable weights. The first method is to directly enter the values (15, 55, 10, etc.) after selecting the appropriate units and range of acceptable values. Alternatively, the user can change weight values by sliding the corresponding bar charts left (to decrease) or right (to increase). Finally, the user can choose a descriptive term from a drop down menu that best describes the relative importance of that variable. These terms include critical, very important, important, unimportant, and trivial. Each term has a default numerical weight associated with it (100, 75, 50, 25, 0 respectively). The Source Selection Support System will use the first

method, since the calculated weight percentages are too precise for either of the two remaining options to be feasible in certain scenarios.

Once the hierarchy is constructed and the variable weights are imported, the next step is to enter each contractor's scores for the variables. The user must enter the scores for cost, delivery date, and warranty while the data warehouse will automatically supply the scores for the remaining three variables. The input screen for the direct entry variables is shown in Figure 18. Note that this screen must be completed for each contractor. Figure 18 displays data for Contractor A (Davis Army Supply).

Figure 18.   Variable Scores for Contractor A (Davis Army Supply)

Once the hierarchy is constructed, the variable weights are imported, and the variable scores for each contractor are entered, the model is ready to be run. The default results screen is shown in Figure 19.

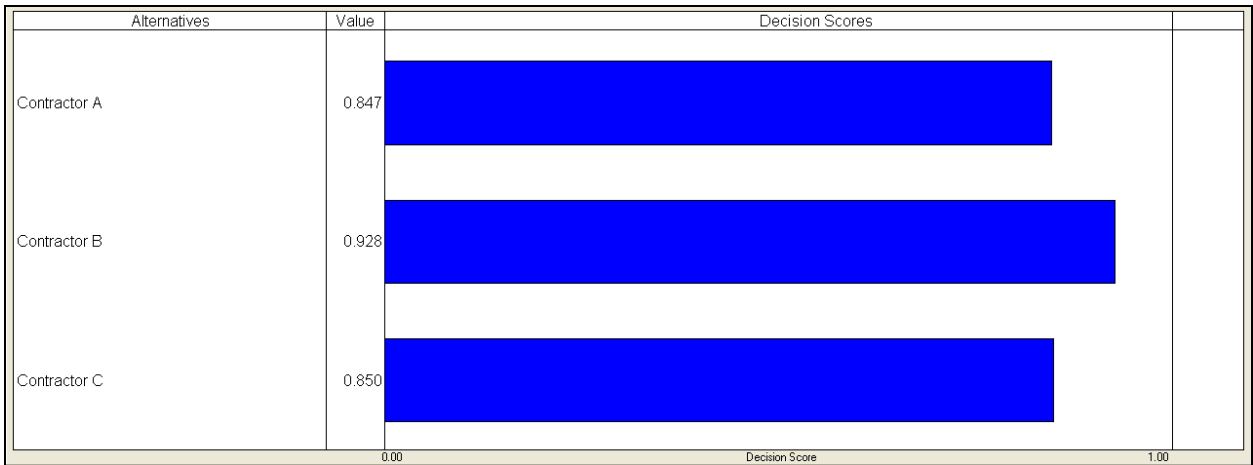| Alternatives	Value	Decision Scores
Contractor A	0.847	
Contractor B	0.928	
Contractor C	0.850	

Figure 19.   Default Results Screen

In this scenario, contractor B (International Security) is the recommended contractor with an overall acceptance score of 92.8 percent. Recall that International Security's proposed price was not the lowest of the three proposals. In fact, it was $825 (almost three percent) higher than the lowest proposed price—that of Shipboard Solutions. Thus, although International Security had a lower score for the price variable, it was still able to earn the recommendation because it outperformed the other two contractors with respect to the non-price variables. The Decision Plus results match those the user would obtain had he manually calculated the variable scores for each contractor and applied the corresponding weights. Figure 20 shows the individual variable results for each contractor.

