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Integrated Decision Technology for Acquisition and Contracting

30 May 2008

by

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Abstract

Decision technologies in the form of decision-oriented software systems have proliferated dramatically over the past two decades. Most of these systems tend to be stand-alone systems which are focused on a relatively narrow set of analytical techniques for solving quite specific problems. Many applications, however, require a combination of these technologies to address complex decision-making problems. What is missing in the DSS landscape is an environment in which to create a *DSS Generator* that integrates requisite technologies flexibly and quickly to construct a robust application. We discuss the notion of an integrated decision technology environment (IDTE) in the context of Federal acquisition and contracting. Specifically, we show 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 that contracting personnel evaluate proposals both consistently and fairly for simplified acquisition procedures (SAP). The proposed system, Source Selection Support System (S^4), integrates several decision support technologies including a weight-based ranking model, a multi-criteria decision analysis software system, an expert system, data mining, and a data warehouse. We describe the data, model, knowledge, and user interface components of S^4, present a use case, and show how virtualization technology can facilitate the implementation of this DSS. We conclude by discussing how this approach can be generalized to embrace a fuller portfolio of decision technologies which can, in turn, address a wider array of more complex contracting applications.

Keywords: simplified acquisition procedures; decision technology, decision-support system (DSS), DSS generator, integrated decision technology environment (IDTE)

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Executive Summary

The history of information systems (IS) has been plagued by the continued inability to deliver systems which satisfy user requirements in a timely and cost effective manner. This has been especially true in the case of decision support systems (DSS) wherein the intent is to support various phases of the decision-making process. One strategy that has been adopted to reduce system development time is the use of component-based software which relies heavily upon the reuse of already existing software. Although this strategy is widely used in object-oriented approaches to software development (e.g., Microsoft's Component Object Model (COM)), it has not been employed in the DSS development domain. This research examines the use of an integrated decision technology environment (IDTE) as a high level counterpart to component-based software for developing DSS Generators (DSSG). As a vehicle for investigating how this approach might work, we demonstrate a DSS which links several preexisting decision support platforms to allow contracting personnel to evaluate proposals both consistently and fairly for simplified acquisition procedures (SAP).

One of the problems with existing COTS DSS software is that each system solves only a narrow type of decision problem, and furthermore these systems, in general, are very difficult to link with one another. When confronted with complex real world decision-making processes, developers may find that no single COTS platform can solve the overall problem, and that it is prohibitively expensive to integrate any set of systems which may be required to provide a solution, even if those systems could be identified.

An IDTE is intended to facilitate DSS development by enabling not only the identification of various decision technologies and their relevance to decision-making problems, but also the integration of those systems to provide a cohesive application. For the SAP domain, we implement a data warehouse-based solution for evaluating proposals which integrates a weight-based ranking model, a multi-

criteria decision analysis model, an expert system, and post facto data mining analyses. The S^4, Source Selection Support System, links commercially-available decision support software systems with a database using a custom designed user interface. Specifically, the prototype uses Criterium Corporation's Decision Plus™ for the weight-based ranking system, Informavore Corporation's Firefly™ for the expert system, and Microsoft Access™ for the data warehouse.

At the practical level the requisite S^4 prototype can serve as a detailed requirements specification for a DSS which provides consistent evaluation of SAP proposals. At the conceptual level, the S^4 is an experiment in integrating multiple decision technologies into a multidimensional DSS Generator. This approach holds promise for implementing additional decision-based applications in the acquisition and contracting domain. Further research is required to design interfaces for higher level integration which not only can reduce DSS development time, but also can facilitate the implementation of systems for supporting very complex decision processes which might otherwise defy analysis.

I. Introduction

Decision technologies in the form of decision-oriented software systems have proliferated dramatically over the past two decades. Most of these systems tend to be stand-alone systems that focus on a relatively narrow set of analytical techniques for solving specific problems. Many applications, however, require a combination of these technologies to address complex decision-making problems. The DSS landscape is missing an environment to create a *DSS Generator* that integrates requisite technologies flexibly and quickly in order to construct a robust application.

We discuss the notion of an integrated decision technology environment (IDTE) in the context of Federal acquisition and contracting. Specifically, we show 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 that contracting personnel evaluate proposals both consistently and fairly for simplified acquisition procedures (SAP).

The proposed system, Source Selection Support System (S^4), integrates several decision-support technologies: a weight-based ranking model, a multi-criteria decision analysis software system, an expert system, data mining, and a data warehouse. We describe the data, model, knowledge, and user interface components of S^4, present a use case, and show how virtualization technology can facilitate the implementation of this DSS. We conclude by discussing how this approach can be generalized to embrace a fuller portfolio of decision technologies, which can, in turn, address a wider array of more complex contracting applications.

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II. Integrated Decision Technology Environments (IDTE)

A decision technology refers to a software system that is deployed to help one or more humans in a decision-making process. For example, neural networks can be used to assist humans in pattern recognition applications, such as target identification or signal processing; optimization models can be used to guide manpower planners where to best locate recruiting stations; and expert systems can facilitate non-experts in diagnostic-based tasks, such as tank or aircraft maintenance.

A. Decision Technology Taxonomy

Decision technologies are often categorized as data-driven, document-driven, model-driven, knowledge-driven or communication (collaboration)-driven (Power, 2004). Figure 1 shows a high-level taxonomy of decision technologies classified in this way. It should be noted that this classification is somewhat arbitrary in the sense that some technologies can be considered members of multiple classes. Combat simulations, for example, are model-driven in structure but are used in war game exercises that are collaboration-driven and may, in turn, result in lessons learned that are knowledge-driven. Nevertheless, the taxonomy provides a useful foundation for thinking about decision technologies.

