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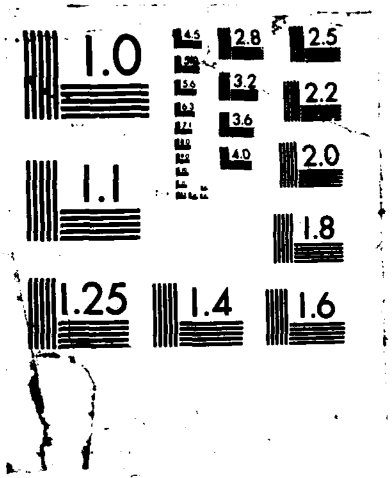
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DECISION ANALYSIS APPLIED TO AN AIR FORCE ORGANIZATION PROBLEM

THESIS

William T. Sorensen
Captain, USAF

AFIT/GLM/ENC/87S-71

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DECISION ANALYSIS APPLIED TO AN AIR FORCE ORGANIZATION PROBLEM

THESIS

Presented to the Faculty of the School of Logistics
of the Air Force Institute of Technology
Air University
In Partial Fullfillment of the
Requirements for the Degree of
Master of Science in Logistics Management

William T. Sorensen
Captain, USAF

September 1987

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William T. Sorensen

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Abstract

This study investigated the application of decision analysis to a problem involving choices between various military organizational structures. The office involved in this study was the Program Control Directorate of the Propulsion System Program Office, Aeronautical Systems Division, Wright-Patterson AFB, ~~Ohio~~.

The research goal was to evaluate different organizational structures and to determine the optimal alternative. The decision analysis methodo~~logy~~ applied is comprised of three phases: deterministic, probabilistic, and informational. The deterministic phase structured the problem, the probabilistic phase incorporated the uncertainty associated with the decision problem and determined the optimal alternative, and the informational phase determined the associated utility of obtaining information to reduce uncertainty. Through this methodo~~logy~~, the decision-maker was assisted in determining a best logical alternative. The end product was a decision-maker who ~~that~~ thoroughly understood the decision problem, knew his optimal alternative, and possessed a model that shows the logic by which the optimal alternative was determined. ([illegible])

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DECISION ANALYSIS APPLIED TO AN AIR FORCE ORGANIZATION PROBLEM

I. Introduction

Background

The process by which man makes a large number of decisions is intuition. Intuition is used to balance a decision-maker's choices, information, facts, and preferences to arrive at a course of action. One problem with intuition is that its logical sequence of events is not verifiable. Also, our intuition is frequently not consistent with our information and preferences. In other words, there is no way of checking whether a decision is a logical consequence of the alternatives, information, and preferences possessed by the decision-maker. One of the goals of a decision analyst is to assess the decision-maker's alternatives, judgement, and preferences, quantify them and place them into programmatic form so that logic can be applied to them (3:7).

Decision analysis has established itself in the last twenty years through combining aspects of systems analysis and statistical decision theory. Systems analysis grew as a branch of engineering whose strength was consideration of interactions and dynamic behavior in complex situations. Statistical decision theory was concerned with how to be logical in simple uncertain situations. When the concepts are merged, they help us to be logical in complex, dynamic, and uncertain situations; this is the province of decision analysis (3:7).

The technique of decision analysis has been applied to a wide variety of decision problems. Those decision problems were in such areas as investment and strategy planning, research and development, and social planning. Examples of analyses in each of these areas are: An Inside View: Analyzing Investment Strategies (2), Evaluating Basic Research Strategies (9), and Saturn/Apollo and Beyond (8) Space Projects.

Decision analysis elicits the alternatives, information, and preferences of the decision-maker to assist him in determining the best logical alternative.

The decision analysis cycle used in the decision analysis approach is made up of three phases: deterministic, probabilistic, and informational phases (3:9). The deterministic phase is concerned with the basic structuring of the decision. The structuring process involves establishing the decision-makers' alternatives (decision variables) and relevant outcomes (random variables) of the decision problem and assigning values to each possible combination of alternatives and outcomes. This assigning of values is in the form of a mathematical model. The relative importance of the different variables is determined through sensitivity analysis (14:132).

Uncertainty is incorporated during the probabilistic phase by assigning probability distributions to the important random variables in the decision problem. The distributions are incorporated into the model to capture the uncertainty of the final outcome. After the decision-maker's risk preference has been determined and taken into account, the best alternative in the face of uncertainty can be calculated (14:133).

Finally, the informational phase determines the value of further reducing uncertainty in each of the important random variables (14:133). The value of additional information is compared to the cost of obtaining it. If the cost of obtaining additional information is favorable, the three phases are repeated again. The analysis is complete when the cost of obtaining additional information is no longer favorable.

This thesis addresses the decision to restructure the organization of the Program Control Office (YZP) in the Propulsion System Program Office (YZ) of the Aeronautical Systems Division (ASD) at Wright Patterson Air Force Base. YZP, a subordinate component of the matrix organization ASD Comptroller (AC), is responsible for the financial management of the various engine programs within YZ.

The following background description of YZ and YZP organization is based on my four years of working experience in YZP (having worked in every YZP division) and from the data contained in the YZP Orientation Book (18). An organization chart of YZ is depicted in Appendix A.

Deputy for Propulsion (YZ) Mission Statement. The Deputy for Propulsion manages (plans, organizes, coordinates, controls, and directs) the life cycle acquisition activities for Air Force aircraft gas turbine engines, including appropriate engine deployment efforts, in association with other system program offices (SPOs), Air Force Logistics Command (AFLC), and the user commands that actually use the engines (TAC, SAC, ATC, etc.). YZ serves as the Air Force focal point for all matters pertaining to Air Force aircraft gas turbine engines and interfaces with other services on items of joint interest. YZ proposes and/or prepares modifications of, or changes to engine programs within the limits of guidance received. YZ establishes propulsion requirements and considering existing engines, upgrading of existing engines and new engines, translates these requirements into integrated hardware. YZ provides management, procurement, and engineering support for engines transferred to AFLC when required by joint Air Force Systems Command (AFSC)/AFLC agreements, and for engines assigned to other services when required by inter-service agreements.

YZ manages the engine component improvement program (CIP) for assigned engines and provides CIP policy and guidance for all Air Force engines, coordinates overall CIP planning and funding with Army and Navy to assure proper support for Air Force engines, and manages the Engine Model

Derivative Program (EMDP), Alternate Fighter Engine (AFE) and Increased Performance Engine (IPE) programs.

Directorate of Program Control (YZP) Mission Statement. The Director of Program Control (YZP) is responsible to the Deputy Commander and his staff for all financial and resource management functions on assigned programs. The functions of YZP are planning, scheduling, cost analysis, budgeting, and analyzing. The planning process consists of describing and assigning tasks so that all participants will mutually understand who is responsible for each acquisition action. Scheduling develops and maintains a Master Schedule which incorporates all of the sub-schedules that are needed to fulfill the requirements of the Program Management Plan. The Cost Analysis function includes the estimating of program cost to serve as a basis for justifying financial requirements included in the Program Objective Memorandum (POM)/Budget Estimate Submission (BES). It also performs the program cost/schedule evaluation through trend analysis of data reported by the contractors' cost/schedule control system. Budgeting includes the programming and financial management. The programming aspect refers to entering a weapon system cost into a Five-Year Defense Plan package within the POM. Analyzing provides the program manager with the accurate analysis of the data he needs to direct the program, as well as to report program status.

There are three divisions within YZP: the Engine Interface Division (YZPI), the Resource Management Division (YZPR), and the Plans and Integration Division (YZPP).

Engine Interface Division (YZPI). The responsibilities of the financial managers assigned to YZPI fall into four broad categories of budget formulation/pricing submissions, funds execution, reporting and tracking funds, and participating in financial reviews and meetings. The financial manager provides all financial management for his/her assigned engine program(s) except cost estimating and analysis, which is performed by the assigned analyst(s) in the estimating & evaluation branch of the financial management division (YZPRE). In addition, he/she is the primary program control focal point to the engine program manager, to the weapon system SPO, and the engine contractor on program control matters.

This division provides financial management for those ASD engines which are installed in aircraft/weapon systems managed by SPO's other than YZ. As a result, most financial inputs/submissions flow through the weapon system SPO for their consolidated submission to higher headquarters.

The primary branches in YZPI are: the branch responsible for USAF Tactical engines (YZPIT), and the branch responsible for the USAF Strategic, Airlift, and Trainer engines (YZPIS).

Resources Management Division (YZPR). YZPR is made up of two branches: the Financial Management Branch (YZPRF) and the Estimating and Evaluation Branch (YZPRE). The Resources Management Branch (YZPRF) has total financial management, cost estimating, and analysis responsibility for YZ assigned engine programs that are directly funded by HQ AFSC. This branch manages the Air Force's CIP, EMDP, AFE, F100 Durability Engine, IPE, and Integrated Turbine Engine Monitor System (ITEMS) programs.

The Estimating and Evaluation Branch (YZPRE) provides cost estimates and analysis support for all YZ engine programs whose funding comes from other ASD SPO's. The cost analysts prepare estimates for special competition studies and other ad hoc source selections, independent cost analyses, and annual estimate reviews.

Plans and Integration Division (YZPP). The primary functions of YZPP are planning, reporting, and integration of program information. YZPP is the responsible source for all Program Management Plans, Program Management Directives, Program Management Responsibility Transfers, Memoranda of Agreement/Memoranda of Understanding. It also maintains the Master Integrated Schedules for the engine deliveries of the F-15 and F-16 fighter aircraft. This division is the focal point for the Automated Management System (AMS). The AMS includes: 13 dumb terminals, 74 Zenith personal computers, networking, software procurement, and computer training.