		Davis Army Supply		International Security		Shipboard Solutions	
Variable	Variable Weight	Variable Score	Weighted Score	Variable Score	Weighted Score	Variable Score	Weighted Score
Price*	55.00%	100.00%	55.00%	92.99%	51.15%	95.81%	52.70%
Delivery Date**	15.00%	79.31%	11.90%	100.00%	15.00%	70.69%	10.60%
Warranty***	10.00%	0.00%	0.00%	87.50%	8.75%	100.00%	10.00%
ROD	6.67%	94.00%	6.27%	90.00%	6.00%	48.00%	3.20%
Ontime Delivery	6.67%	94.00%	6.27%	100.00%	6.67%	48.00%	3.20%
Customer Satisfaction	6.67%	79.00%	5.27%	78.00%	5.20%	79.00%	5.27%
Overall Acceptance Score			84.70%		92.76%		84.97%

Figure 20.   Individual Variable Results For Each contractor

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Additionally, Decision Plus allows the user to view the results in stacked bar graph format, as shown in Figure 21. In this view, it is easier for the user to see why a particular contractor is recommended over the others. In this scenario, although International Security (Contractor B) earned the least score for the price variable, its first place delivery date score helped to compensate for that shortcoming.
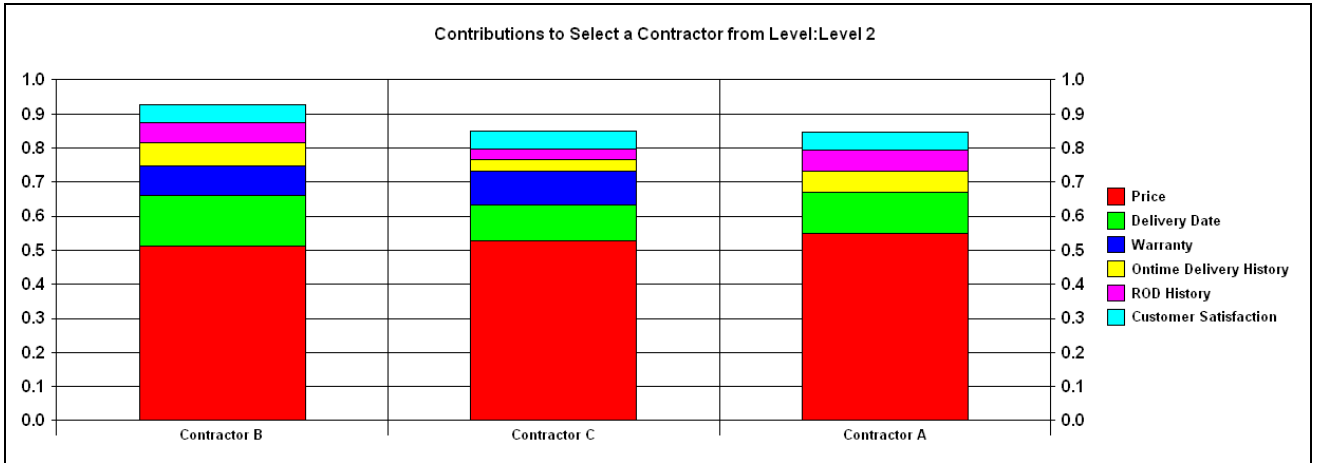

Figure 21.   Stacked Bar Graph Results Screen

Finally, Decision Plus has a sensitivity analysis feature. In order to conduct a sensitivity analysis, the user chooses a particular variable. Decision plus presents the results of the analysis for this variable in the form of a line chart with a vertical line that the user can slide horizontally, as shown in Figure 21. There is a different line on the chart for each contractor and the points at which the lines intersect represent points where the recommended solution would change. That is, the x-axis of the line chart represents the weight for that variable. The user can slide the vertical line left or right to modify the variable weight, shown in the lower right corner of the screen. The points of intersection represent what the variable weight would have to be in order for the final solution to change. For example, Figure 22 confirms that Contractor B, International Security, is the recommended contractor given a weight of 10 percent for the warranty variable (see lower right of screen).
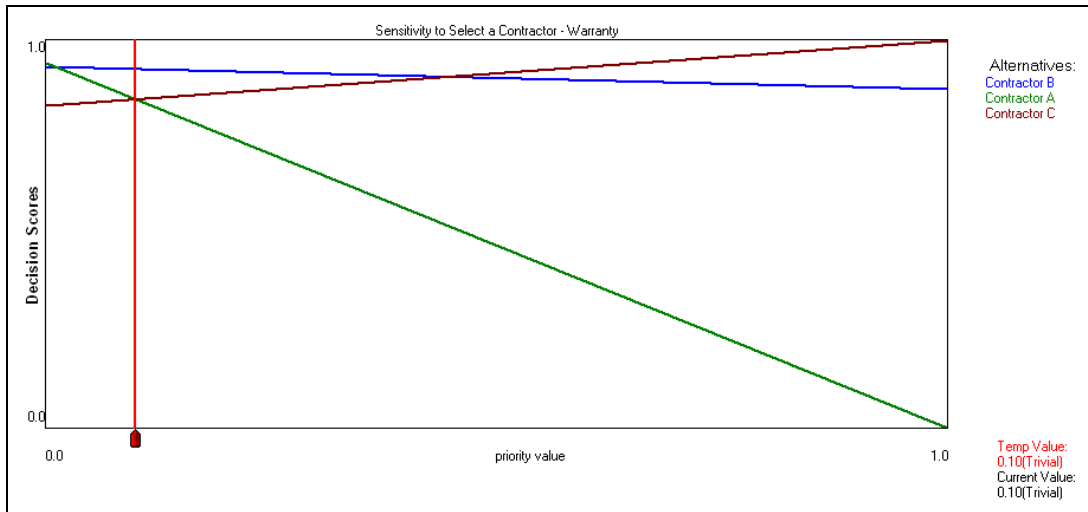
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Figure 22.   Initial Sensitivity Analysis Screen For Warranty Variable