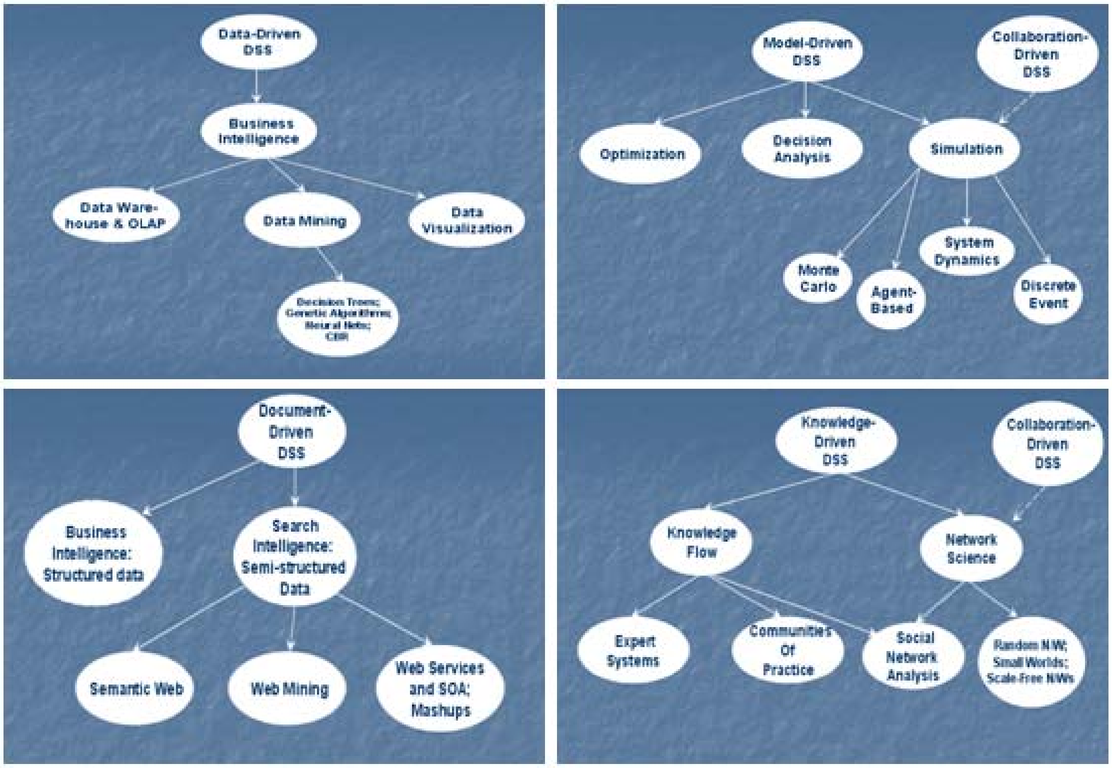

Figure 1. High-level Decision Technology Taxonomy

B. DSS Generators

DSS Generators are environments consisting of one or more software tools that help developers design and implement decision-support systems. The most familiar example of a DSS Generator is the typical spreadsheet, which can serve as a foundation for multiple kinds of financial simulations and augmented by add-in software capabilities—models such as regression forecasting and linear programming optimization.

Despite the versatility and utility of spreadsheets, they constitute a low-level medium for building decision technologies, akin to assembly programming in the software engineering world. Bhargava, Sridhar, and Herrick (1999) identify and demonstrate alternative DSS Generators in the form of standalone software systems for performing decision analysis. There are literally hundreds, if not thousands, of such proprietary systems that can be deployed for specific decision-oriented applications as represented in Figure 1.

Although the DSS Generators identified above represent significant advances over the native spreadsheet, they still work within relatively narrow scopes. Each system addresses only a fraction of the overall decision technology domain. Decision analysis software cannot do agent-based simulation; agent-based simulation software cannot typically do optimization; optimization software cannot do neural network analysis, and so on. This stove piped landscape artificially restricts the deployment of such DSS Generators in the service of more complex decision-making situations that require multiple decision technologies.

C. IDTE as DSS Generator

Not all decision support applications can be neatly compartmentalized into a single decision technology. We present two scenarios that would require a portfolio of decision technologies to arrive at effective solutions.

Scenario 1: Supply Chain Management

A typical, simplified supply chain process might consist of identifying demand for a single product, manufacturing the product in sufficient quantities to meet demand, forecasting inventory requirements, distributing the manufactured product to existing warehouses around the world, and pricing the product. The required associated decision technologies might consist of an econometric forecasting model for predicting demand, a discrete event simulation for modeling the manufacturing process, a queuing model for inventory prediction, a trans-shipment optimization model for specifying the distribution schedule, and a Monte Carlo risk model for determining the product price. In the current DSS Generator world, each of the five models described above would likely be developed in a separate software environment with little or no interplay.

Scenario 2: Emergency Response Planning

Planning effective emergency response policies for a bio-terrorist attack on a major city or event might require a simulation war gaming environment involving players from the agencies likely to be engaged in such a scenario. A realistic simulation would require coordination of an epidemiological model for tracking the spread of the bio-agent in the populace, a qualitative model for gauging the psychological "mood" of the populace given the status of the epidemic, and a traffic model for simulating the evacuation of the populace at different levels of panic. The required associated decision technologies might consist of a model of a system of differential equations for tracking the diffusion of the bio-agent, an agent-based simulation for measuring the psychological profile of the population, and a discrete event simulation traffic model. Again, with current DSS Generator technology, there is no single system or environment for building such a system without developing it from scratch.

The objective of an integrated decision technology environment (IDTE) is to provide capabilities for storing, retrieving, and integrating "standalone" DSS Generators into more complex chains in order to address more complex decision scenarios such as those described above. We see this as having the dual benefits of broadening the utility of these individual DSS Generators in concert with broadening the power and reach of the DSS Generator paradigm. In its most general form, this is a very daunting challenge, and we accordingly want to begin with relatively simple and structured applications. In the next section we describe such an application from the acquisition and contracting domain.