Engine Purchasing. Below is a simplified example of the procedures involved in an engine purchase. Figure 1 will assist the reader's understanding of the engine purchasing procedure. This example of an engine(s) acquisition is based on a program that is already in the Production/ Deployment Phase. The events and phases leading to the Production/Deployment Phase. The events and phases leading to the Production/Deployment Phase are briefly discussed and a more detailed explanation of the Production/Deployment Phase as it relates to the Propulsion SPO is then given to assist the reader in understanding one aspect of YZP's operations. The example to be described below includes the purchase of USAF production engines only. It does not include foreign military sales. Again, the events are intentionally simplified to give the reader an overall picture of how the YZ program control division operates.

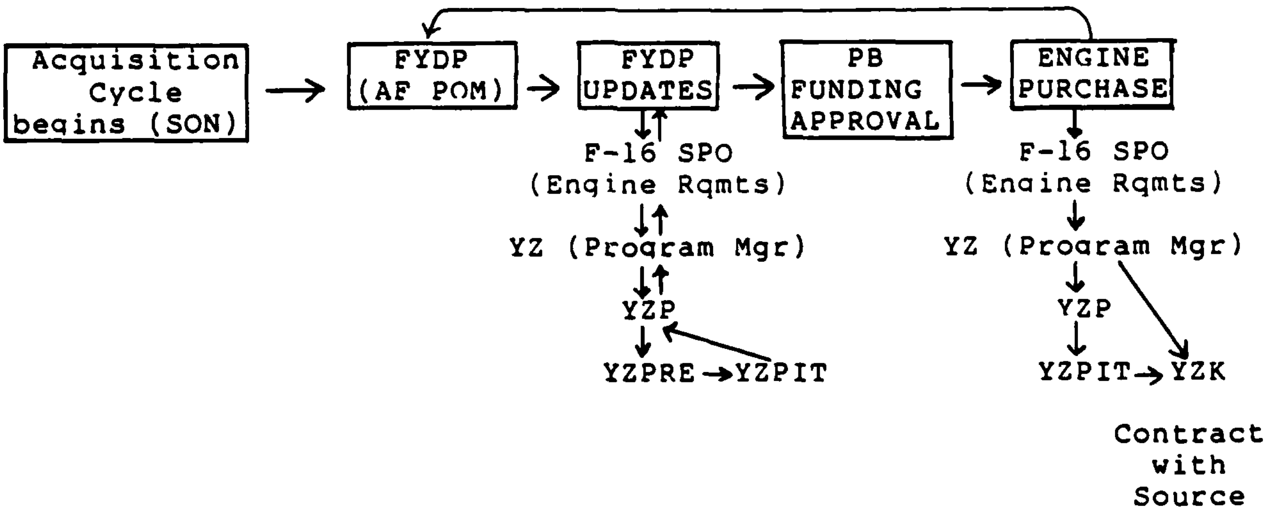


Figure 1. Engine Purchase Cycle

The events and phases leading to the Production/Deployment Phase begin with the operational requirements of a user command. The user command is that command which eventually uses the end product (in this example the user command is the Tactical Air Command and the product is the F-15 aircraft). The user command will identify an operational deficiency in terms of a projected deficiency, obsolescence in existing system, a technological opportunity, or an opportunity to reduce cost (10:13), and originate a Statement of Operational Need (SON). Once the SON has been validated at HQ USAF and the Justification for Major System New Start has been given, the program will proceed through the Concept Exploration Phase, the Demonstration/Validation Phase, the Full Scale Development Phase, and the Production /Deployment Phase.

The Concept Exploration Phase, initiated by the mission need determination, identifies possible alternatives to the deficiencies and examines costs, shcedules, support parameters, and performance parameters. The Demonstration/Validation Phase is responsible for primary system hardware prototyping. The goal of this phase is reducing technical risk and economic uncertainty (10:13). In the Full Scale Development Phase, the system, including all essential support equipment and documentation is designed, developed, fabricated, and tested (fighter engine is tested on the F-15 aircraft). The intended output is to produce a system for the operational inventory (10:15). The Production Phase begins when the USAF actually commits to the production of the F-15 weapon system. The Deployment Phase begins when the F-15's are deployed to and used by the user command.

Concurrently to the above process, the funds and personnel resources necessary to correct the stated deficiency (the SON) are obtained through the Planning, Programming, and Budgeting System (PPBS). The PPBS was developed to provide a systematic review of currently approved DOD programs as stated in the Five-Year Defense Plan (FYDP). The FYDP is the Defense portion of the President's Budget. The FYDP is a composite of the resource and funding requirements of the armed services and other DOD agencies (e.g. NASA).

Updates of the FYDP occur after major decision points in the planning, programming, and budgeting cycle. In May/June, an update is performed to reflect the Program Objective Memorandum trade-offs made by the services. In August/September, the update reflects program adjustments as a result of Program Decision Memorandum (PDM) decisions of the Secretary of Defense. The third update, in December/ January, reflects any changes coming out of the Office of Secretary of Defense/Office of Management and Budget (6:136).

The process of a POM update and its consequences on YZP's activity in the production/deployment phase is briefly discussed. The Air force POM represents the first time each command has an opportunity to state its individual requirements. The POM is the most important document to obtain funding for programs. "If it's not in the POM, it's not in the budget" (6:129).

For the purpose of explanation, consider an additional request has been made for an additional 50 F-15 aircraft to be delivered at some future date. The F-15 SPO program manager is required to determine the additional costs associated with the procurement of 50 additional F-15s. One of the many price components of the F-15s is the F100-PW-220 engine. The F-15 SPO program manager directs the F100-PW-220 engine program manager to perform a "what if" exercise to determine the additional cost and delivery schedule associated with the procurement of 100 additional F100-PW-220 engines (two engines for every aircraft). The engine program manager contacts the various functionals (YZP, YZK, YZE, etc.) so they can perform their appropriate estimates. The YZP director transmits the engine program manager's request down the chain of command. YZPRE and YZPIT eventually receive the request. YZPRE performs the engine cost estimate based upon USAF/Pratt & Whitney approved pricing matrix. The pricing matrix basically calculates the unit price of an engine based on the formula, the larger the total cumulative number of engines bought, the lower the unit price of the engine. Once the estimate has been determined, YZPRE transmits this information to YZPIT. YZPIT then takes the estimate, coordinates the estimate with the engine program manager and the appropriate parties in YZP, and then submits the estimate to the F-15 SPO for incorporation into the F-15 estimate and is placed in its POM.

Assuming all goes well, the President's Budget is signed and program funding is approved. The F-15 SPO can now move out and buy the additional F-15 aircraft. The F-15 SPO sends a letter of notification of congressional direction for the additional engine purchase to YZPIT. The SPO will also cite its budget authority for purchasing the engines. YZPIT then writes a Purchase Request (PR) (an instrument that commits the USAF monies to procuring the engines) and when the PR comes back approved from the ASD accounting and finance office, it is given to the appropriate personnel in the contracts office (YZK). YZK personnel, with legal tender in hand (in the form of an approved PR), can now place the acquisition of the additional 100 F100-PW-220 engines on contract with the prime contractor, Pratt & Whitney.

Specific Problem

ASD/AC directed ASD/YZP to establish a new separate and distinct estimating division. AC also notified YZP that YZP would have to eliminate one of its GM-13 positions. This thesis problem was directed to assisting the YZP Directorate in choosing the best organizational alternative, while accomodating the AC directive. The decision-maker in this problem is Mr. Clyde Wethington (19), Director of Program Control (YZP). Mr. Wethington will be making the final decision on the organizational restructuring issue, including scope of restructuring and time schedules for implementation, if any. The focus as a decision analyst is to help the decision-maker make his/her decision.

Purpose/Objectives

The objective of the decision analysis is to assist the decision-maker, Mr. Clyde Wethington, to better understand his decision problem so that he can confidently choose the optimal alternative.

Subobjective

The subobjective was to perform a literature review to discover the areas where decision analysis had been applied in the past, and to determine whether this thesis was a novel application of decision analysis. It appears that decision analysis has not been applied to a problem involving choices between various organizational structures.

Limitation of Scope

This decision problem is unique. The values, alternatives, and preferences, etc. are those of the subject decision-maker. The recommendations from this analysis should be considered applicable only to his organization. Due to time constraints, this decision analysis was performed at the pilot model level. The pilot model is a simplified yet comprehensive representation of the problem.

II. Methodology

Overview

The decision analysis methodology was used to assist the YZP Director in deciding the appropriate organizational structure for his directorate.

The decision analysis cycle is the process by which a mathematical model, representing the decision-maker's very best knowledge and preferences about a unique, uncertain, complex decision, is developed and analyzed to give the decision-maker insight into his decision problem. This cycle uses a three-phased (deterministic, probabilistic, and informational), iterative cycle. The end product of the decision analysis cycle will be a decision-maker that thoroughly understands his decision problem, knows his optimal alternative, and possesses a model that shows the logic by which that optimal alternative was determined. The analyst works closely with the decision-maker and his experts, through personal interviewing, to elicit information which is incorporated into the model.

Deterministic Phase

The first step in the process was to specify the decision to be made; to delineate and bound the decision problem. The decision-maker and the analyst decided that the decision-maker and his experts (division and branch chiefs) would assist in describing and defining, precisely, the alternatives to the decision problem. Interviews were conducted in private on an informal one-on-one basis with and without the use of a tape recorder. This was done to eliminate potential group pressure and to insure the process was responsive to the people being interviewed. The preferences of the subject(s), on whether to have the interview sessions recorded or not, were always accomodated. The interview process was an adaptation to the technique employed by Spetzler and von Holstein (13:618). All interviews were given using the following four-phase approach.