Note that the lines for International Security and Shipboard Solutions (contractor C) intersect to the right of the vertical line. This represents the warranty weight percentage that would result in Shipboard Solutions becoming the recommended contractor. As shown in Figure 23, if the weight for the warranty variable is increased to exceed approximately 45 percent (refer to the lower right corner of Figure 23), the solution changes.
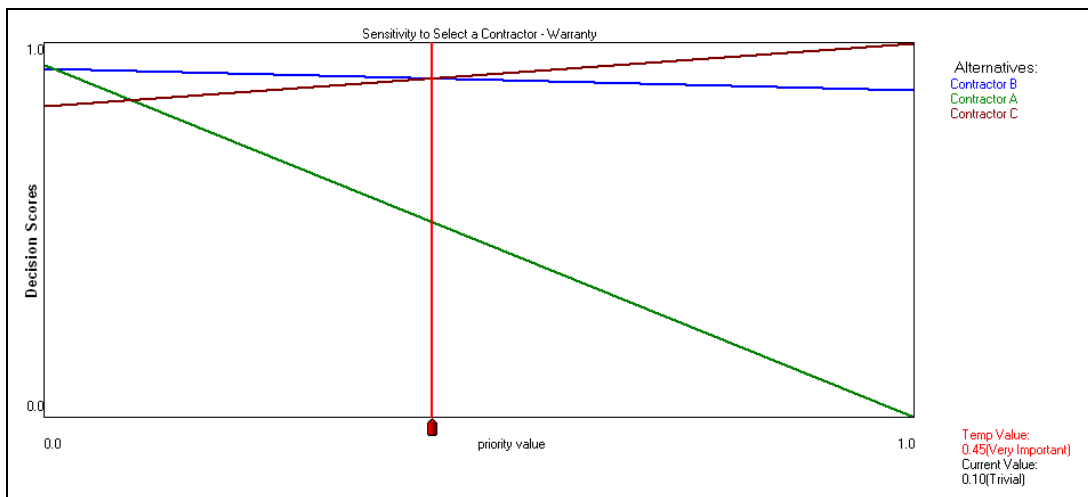

Figure 23.   Revised Sensitivity Analysis Screen For Warranty Variable

Due to the programming required and the author's lack of programming expertise, a user interface was not constructed. However, the preceding prototypes of the individual components are sufficient to provide a sense of how the entire system will function once fully developed. As stated in the Introduction, a fully functional system is not within the scope of this thesis, but serves as an exciting opportunity for further development.

E.   USER ACCEPTANCE

As with any new system, the user acceptance of the Source Selection Support System will likely not be immediate. The contracting community is a highly specialized workforce, trained to exercise judgment influenced by experience, education, and training. They are empowered with considerable autonomy to make decisions that commit taxpayer dollars. As such, any system that perceivably decreases the level of autonomy with which they are entrusted will likely meet with resistance. Upon introduction of the system, a popular refrain within the contracting community may be that an automated system cannot duplicate the human thought process that is used to select sources for government work. This perception can be countered by successfully conveying the message that the model is a product of the human thought process involved in the source selection decision and not simply an information system haphazardly developed to automate a formerly human process. Furthermore, the fact that it is a static model, updated as necessary in response to the output of the embedded data mining capabilities, must be communicated to acquisition personnel in order to reinforce the fact that the system is a reflection of human thought and reason as opposed to a replacement for those activities. That is, the Source Selection Support System is not designed to replace the human decision maker. Rather, since it is a decision support system, it serves as a tool to assist the decision maker in arriving at a decision.