III. Acquisition and Contracting Domain

A. Lifecycle

As shown in Figure 2, 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 concepts and technologies can be employed throughout several stages of the overall process to assist contracting officers and other government acquisition professionals.

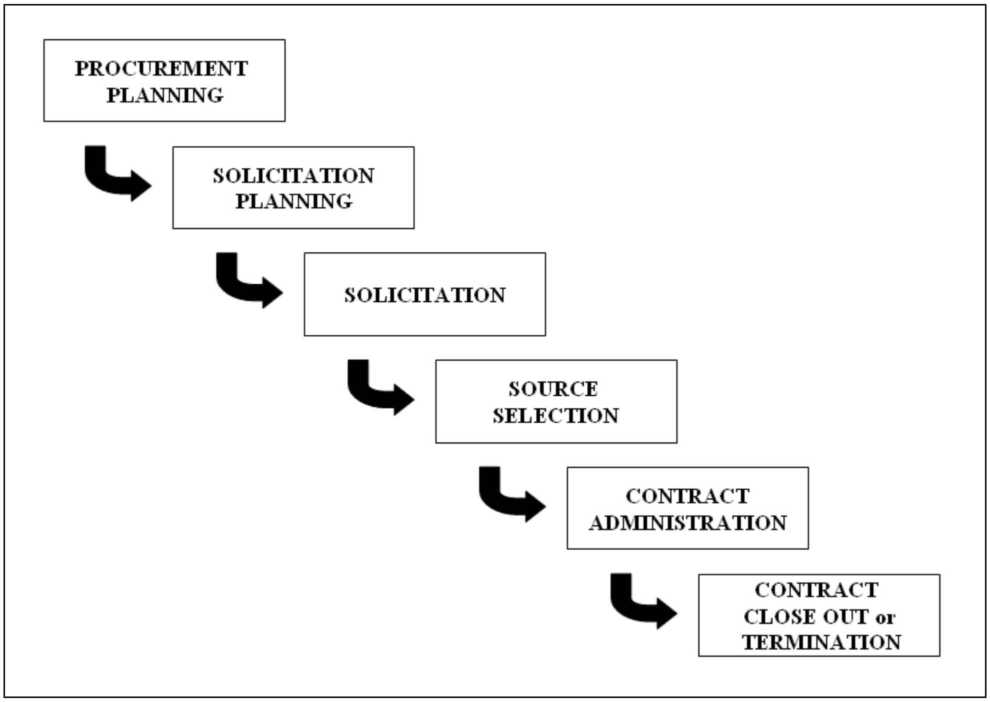

Figure 2. The Government Procurement Process

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 meant 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 best overall proposal to 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 a contractor. In certain contract types, contractor performance may also impact how much profit the contractor earns on a 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.

B. Types of Procurement

The federal government utilizes three major methods of procurement: 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*.

1. Sealed Bidding

Sealed bidding involves evaluating bids on a competitive basis, 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.

2. 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.

3. 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.(*FAR*, 2008, Part 13).

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

C. 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.

Numerous evaluation factors may be considered when selecting a source. Obviously, cost is a necessary consideration 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 in which 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 when 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. However, as with every rule, there are exceptions; the acquisition objective remains that small businesses are to receive any contract in which 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. The disadvantaged business set aside program is similar in 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.

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, it must be owned and controlled by United States citizens, it must have its principal office located in the HUB Zone, and have at least 35 percent of its employees residing in the HUB Zone.

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.

IV. Source Selection Support System (S^4)

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 3. The various components of the DSS are discussed in detail in the sections below.

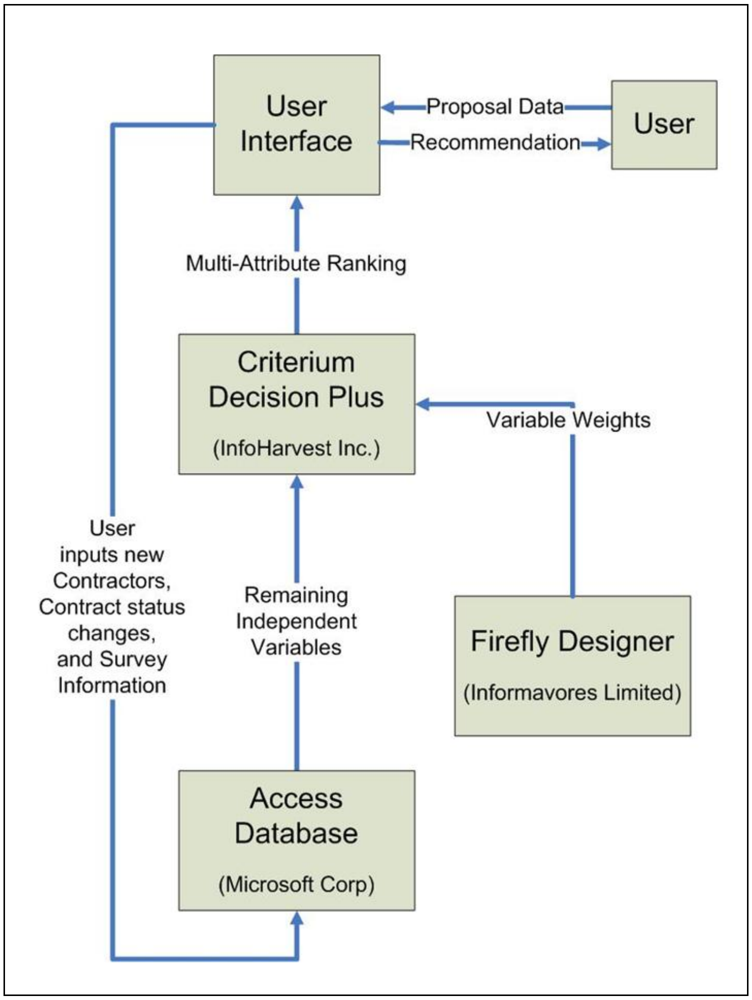

Figure 3. Integrated Decision Technologies for S^4

A. Model

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. 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 criteria to be applied to the ranking of the set of competing contractors.