1. Motivating - Rapport with the subject was established and possible motivational biases explored.

2. Structuring - The structure of the decision was defined.

3. Questioning - To elicit organizational structure ideas, new or existing, the subjects were questioned for their attitudes of possible organizational alternatives.

4. Verifying - The responses obtained in the interviews were reviewed with the subject to ensure that both the analyst and subject arrived at the same meaning and explanation of the alternatives.

Alternatives were also elicited from the decision-maker, and the potentially new alternatives were discussed. In total there were six different organizational alternatives proposed. The decision-maker chose not to examine those organizational alternatives politically undesirable or non-implementable. Those alternatives chosen offered the greatest potential of implementation.

The next step was the identification of outcomes which sufficiently described the results of the decision problem. An outcome is that information which the decision-maker would like to have known, in retrospect, to determine the consequences of the decision problem (16).

Value modeling was then performed on the outcomes. Value modeling assigns numerical values to all combinations of alternatives and outcomes in terms of their desirability. These numerics are incorporated into the mathematical model.

Initially the analyst planned to accomplish the value modeling by attaching a dollar value to each combination of alternatives and outcomes to give an accurate measure of their true value. However, the decision-maker involved in this effort stated several factors which made him uncomfortable with assigning such monetary values. By its nature, a military environment is a nonprofit organization. Military organizations are described in terms of effectiveness and efficiency, and not in terms of dollars. With this information at hand, utility theory was used since it assigns numbers to outcomes based on an accurate reflection of the strengths of the decision-maker's preferences (among the outcomes) without giving them precise dollar values.

Utility theory was developed by von Neumann and Morgenstern (17). They recognized that a full cardinal measure of satisfaction is not required for unitary decision making under uncertainty, although simply ordinal preferences are also not not sufficient. Von Neumann and

Morgenstern developed an ordering system, more than ordinal but less than fully cardinal, that works for uncertain choices (15:242). A general description of the assumptions that underlie the utility theory are:

1. The decision-maker knows what he likes. Offer him any pair of outcomes and he is able to state either that he prefers one to the other or that he is indifferent. Note that this implicitly includes the possibility of comparing a sure outcome with a lottery, for a sure outcome is in fact the limiting factor of a lottery with probabilities 1 and 0.

2. The decision-maker is transitive in his preferences. That is, if he likes A better than B, and B better than C, then he is guaranteed to like A better than C. This applies in both sure outcomes and lotteries.

3. If the decision-maker is equally happy with either of two sure outcomes, then he is also willing to substitute one for the other in a lottery.

4. The decision-maker will always accept a lottery between the best and worst outcomes, in preference to a sure intermediate outcome, provided we sweeten the odds enough.

5. If a decision-maker is offered a choice between two two-outcome lotteries with identical prizes but different odds, he will choose the lottery that offers him/her the larger chance of receiving the preferred prize.

6. The decision-maker is neutral between a compound lottery and the simple lottery to which it is reduced.

In summary, utility modeling using lotteries, was successful at providing a replacement to the value modeling process.

Those requiring a more rigorous mathematical discussion of utility theory should consult R. Duncan Luce and Howard Raiffa, Games and Decisions (7).

Utility Function Determination. The following outlines the procedure used in determining the utility function for the two most important decision outcomes. To make the discussion easier to understand, the outcomes are assigned the following labels: a written letter of commendation or a verbal commendation originating from either a two-letter or three-letter organization is represented by WC and VC. A written letter of reprimand or a verbal reprimand may also originate from either a two-letter or three-letter organization and is represented by WR and VR. A merit promotion (a competitive promotion process based primarily on work experience and job performance rating) moving average increase of two over the two-year moving average is represented by MA++. A moving average decrease of two is represented by MA--, and so forth. Therefore, MA++WC is a merit promotion moving average increase of two with written letter(s) of commendation from either two-letter or three-letter organizations. MA--WR is a merit promotion moving average decrease of two with written letter(s) of reprimand from either two-letter or three-letter organizations. MA* is any alternative other than MA++WC or MA--WR.

First, the very best outcome MA++WC was assigned a utility of 1. The very worst outcome MA--WR was assigned a utility of 0. Given the choice of the decision tree listed below in Figure 2, the value of p that would leave a decision-maker neutral between alternatives I and II is when p takes on the value of zero. At p=0, the utility of MA--WR must also be 0. By similar reasoning, the utility of MA++WC must be 1.

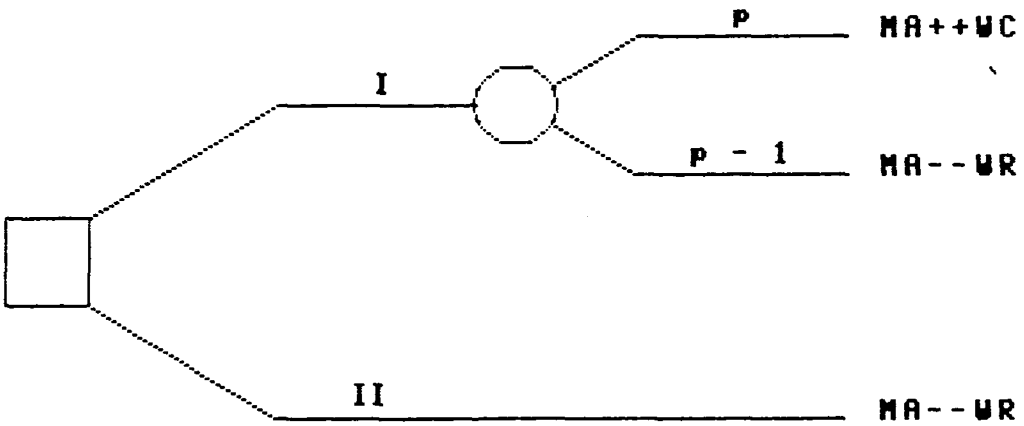


Figure 2. Decision Tree for Initial Utility Determination

The utilities for other potential outcomes were determined using this approach. In Figure 3 for example, p is the (unknown) probability of winning MA++WC in lottery I. The decision-maker was then asked what value of p would leave him just indifferent between choices I and II. In other words, what would the probability of winning MA++WC have to be to make him genuinely neutral between getting MA* for certain and getting the MA++WC/MM--WR lottery. This process was performed to approximate the utility curve.

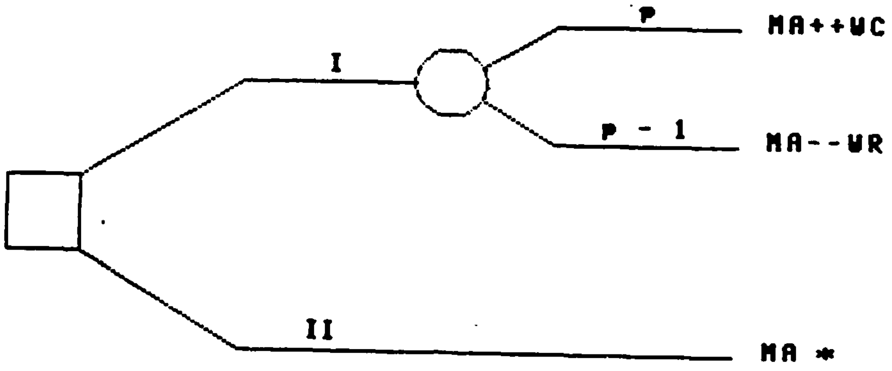


Figure 3. Decision Tree Used to Obtain Utility Curve

After plotting the utility curve, the accuracy of the values in the utility function were verified with the decision-maker. This was done in a manner identical to the process described above, except now the value of p has already been determined and its accuracy is validated through the interview process.

Finally, to determine which variables were truly important to the decision analysis, the variables are usually evaluated using sensitivity analysis. This step was not initially performed, but was later performed in this analysis using an influence diagram solving program. Analysis with this software package is discussed in the Results and Analysis chapter of this thesis. The sensitivity analysis indicates the variables for which uncertainty is important. The uncertainty on these will be encoded in the next phase (9:137).

Probabilistic Phase

The probabilistic phase begins by encoding uncertainties on each of the random variables. The uncertainties are captured as a probability distribution through probability encoding. This process is best described by Spetzler and Stael von Holstein (13:608-623). First, the extreme values for the uncertain quantities (variables) were determined by interviewing the division chief (1) of YZPR. He was asked to assess the largest and smallest extreme value for the moving average given the organizational structure of alternative I. To encode the various probability levels, both the probability wheel and indirect response mode of questioning was used.

The interval technique was then used to generate values for the median and quartiles. The encoded uncertain distribution was validated with the expert and inconsistencies are resolved. If he agrees with the distribution, the encoding of uncertainty is complete. If not, the process is repeated until agreement is reached.

The next step was to determine, for each alternative, the probability distribution for value. The derived probability distribution of value (of each alternative, called a value lottery) was determined with PerForma, an influence diagram solving software program.

To choose the best alternative, PerForma was again used. The presence of stochastic dominance (the cumulative probability distribution of one variable always exceeding another) allows choosing the best alternative based on the value lotteries alone. If stochastic dominance does not exist, then we must choose the best alternative based on expected utility of the value lotteries.

Informational Phase

The informational phase was used to calculate the worth of further reducing uncertainty in each of the important variables in the problem. The value of perfect information was calculated as soon as the decision tree structure has been established. The process of perfect information determination involves changing the order of the nodes in the decision tree. The value of information, perfect or imperfect, is equal to the difference in expected value for the best alternative(s) with or without information (14:150). The value of additional information is then compared to the cost of obtaining it. If the cost of gathering additional information is favorable, the three phases are repeated, incorporating the new data into the model. The analysis is complete when further analysis and/or information gathering are no longer profitable.