Once the intent is clearly communicated to the contracting community, those personnel will be able to see several appealing characteristics of the system. These include a time-saving aspect, as contracting personnel will not have to spend as much time performing tradeoff analyses. Additionally, the system provides contracting officers with a more defensible position in awarding a contract to a particular contractor should

there be a protest. From a command standpoint, contracting personnel will be able to increase contract award throughput, thereby reducing customer response time as well. Finally, perhaps the most appealing benefit is the knowledge that the contractor offering the best value to the government was awarded the contract.

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V. CONCLUSION

A. SUMMARY DISCUSSION

Under current procedures, federal government contracting personnel are empowered to evaluate competing contractor proposals and exercise personal, professional judgment in determining which contractor is awarded the contract. This approach is highly subjective in that contracting personnel need to perform tradeoff analyses based on personal experience and acquired knowledge. As experience and knowledge levels can vary greatly from person to person, it is highly possible that two contracting officers, when evaluating the same set of proposals, could arrive at a different conclusion. And as only one contractor can offer the true best value to the government, the contracting officer who would award the contract to a different contractor would clearly be making an error in judgment. There is little consistency in the proposal evaluation process and that lack of consistency is contributing to improper selection of sources.

There are multiple commercially available decision technologies contracting personnel can employ to establish not just consistency in the evaluation process, but validity as well. Through the integration of these technologies, contracting personnel can leverage their capabilities into forming a useful source selection tool. This is what the Source Selection Support System seeks to accomplish.

The Source Selection Support System combines a multi-criteria decision analysis system with an expert system and a data warehouse to form an objective evaluation model. The system is structured around a weight-based ranking model and links the various individual software components through a custom designed user interface. Furthermore, the ideal system is distributed via a virtualization environment, where multiple users virtually connect to a single system installed on a central server platform.

Ultimately, the Source Selection Support System is designed to provide the contracting officer with as to which contractor offers the "best value" proposal in a competitive solicitation by weighing multiple variables such as price, delivery terms, and past performance measures.

B.   RECOMMENDATIONS FOR FURTHER RESEARCH

There are two primary areas where further research is recommended. First, the prototype currently does not represent the complete vision of the system. While individual components (weight-based ranking model, expert system, and data warehouse) have been constructed, the user interface and data mining functionalities have yet to be developed. In addition, once the prototype is fully functional, experimentation in a virtualization environment is recommended prior to system deployment.

A second area of research that may be explored centers around creating an implementation strategy for a test deployment of the system. This research will involve issues such as feasibility studies, hardware and software procurement plans, data warehouse population strategies, and management of organizational change.

A final possible area of research involves the application of integrated decision technology to areas within the acquisition domain other than simplified acquisition procedures. Where simplified acquisition procedures represents a structured problem well suited to the proposed model, there are numerous facets within the acquisition arena that are not as structured. For example, the problem of determining what to buy is considerably less structured than the problem of determining from whom to buy a particular item. As such, it would be useful to explore how integrated decision technologies can assist with decisions such as these as well.

C.   FINAL THOUGHTS

Decision support systems are typically single scope applications that focus on one type of application domain. While this is acceptable for many decision environments, it does not fully harness the capability of decision support systems. This thesis focused on how an integrated decision technology environment can be employed to assist contracting

personnel in determining which contractor offers the best value as compared to other contractors competing for the same contract. While the proposed system combines the concepts of multi-criteria decision analysis, expert systems, and data mining, it also serves to indicate the general potential of integrating multiple decision technologies to spawn decision support system generators for complex decision-making problems. That is, decision technologies such as agent-based simulation, optimization, social network analysis, and other application domains can potentially be integrated to address complex problems that previously could not be adequately addressed by a single-scope decision technology. Decision technology integration, as proven in this thesis, opens new doors to solving problems previously considered too complex for standard decision support systems.

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