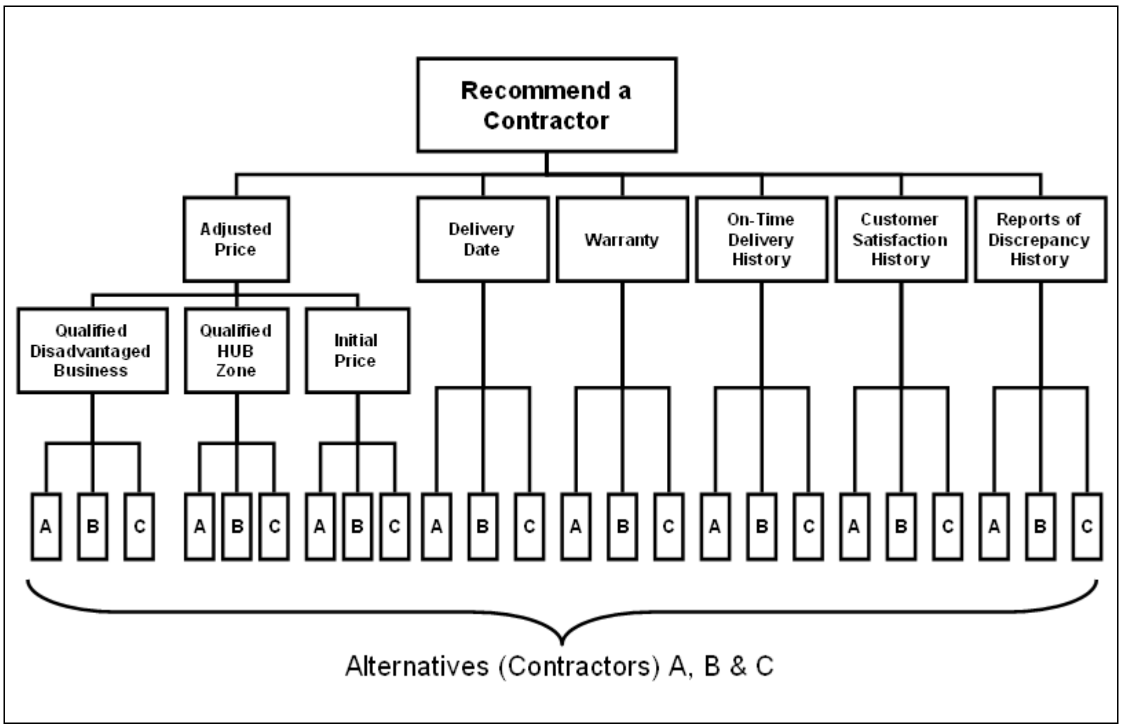

Figure 4. The S^4 Analytical Hierarchy Process Diagram

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 of course be incorporated into the model, but these aforementioned six variables are important criteria in any SAP contract award.

Table 1 lists each variable and the computation for calculating its value. We describe each variable in detail below.

Independent Variable Name	*Equation*	*RHS Variables*
Disadvantaged business price adjustment	$PA_{DIS} = P_I * (AP_{DIS})$	$P_I =$ Initial Proposal Price $AP_{DIS} =$ Disadvantaged business price adj. %
HUB Zone price adjustment ($)	$PA_{HUB} = P_I * (AP_{HUB})$	$P_I =$ Initial Proposal Price $AP_{HUB} =$ HUB Zone price adj. %
Delivery Date score	$S_{DD} = 1 - \left(\frac{D_{IND} - D_{LOW}}{D_{LOW}} \right)$	$D_{LOW} =$ No. of days from expected contract award date to earliest promised delivery date $D_{IND} =$ No. of days from expected contract award date to this individual contractor's promised delivery date
Warranty score	$S_W = 1 + \left(\frac{W_{IND} - W_{HIGH}}{W_{HIGH}} \right)$	$W_{HIGH} =$ No. of months of coverage longest warranty offers $W_{IND} =$ No. of months of warranty coverage offered by this individual contractor
Customer Satisfaction score	$S_{CS} = \left(\frac{\sum S_{IS}}{n} \right)$ *for all* S_{IS}	$S_{IS} =$ Avg score for each individual survey filled out for this contractor $n =$ No. of contracts for this contractor for which a customer satisfaction survey has been submitted
On-time Delivery Percentage score	$S_{OT} = \frac{N_{OT}}{n}$	$n =$ No. of govt contracts awarded to this contractor $N_{OT} =$ No. of govt contracts this contractor has fulfilled on time.
Report of Discrepancy (ROD) percentage score	$S_{ROD} = 1 - \left(\frac{N_{ROD}}{n} \right)$	$n =$ No. of govt contracts awarded to this contractor $N_{ROD} =$ No. of govt contracts awarded to this contractor for which a ROD was submitted.
Price score	$S_P = 1 - \left(\frac{(B_I - AP) - RB_{LOW}}{RB_{LOW}} \right)$	B_I = Initial bid amount RB_{LOW} = Lowest revised bid (i.e. after application of price adjustments) AP = Total price adjustment
Overall acceptance score for a particular contractor's bid	$S_{TOT} = \Sigma_X (W_X * S_X)$	W_X = % weight assigned to variable X S_X = Score assigned to variable X

Table 1. Decision Variables for S^4 AHP Model

1. Decision Variable: 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, which is used to retrieve individual contractor's relevant information from the database. New contractors can be added to the database at any time.

2. Independent Variables

i. 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' 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 10 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 retrieves 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 amount (PA_{DIS}) as shown in Table 2.