Methodology Modifications

Due to the time constraints involved, this decision analysis was performed only at the pilot model level. The pilot model is a simplified but comprehensive representation of the problem. The pilot model is useful in determining the most important relationships of the decision problem and directions that a more thorough analysis should take.

The analyst made two modifications in the deterministic phase of the decision cycle. First, sensitivity analysis was not initially performed on the variables identified by the decision-maker. To keep the decision analysis cycle simple, the decision was made to analyze the two variables identified by the decision-maker as being most important to him. The decision analysis cycle would be performed on the other variables as time permitted. Second, the assignment of values to the outcomes (the value modeling) is typically done in monetary terms. However, in this situation the assignment of a profit value to the outcomes was not possible. As stated earlier, the decision-maker did not feel comfortable with, nor was he able to attribute a monetary value to the outcomes. He considered the two most important outcomes to be non-monetary in nature (merit promotion and level of commendation/reprimand). Therefore, utilities were determined using the Utility Theory developed by von Neumann and Morgenstern (described in the methodology section of this thesis).

The use of utilities had advantages and disadvantages. The obvious advantage of using utilities was the ability to assess them easily from the decision-maker. Determining sensitivity analysis, expected value of perfect information

(EVPI), and optimal alternative determination were not affected by using utilities. The greatest disadvantage in using the utility theory was that the results obtained were difficult to interpret. Utilities are relative figures and gain clarity only when considered in context. The examination of a single unique point was less meaningful. For example, the value of the EVPI was expressed in terms of utility, and the analyst must search for standards of comparison to make EVPI meaningful. On the other hand, when EVPI is expressed in monetary values, the analyst interprets the values based on the highly familiar dollar standard.

To correct this problem, the following step could have been taken. Once things had been narrowed down to the moving average (MA), the analyst could have let the value (not utility) be expressed in terms of MA. This process most definitely would have taken some effort on the parts of the decision-maker and analyst. After obtaining value for the MA's, the analyst could assess the utility function to model risk. This adaptation would had lead to more easily interpreted results.

In addition, since cardinal profit values were not assigned to the outcomes (as mentioned above), and only utilities were assessed in the probabilistic phase, the analyst was not required to assess the risk preference of the decision-maker as modeled in a utility function over value. This is so because utilities contain both value and risk information.

III. Results and Analysis

Overview

This chapter will lead the reader through the application of decision analysis in this organizational problem: from decision specification and bounding to the determination of the optimal decision. Interviewing the decision-maker and his division/branch chiefs resulted in the identificaion of six potential organization structures. The two organizational structures deemed most viable by the decision-maker are presented in detail and were processed through the decision analysis cycle. Within these alternatives, five outcomes were important to the decision-maker; of these, the two most highly ranked were further examined. Use of the utility theory demonstrated the moving average outcome to be of primary importance to the decision-maker. The outcome of commendation or reprimand actions was also important. Probability encoding (as well as other procedures) was performed on both outcomes. The influence diagram solving software package, PerForma, was used to determine stochastic sensitivities, expected value of perfect information, and the optimal alternative.

Organizational Alternative Determination

During the course of the preliminary interviews, (which were directed at identifying potential organizational structures) the YZP director, division chiefs, and branch chiefs identified six potential organization alternatives. The organization alternatives are shown in Appendix B.

The decision-maker considered only the organizational alternatives depicted in Alternative I and Alternative II (Figure 4) to be viable because of workload or political reasons. These two configurations met the AC requirements for the establishment of a separate estimating division and a reduction in one general management (GM) position within YZP. Alternative III is the schematic of the Program Control office (YZP) as it currently exists, and is presented here as a comparative reference to the organizational structures examined (Alternatives I and II) in the thesis.

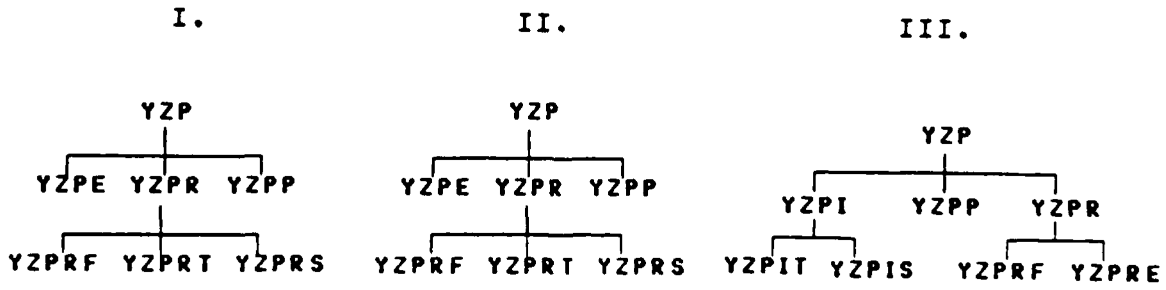


Figure 4. Alternatives Analyzed

The functions and responsibilities of each division and branch were discussed in Chapter 1 in the YZP Mission Statement, and remain unchanged for each alternative discussed. The differences in any organizational structure are change in physical location (of the divisions and branches) and change in immediate reporting officials.

Alternative I depicts YZP with a separate and distinct estimating division, in compliance to ASD AC. This division is composed entirely of estimating personnel originally located in YZPRE. The Tactical Engine (YZPIT) and Strategic, Airlift, and Trainer (YZPIS) branches are placed under the supervision of the Resources Management Division (YZPR) chief. Deletion of the GM-13 position of the Engine Interface Division (YZPI) accommodates the AC requirement for a GM reduction.

The organizational plan in Alternative II is nearly identical to that of Alternative I. In Alternative II, however, the scheduling personnel of the Plans and Integration Division (YZPP) are placed in the Estimating Division (YZPE) and the responsible reporting official of the scheduling personnel is the new division chief of YZPE.

Outcome Determination

Through a private one-on-one interview, the analyst and decision-maker determined which outcomes were most important in identifying a successfully implemented program control organization structure. Table 1, lists the decision-maker's outcome responses along with their ranking (as prioritized by the decision-maker). As discussed earlier in the Methodology Modification section of the chapter, to maintain simplicity, those outcomes determined most important by the decision-maker were to be examined first and, time permitting, other outcomes would be analyzed as well. With the two most important outcomes identified, the attention of the analyst was directed toward the determination of the utilities.

TABLE 1

Outcome Responses and Ranking

RANK	OUTCOMES
1	YZP personnel are being promoted to the GM series level more or less than previously.
2	The ratio of positive job performance feedback (two or three letter organization written commendation through 2/3 letter written reprimand) is improving.
3	Ninety-five percent of suspenses are met in a timely and quality manner.
4	One Hundred percent of all obligation and expenditure forecast goals are being met.
5	There are zero cost alert lists.

TABLE 2

Definition of Variables

MA - The two-year moving average of YZP merit promotions over the course of six years.

LTR - A written letter of commendation, verbal commendation, verbal reprimand, or written letter of reprimand originating from either a two-letter or three-letter organization.

Utility Determination

The utility curve on the outcomes ranked first and second in Table 1 was determined using the method developed by von Neumann and Morgenstern. The results of the initial utility gathering interview are shown in Figure 5.