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 2. Example Disadvantaged Business Price Adjustment Calculation

The price adjustment is applied to all qualifying contractors, regardless of the difference in price. 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.

ii. 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, it must have its principal office physically located in the HUB Zone, and it must 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 amount (PA_{HUB}), as shown in Table 3.

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

Table 3. Example HUB Zone Business Price Adjustment

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 the difference in 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.

iii. 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 shown in Table 4.

Expected Contract Award Date: 7/1/2008				
Company	Delivery Date	D_{IND}	$1-\left(\frac{D_{IND}-D_{LOW}}{D_{LOW}}\right)$	S_{DD}
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 4. 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.

iv. 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 shown in Table 5.

Company	W_{IND}	$1+\left(\frac{W_{IND}-W_{HIGH}}{W_{HIGH}}\right)$	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 5. Example Warranty Score Calculation

v. 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 shown in Table 6.

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 6. Example Customer Satisfaction Score Calculation

vi. On-time Delivery Percentage

This variable measures the percentage of government contracts the contractor has won in which 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 shown in Table 1.

vii. Report of Discrepancy (ROD) Percentage

Reports of Discrepancy are complaints against a contractor, filed by a customer, on a federal government contract. They can result from the wrong product received, the wrong service performed or 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 shown in Table 7.

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

Table 7. Example ROD Percentage Score Calculation

3. Dependent Variables

i. 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 shown in Table 8.

Company	B_I	AP	B_I - AP	$1-\left(\frac{(B_I - AP) - RB_{LOW}}{RB_{LOW}}\right)$	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 8. Example Price Score Calculation

ii. Overall Acceptance score

This goal variable is 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 shown in Table 1.

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.

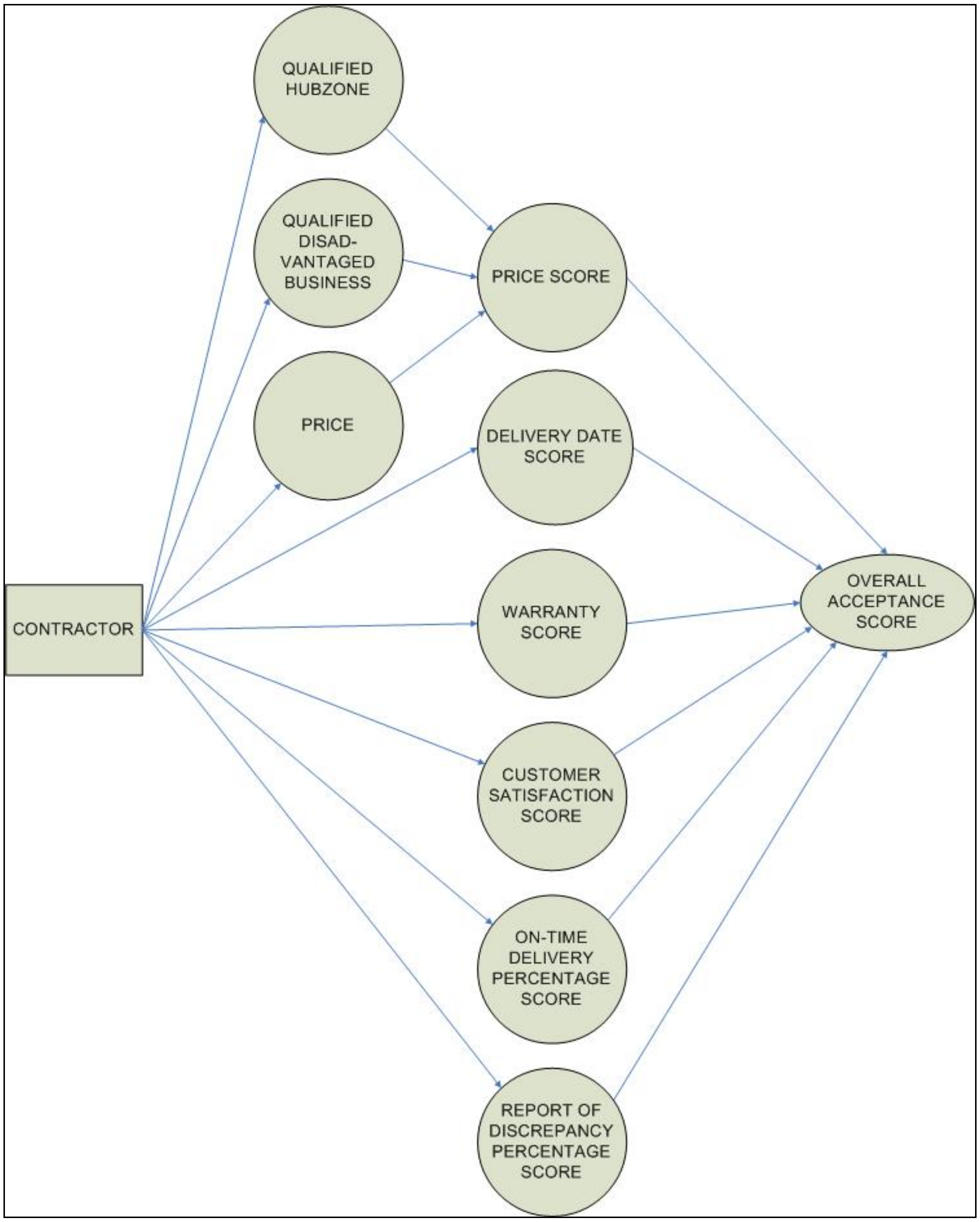

Figure 5. Source Selection Support System Influence Diagram

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 9 (note that the lower limit for delivery date score is 0).

Expected Contract Award Date: 7/1/2008				
Contractor	Delivery Date	D_{IND}	$1-\left(\frac{D_{IND}-D_{LOW}}{D_{LOW}}\right)$	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 9. Delivery Date Scores for Example Scenario

The scores on all variables for each contractor are listed in Table 10.

		Contractor A		Contractor B		Contractor C	
Variable	Weight	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 10. 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 in which that constraint cannot be incorporated into the request for proposal.

B. Knowledge

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 11.

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 11. 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. In this situation, delivery date should clearly 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 12.

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 12. 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, then 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 in which 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 scenario. 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 to accommodate other variables.

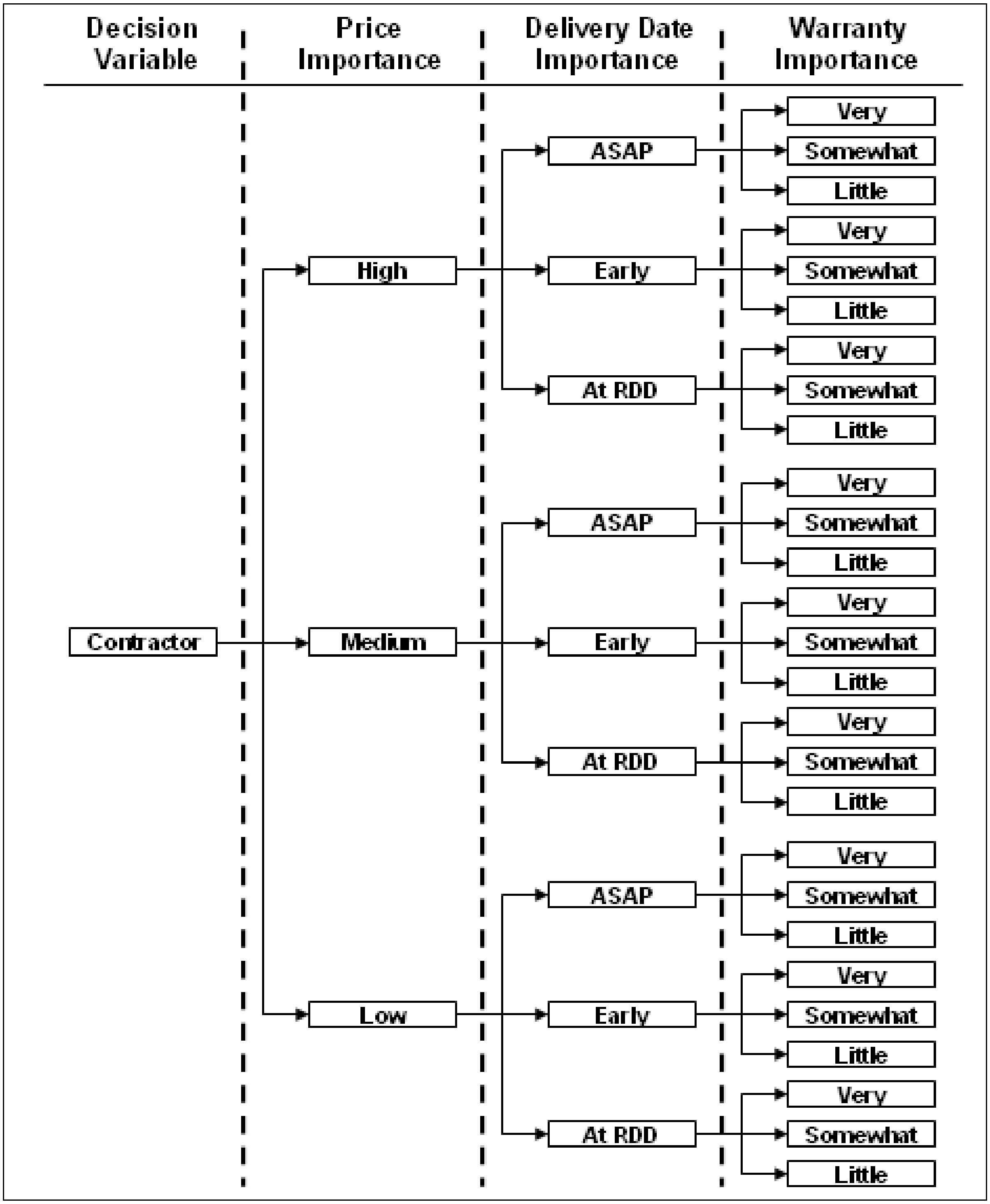

Figure 6. Portion of Sample Decision Tree

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. 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 budget limitations that 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 the range in which the contract's expected price will fall, it then proceeds to the next variable—Delivery Date. In this decision tree, there are three scenarios for Delivery Date:

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

ii. 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 it is not to the point that it matches the Delivery Date score weight for a mission-critical item.

iii. 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 their need 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 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 such 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

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.