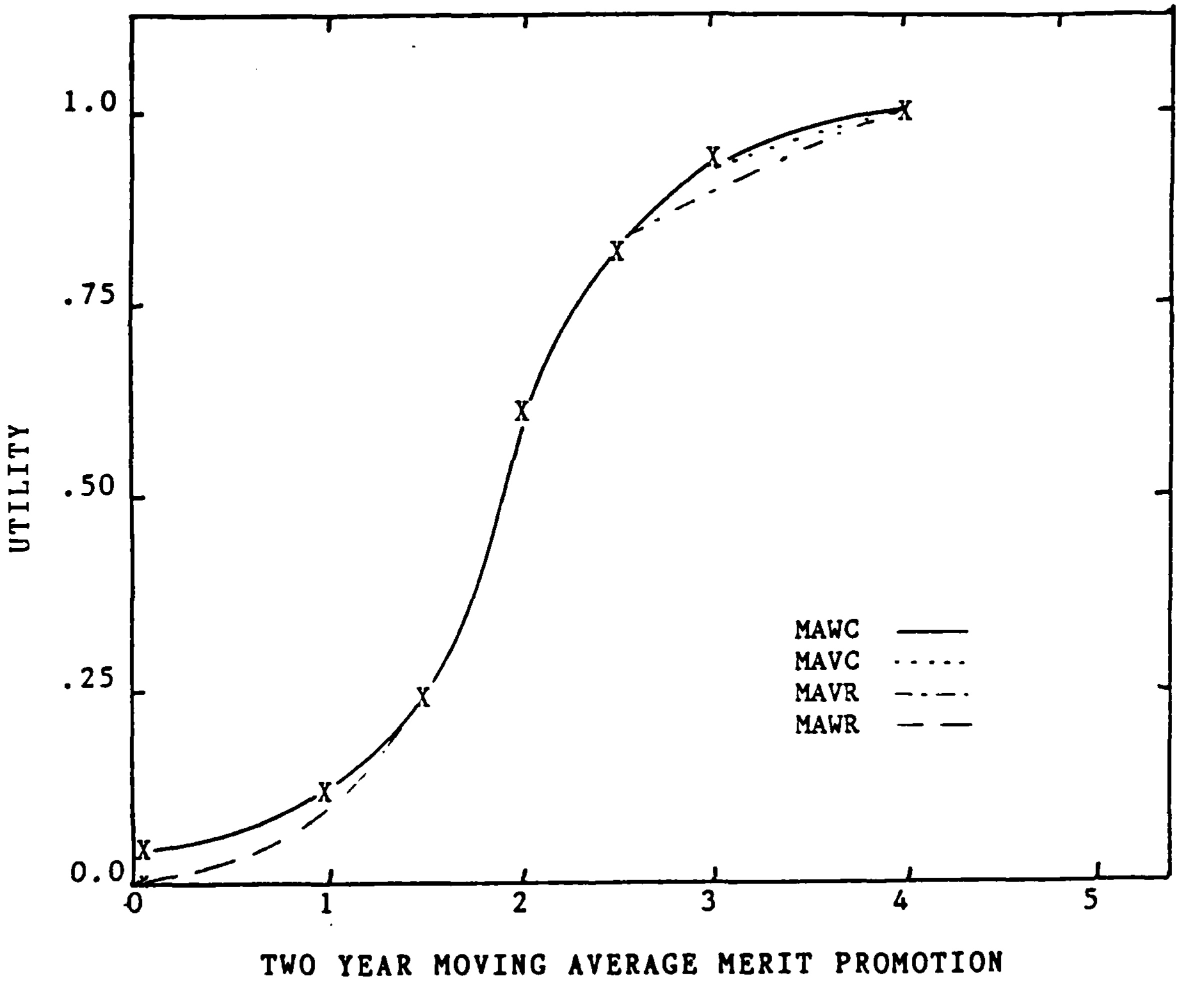


Figure 5. Initial Utility Curve

The graph in Figure 5 indicates that the MA outcome is the most important outcome. With this fact in hand, the utility curve was developed using only the moving average merit promotion. The refined utility curve was verified for accuracy with the decision maker, and is displayed in Figure 6.

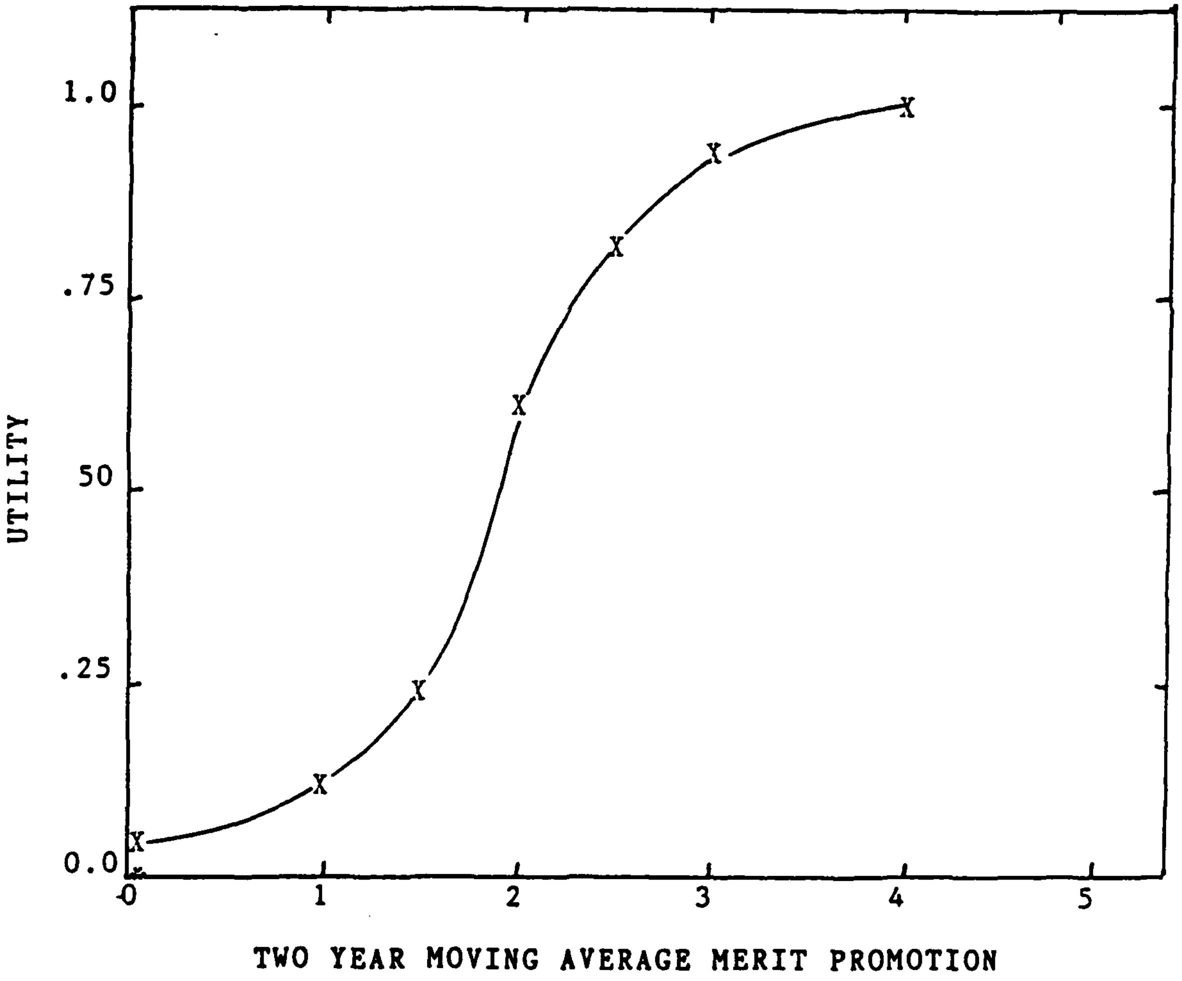


Figure 6. Refined Utility Curve

Probability Encoding

The next step of the decision analysis determined the probability encoding on both variables (MA and WR/WC). All interviews on probability encoding were conducted with the YZPR division chief (1). The division chief is a GM-14. He has worked in ASD for over 20 years and has worked in YZP for over three years. The first two interviews were on the moving average continuous variable, as it related to Alternatives I and II. The results of two interviews with the division chief are depicted in Figures 7 and 8.