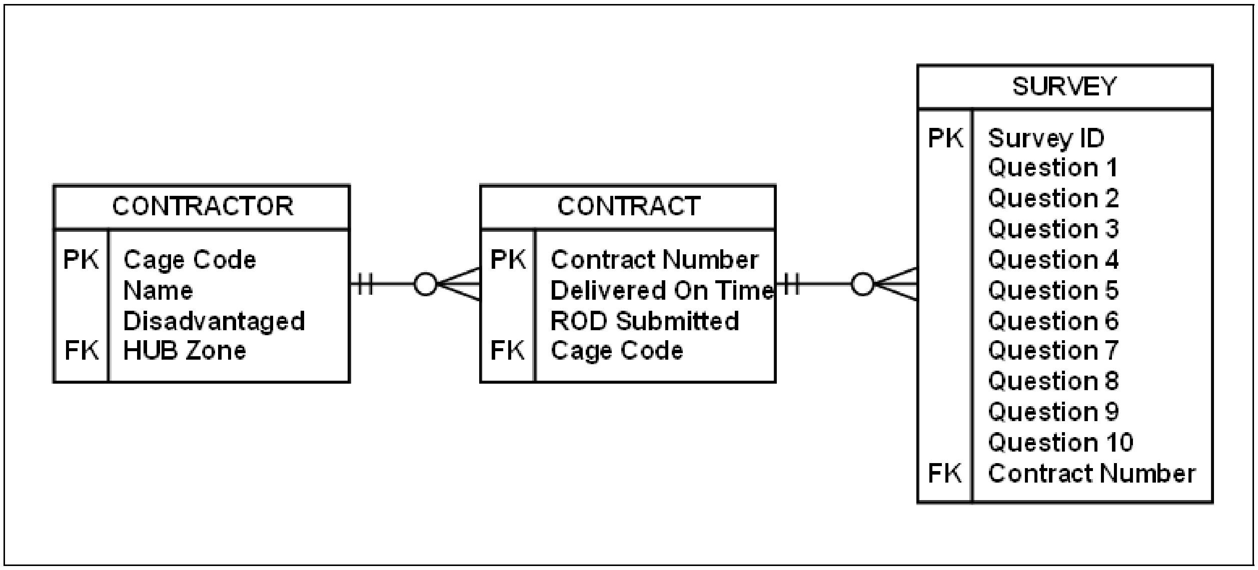

Figure 7. Data Warehouse Entity-relationship Diagram

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 10 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 contracting officers are already looking at it on their screens, 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 completed survey. 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" (Two Crows Corporation, 2005). 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 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 an 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.

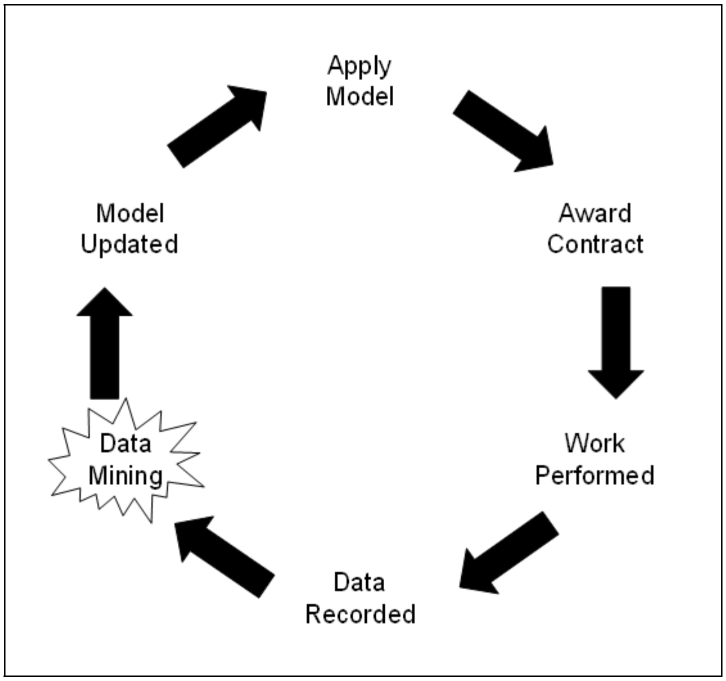

Figure 8. System Feedback Loop

D. User Interface

The 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 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 users wish to evaluate a set of proposals, they select this option from the main menu. The next step is to calculate the variable weights. In determining the weights for the variables, users 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, users search the data warehouse for the contractors from whom 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, user will be prompted to do so at that time. Users then enter the remaining required data directly after reviewing each contractor's proposal. For each proposal, users will have to input the price, delivery date, and warranty length.

If users wish to perform any database management tasks, they select this option from the main menu. Users have access to all three tables of the database and can insert or modify records as necessary. That is, with respect to the Contractor table, users will be able to add new contractors or modify a contractor's status (disadvantaged business and/or HUB Zone). Users will also be able to update records in the Contract table. Although the system records a new contract once users accept the recommendation (assuming the recommendation is accepted), users will still need to update the contract record with on-time delivery and ROD data. Users may also need to insert a new contract in the table in the event they do not accept the recommendation of the decision-support system, thus this capability will be included as well. Finally, users 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 9. There are branches from the main menu for the two primary activities.

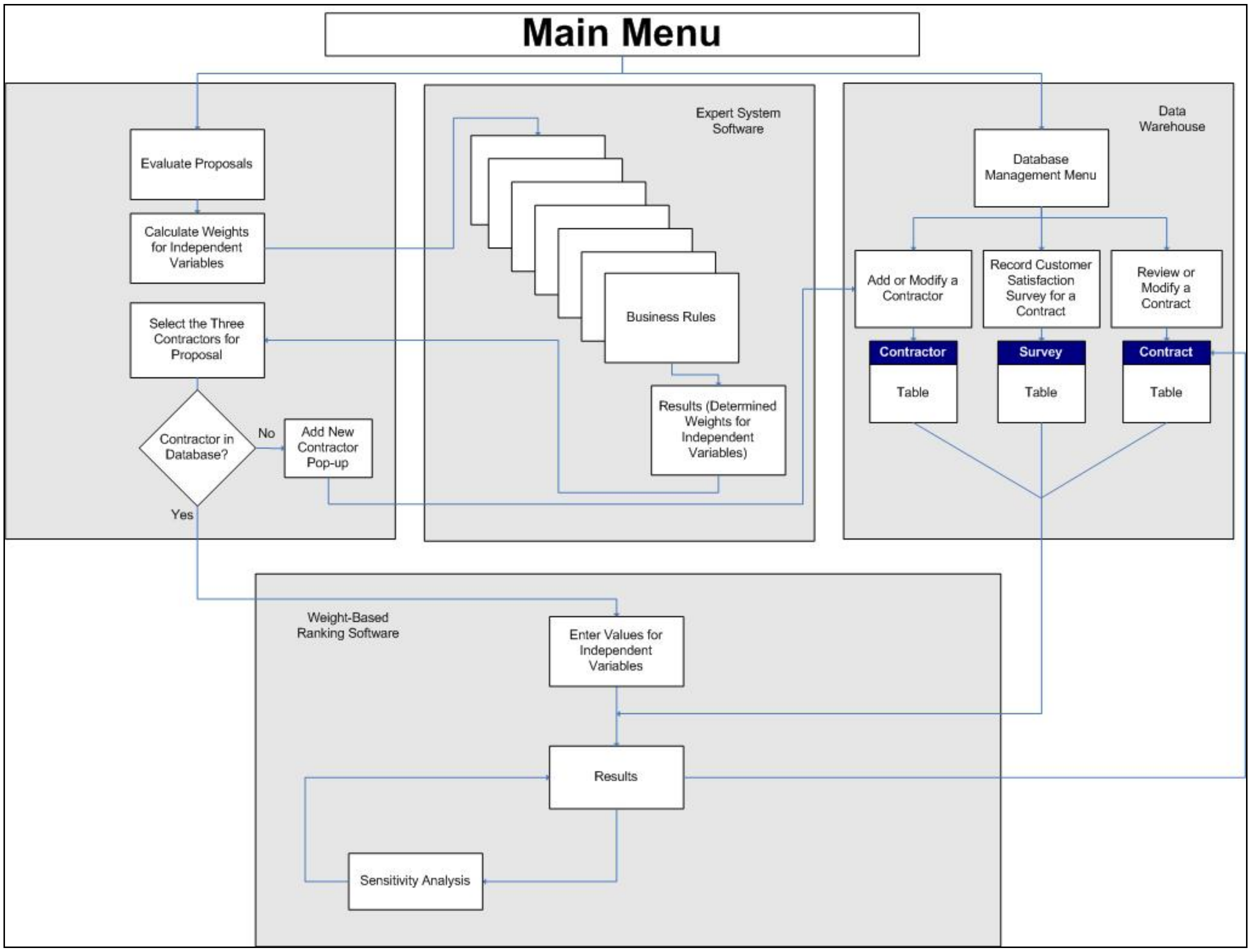

Figure 9. User Interface Navigation Schema

E. Implementation via Virtualization

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 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 workstation. 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" (Mann, 2007). Essentially, virtualization allows multiple individual workstations to access the same resource housed by a single physical resource. This virtual relationship is shown in Figure 10. 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 10. Virtualization Environment for the Source Selection Support System

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 realizable benefits from virtualization include improved security, reduced downtime, increased ability to achieve service levels, accommodation of legacy systems on new hardware without major upgrades, and better conduciveness to location and staff mobility issues.

V. Conclusions and Future Research

We have shown in this paper how to apply integrated decision technology to the Source Selection phase of Simplified Acquisition Procedures. The S^4 prototype combines decision analysis using the analytical hierarchy process in concert with a decision tree for determining weights to build a consistent evaluation and ranking system for SAP proposals (Figure 4). Data warehouse, OLAP and data mining systems can store and analyze historical data accrued through usage of such an integrated system. Virtualization environments can be leveraged to deploy an operational version of this system in a flexible and compact manner with respect to software and hardware resource allocation. We contend that the IDTE DSS Generator broadens the feasible space of cost effective decision-oriented applications in a way that transcends current, stand alone systems.

A. Limitations of S^4

We envision S^4's major benefit to be a consistent and defensible SAP contract award process, packaged in a resource-efficient way. However, were S^4 to be operationalized, its acceptance and subsequent adoption by the user community cannot be assumed. DSS can meet resistance from users if they perceive that their decision autonomy is being co-opted by the system. Thus, a pilot study would be advisable before undertaking actual implementation.

B. Future Research for the IDTE DSS Generator.

S^4, as described above, was developed in a customized way rather than using any generalized system integration interface. In order to more fully realize the economies of scale of an IDTE DSS Generator approach towards system development, an environment for linking and coordinating standalone systems is desirable (e.g., see Muhanna & Pick, 1994). This is a promising area of future research, which we are conducting at Naval Postgraduate School as part of our IDT Laboratory project. Inherent in any integration undertaking, however, is recognition of the limitation that full automation of any integration process is rarely either possible or desirable. Human interaction is an indispensable component that must be engineered into the process.

C. Extending the Decision Technology Portfolio for Acquisition and Contracting

The S^4 proof of concept looks at a relatively narrow and well-structured piece of the contracting lifecycle, requiring only a small subset of decision technologies. We envision acquisition and contracting in the large as a fertile domain for extending the IDTE concept, as shown in Table 13, for the various lifecycle stages shown in Figure 2. 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. 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.

CONTRACTING LIFECYCLE STAGE	DECISION TECHNOLOGIES
Procurement Planning	Data mining; Multi-criteria decision analysis; Decision trees; Influence diagrams
Solicitation Planning	Expert system
Solicitation	Agent-based search
Source Selection	Decision analysis (AHP); Decision tree; Data mining; Risk analysis
Contract Administration	Text mining
Contract Closeout and Termination	Data mining
Overall Process	Simulation (agent-based; discrete event); Data warehouse and OLAP

Table 13. Relevant Decision Technologies for Contracting Lifecycle.

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 a given contract. Once again, multi-criteria decision analysis can be used to assist acquisition personnel. Contractors can be evaluated on specific performance criteria (e.g.,cost control, schedule management, etc.) in order to make overall past performance determinations.

The overall process requires data warehouse and attendant on-line analytical processing (OLAP) capabilities for data collection and multi-dimensional reporting at all stages. Simulation is also a valuable process-driven decision technology for modeling large, complex processes and their associated project management.

In summary, no single decision technology is sufficient to address the high levels of complexity that characterize large-scale acquisition and contracting applications. An environment that provides a portfolio of such services in ways that can be easily integrated and deployed is a more flexible approach for addressing the decision problems in this critical domain.

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