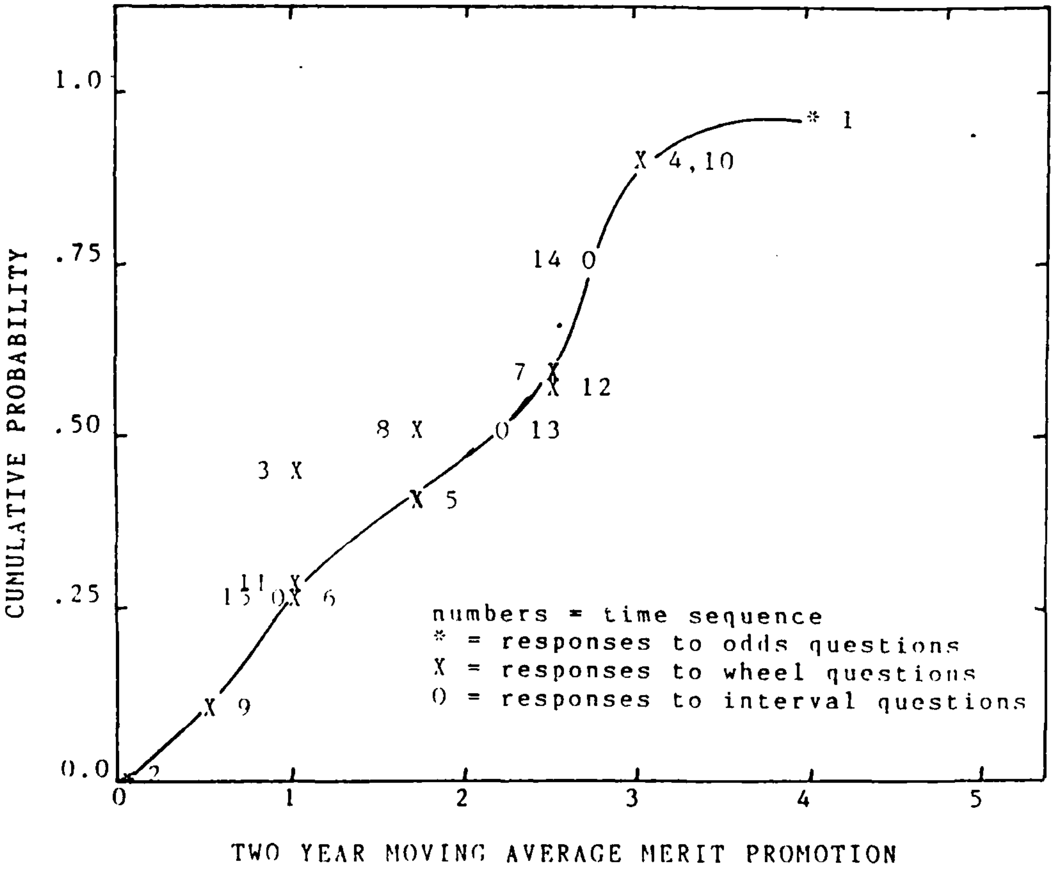


Figure 7. Probability Encoding on Alternative I

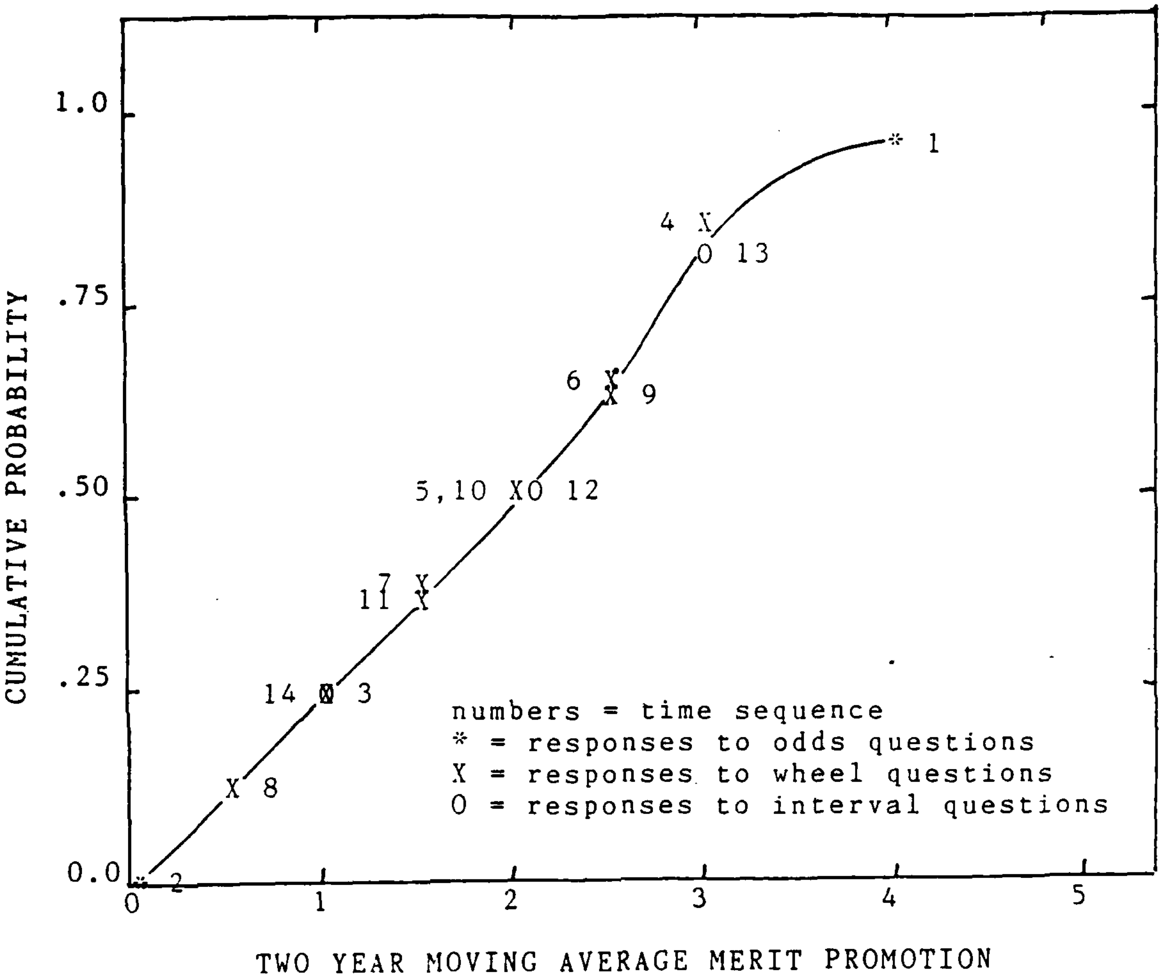


Figure 8. Probability Encoding on Alternative II

In Figure 7 the reader will note an inconsistent point in the first probability encoding session. This point is most likely skewed because it was the first point determined during the initial interview. The subject was probably not yet completely adjusted to the probability encoding process.

This particular inconsistency was examined until a consistent reply was given. Prior to the commencement of the probability encoding process, the subject being interviewed did not sense any significant differences of one organizational structure alternative over another. This feeling was readily demonstrated in the similarity in the probability curves of Figures 7 and 8.

A third interview was conducted on the remaining random variable to determine its probability curve. The results of this probability encoding is located in Table 3.

TABLE 3

Probability Encoding

on Commendation/Reprimand Variable

	Alternative I	Alternative II
Written Commendation	.5	.5
Verbal Commendation	.23	.23
Verbal Reprimand	.22	.22
Written Reprimand	.05	.05

After the probabilities were determined, all raw data necessary for the decision analysis had been obtained. The curves of the probability encoding were next discretized. Discretization is the transformation of a continuous probability curve into a discrete distribution to make the problem more manageable. Care is taken to preserve the mean and standard deviation. The results of the discretization are shown in Table 4.

TABLE 4

Discretized Probabilities

Organizational Alternative	Moving Averages .5	.6	2.0	2.1	3.1	3.2
I	0.00	0.25	0.00	0.50	0.25	0.00
II	0.25	0.00	0.50	0.00	0.00	0.25

Finally, the utility values to be used in the computer analysis were derived in the following manner. The moving averages obtained in the discretization were projected onto the utility curve (Figure 6) and the utility values determined. The values are listed in Table 5.

TABLE 5

Utilities on Moving Averages

Moving average	Utility
.5	.06
.6	.07
2.0	.60
2.1	.65
3.1	.96
3.2	.97

These values as well as, all information gathered in the the discretization and utility determination were used in Performa (11) to solve the optimal alternative.

Influence Diagramming

The final stages of the decision analysis were solved with the assistance of PerForma, an influence diagram solving software package designed by Captain Joseph A. Tatman and Captain Thomas M. Burwell. The influence diagram is a graphic structure for modeling uncertain variables and decisions, and explicitly revealing probabilistic dependence and the flow of information (11:871). An influence diagram is a network of three types of nodes: chance nodes (circles), decision nodes (squares), and value nodes (diamonds). The influence diagram assists the decision maker and the analyst to visualize the problem at hand. The simplistic influence diagram in Figure 9 depicts the pilot study model representation of the decision problem as presented by the decision-maker to the analyst.

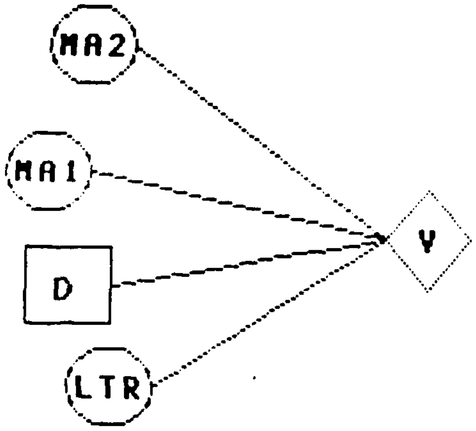


Figure 9. Influence Diagram of Decision Problem

The interpretation of the influence diagram can be represented in the following manner. The decision-maker must make a choice between organization Alternative I and Alternative II. This decision is represented by the node D. The two most important variables that will influence his decision on choosing an alternative are the moving average merit promotion (MA), and the form of the appraisal (LTR), the written letter of commendation through to written letter of reprimand originating from a two-letter or three-letter organization from. The probabilities of both MA and LTR are directly dependent upon the decision to be made (arrows from decision node D to chance nodes MA and LTR). The value (V) is the decision-maker's value or objective function and is a function of the MA and LTR variables. The arcs into V (the value) and MA and LTR (chance nodes) are conditional and represent probabilistic dependence; however this does not imply casuality or time preference. (In contrast, arcs into a decision node are informational and indicates information known to the decision-maker at the time the decision must be made. In this particular decision problem there are no arcs into the decision node.)

There are several advantages to evaluating the decision problem using an influence diagram. The analyst can use the influence diagram as a representation of the problem that is natural to the decision-maker. Influence diagrams enable the analyst to easily calculate many things; a few being optimal alternative, expected values, sensitivity analysis, and expected value of perfect information. More in-depth discussions on influence diagramming are found in works done by Shachter (12) and Howard and Matheson (5).

Model Analysis

The influence diagram was used to determine worth lotteries, stochastic sensitivity analysis, value of perfect information, and expected value.

Worth lotteries. The reason behind determining worth lotteries is to identify if one alternative is stochastically dominant over the other. If one alternative can be shown to stochastically dominant another alternative, the dominated alternative can be dropped from consideration as an optimal alternative.

The most important step in the worth lottery analysis is represented in the influence diagram. In the influence diagram, the value node is changed to a chance node. This particular arrangement is depicted in Figure 10. The variables MA1, MA2, and LTR are integrated out of the influence diagram leaving just the decision node D and chance node V remaining.

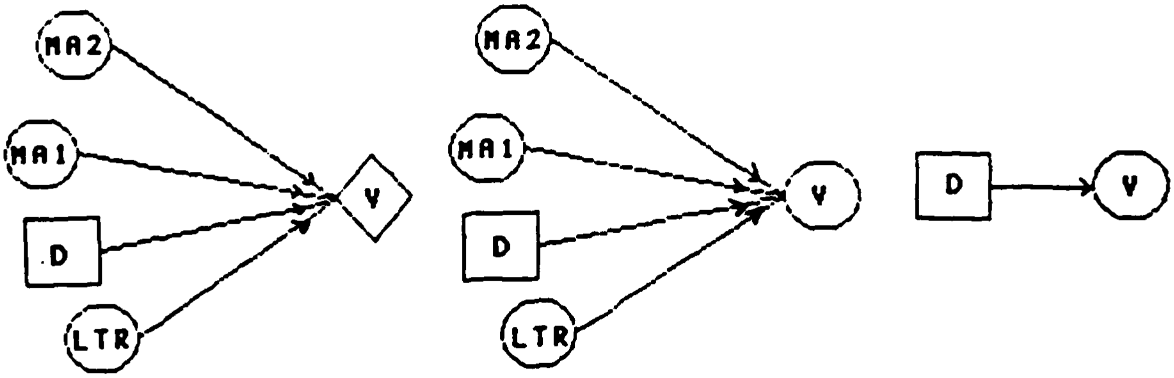


Figure 10. Influence Diagram for Worth Lottery Analysis

The plot of the utilities derived in the worth lottery determination is shown in Figure 11. The figure demonstrates that Alternative 2 dominates Alternative 1 in the low utility region, but Alternative 1 dominates Alternative 2 in the high utility region.

This plot of the worth lotteries indicates one alternative is not dominant over the other and one of the alternatives can not be excluded from further optimal alternative consideration.

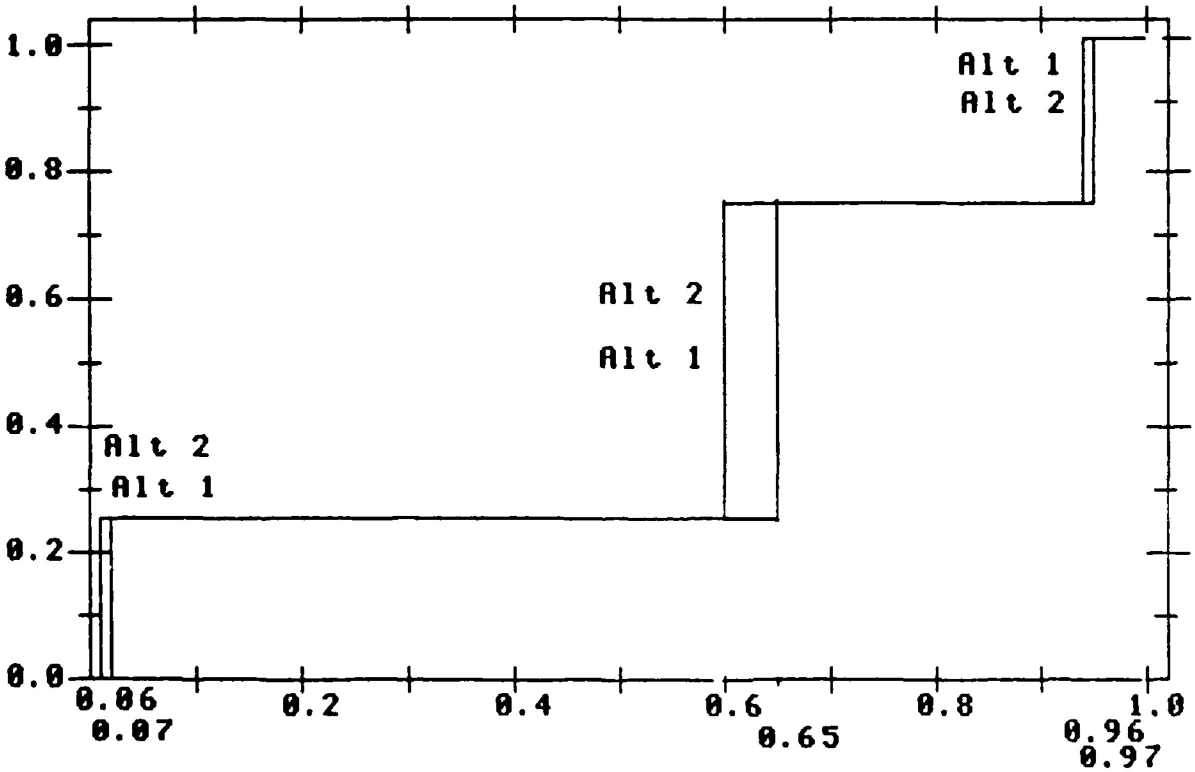


Figure 11. Plot of Worth Lotteries

Stochastic Sensitivity Analysis. In stochastic sensitivity analysis, each variable is examined to determine its particular sensitivity to change in value. The variable is swept from low value through to high value. In this process the analyst is looking at the magnitude of value change; the greater the magnitude of change in value, the more important the variable is. Those variables demonstrating a large magnitude of change are considered most important to the decision-maker and are worthy of probablistic encoding.

Figure 12 and Figure 13 show the influence diagrams used in performing the stochastic sensitivity analysis.

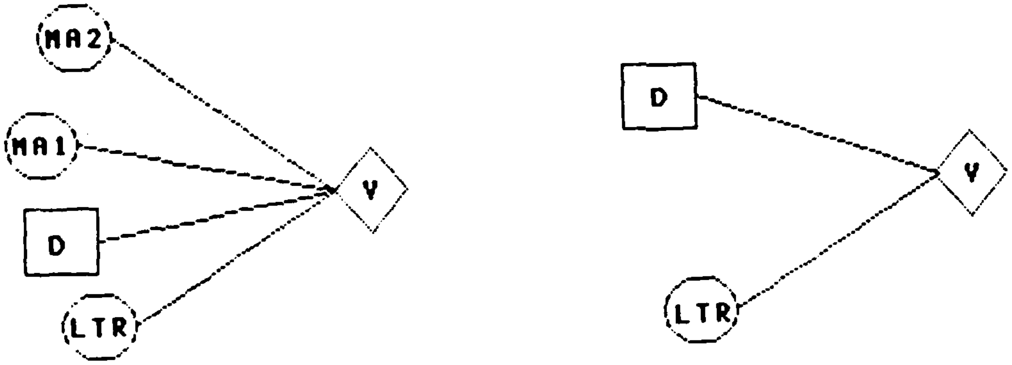


Figure 12. Influence Diagram for Stochastic Sensitivity Analysis on LTR

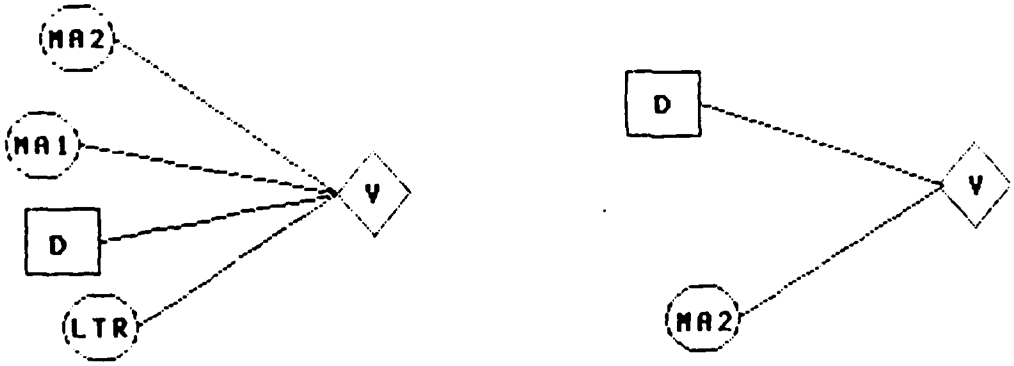


Figure 13. Influence Diagram for Stochastic Sensitivity Analysis on MA2

In Figure 12, the variables MA1 and MA2 were removed from the influence diagram by expectation. After MA1 and MA2 were removed, sensitivity analysis was performed on the LTR variable. This variable was not stochastically sensitive (no utility change). Figure 13, represents the process of removing the MA1 and LTR variables by expectation. The results of the stochastic sensitivity analysis indicate that the MA variable has a large magnitude of utility change (is stochastically sensitive). The results of the stochastic sensitivity analysis confirms MA is an important variable to the decision-maker.

Expected Value of Perfect Information (EVPI). EVPI is useful in determining whether it is worthwhile to partake in a possible expensive information gathering activity before making a decision. For example, if someone were to offer the decision-maker perfect information on the moving average variable (MA) that would help him more confidently choose the optimal alternative, how much should the decision-maker be willing to pay for that advice?

The EVPI was considered on the MA variable only because for this analysis it is most important to the decision-maker. EVPI was performed on variables MA1, MA2, and on both variables combined. The influence diagram in Figure 14 is the one used to determine the maximum expected utility of both MA variables. To determine the maximum expected utility, the LTR chance node was removed by expectation. This was followed by the removal of the decision node D.

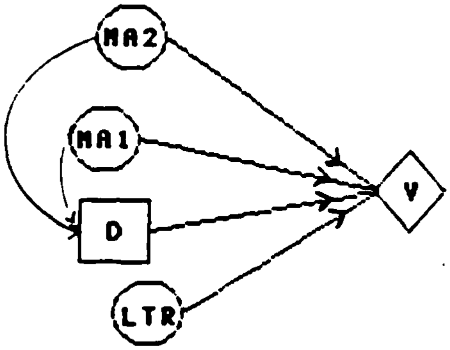


Figure 14. Influence Diagram for EVPI on MA1 and MA2

The removal of node D was accomplished by maximization. Lastly the MA variables were removed by expectation and the resulting maximum expected utility was equal to 0.7456.

Next the expected utility on MA1 was calculated. The influence diagram in Figure 15 was used to determine the maximum expected utility of MA1. The chance nodes LTR and MA2 were removed by expectation and the decision node D was removed by maximization. The variable MA1 was the last node removed. The expected utility of MA1 was 0.7044.

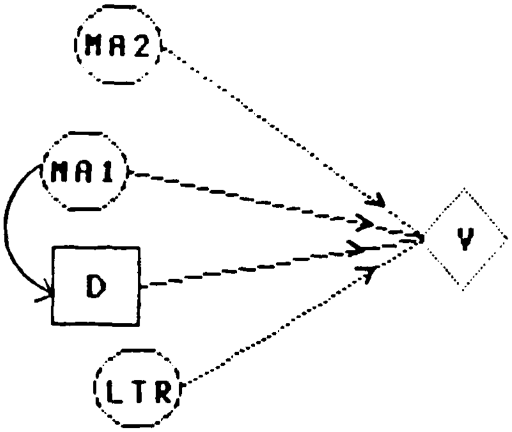


Figure 15. Influence Diagram for EVPI on MA1

The final expected utility calculated was on the MA2 variable. The influence diagram in Figure 16 was used to determine the maximum expected utility of MA2.

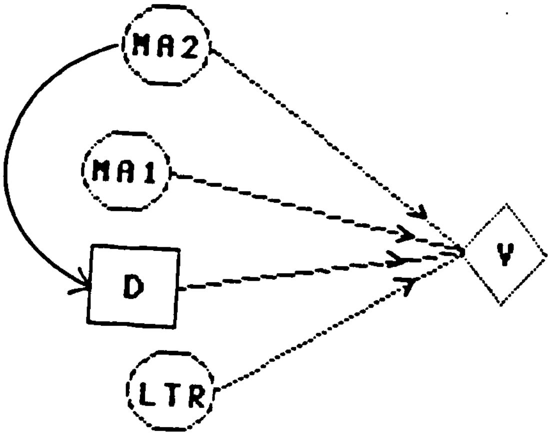


Figure 16. *Influence Diagram for* EVPI on MA2

The only difference between Figures 15 and 16 is the prior knowledge known on the MA1 and MA2 variables: in this case, prior knowledge is known about MA2. The expected utility of MA2 was determined in the same manner as the expected utility of MA1. The chance nodes LTR and MA1 were removed by expectation and the decision node D was removed by maximization. The variable MA2 was the last node removed. The expected utility of MA2 was 0.6881.

The calculated expected utility of MA1 and MA2 are nearly identical (.7044, .6881). Having perfect information on both variables simultaneously had a maximum expected utility of .7456. Obviously, there is value in knowing perfect information on both variables. The interpretation of this data is not simple and seems to suggest that it might be worthwhile to expend some effort in looking for programs to improve on the information. However, since the form of the value of perfect information is utility and not in the usual monetaristic form. It is difficult as an analyst to get a true feeling as to how much time and money should be expended in the effort. The results only indicate that there is worth in attaining additional information and that the decision-maker would have to interpret the utility of perfect information and whether to gather additional information on the variable.

The last step in this analysis was to determine the optimal alternative to this decision. The initial influence diagram is identical to those used in determining stochastic sensitivity analysis. To solve the influence diagram, the probabilities of both chance nodes were taken from the discretized probabilities. The outcome values of the deterministic node V were derived from the utility curve in Figure 6. First, the chance node LTR was removed from the influence diagram by expectation. Then, the MA chance nodes were removed from the influence diagram by expectation. The result of the manipulations gave the following utilities for the deterministic node V: Alternative I had a utility of 0.5825 and Alternative II had a utility of 0.5575. To verify the accuracy of the Alternative values, the chance nodes were removed in a different sequence. The chance node

MA was removed by expectation followed by the removal of LTR by expectation. In both cases the values of both alternatives were the same. The values of the alternatives indicates that based on the interview process on the decision-maker and his expert, the best YZP organizational structure is Alternative I.

IV. Summary, Conclusion, and Recommendation

Summary

The basis for any thesis begins with a thorough search of the pertinent literature. This researcher found applications of decision analysis in the areas of investment and strategic planning, research and development, and social policy. In the present case, decision analysis would be applied in a novel approach: to a complex organizational restructuring. The ASD Comptroller requested the Program Control office (YZP) to reorganize. In compliance with this request, YZP was directed to consider alternative organizational structures.

Integral to any decision analysis application is a decision-maker, having full authority, control, and responsibility for all facets of the decision. The central figure in the thesis was Mr. Clyde Wethington, Director of Progam Control (YZP), the decision-maker.

The problem falls into the realm of conditions that make it suitable for decision analysis. Decision analysis seeks to apply logic and math to difficult decisions of top management. These difficult decisions are characterized by having long range implications, being ill-defined, and by demonstrating complexity and uniqueness.

Interviews with the decision-maker and his experts surfaced six potential organizational alternatives with potential to satisfy the decision problem. The two alternatives which were deemed most viable by the decision-maker were examined in the decision analysis cycle, and one alternative was demonstrated to be best.

The analysis of Mr. Wethington's decision problem was also aided by the analyst's intimate knowledge of the inner workings of the Program Control organization, due to his previous four-year tour of duty as a financial manager in that office. This consideration played a great part in the time requirements needed to actually perform the pilot decision analysis. An important basic step in the decision analysis process is the interview, and the establishment of rapport is essential to a successful interview. Open communication patterns, compatible working relationships, and shared vocabulary were already established between the analyst and YZP personnel before the thesis effort began.

Conclusion

The end product of the decision analysis cycle was a decision-maker that thoroughly understood the decision problem, knew his optimal alternative, and possessed a model that showed the logic by which the optimal alternative was determined. While finding a decision-maker with a problem was vital to performing this decision analysis, equally important was that decision analysis was really useful to him in his efforts to select the best alternative. This analysis clearly demonstrated that Alternative I was truly the optimal alternative for the decision-maker's decision problem. A final, concluding discussion of the results (and the decision analysis process in general) was conducted with the decision-maker to obtain his valued feedback. Several points about decision analysis and the results were very attractive to Mr. Wethington. He felt that the model used to describe the decision problem incorporated the most important variables, especially moving average merit promotion. He felt that the model accurately portrayed his personal ideas and choices about the decision problem. The model gave him a much better understanding of the critical aspects of the problem. He was especially pleased that decision analysis had transformed a complex "fuzzy" problem into a very precise simplified problem that was very manageable. Lastly, the decision-maker considered the results as a support and validation of his intuition.

Recommendations

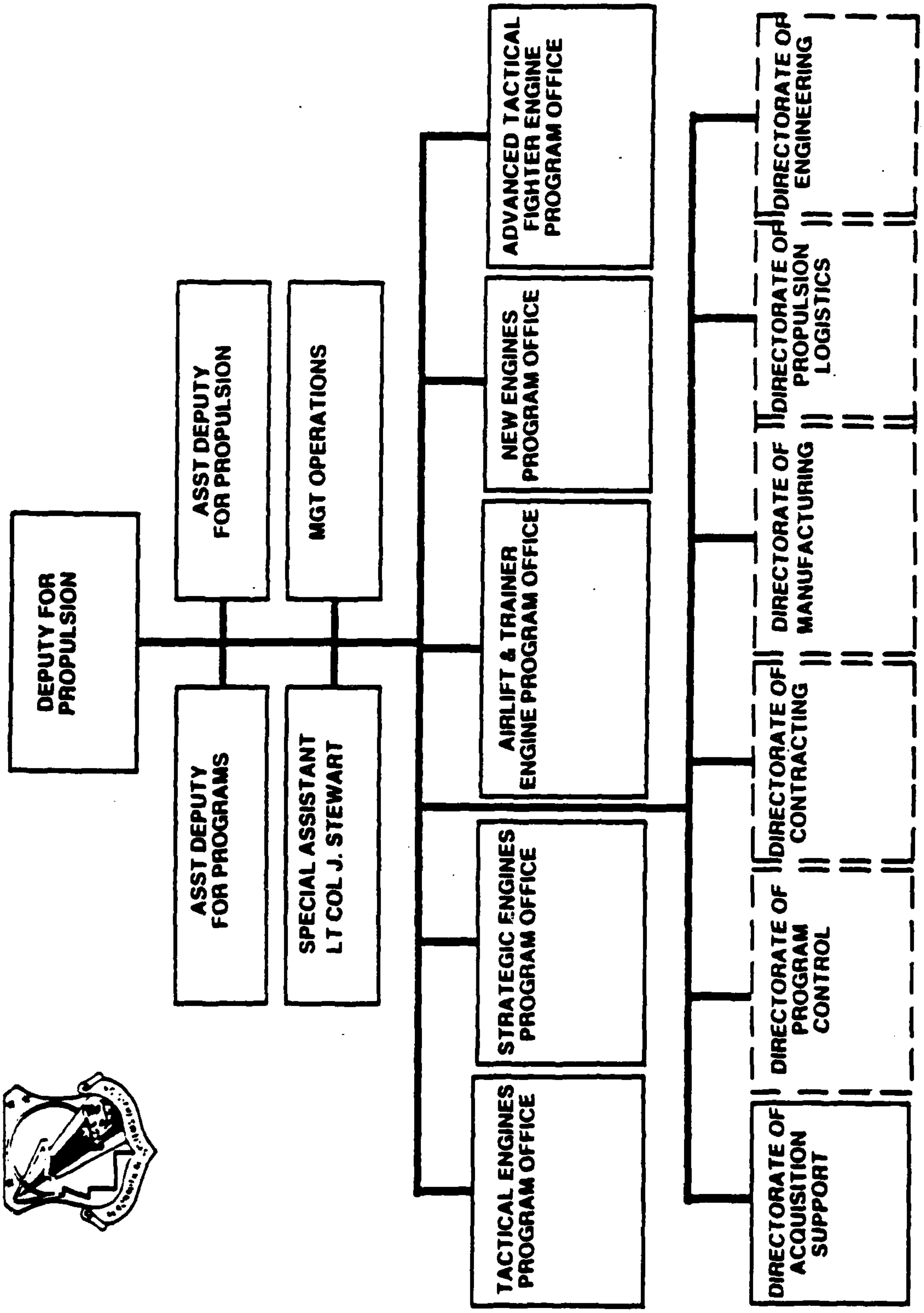
This thesis effort was successful for both the writer and the decision-maker. There were two important positive functions of this application of decision analysis: the decision-maker gained understanding and support for his decision, and the thesis writer gained a novel opportunity to apply this dynamic process. The writer successfully applied decision analysis to a problem involving choice between various organization structures. Several conditions existed which influenced the decision analysis application; they are discussed here. The recommendations which follow are intended to allow the future analyst to reproduce the decision analysis cycle as smoothly as possible.

1. The analyst must develop a working knowledge of the organization, its function, and the vernacular in which the personnel communicates. The early development of rapport with the interviewees, in particular, enhances the accurate open flow of information during all phases of the cycle.

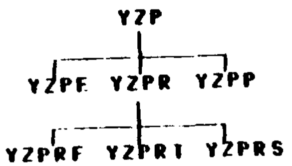
2. The analyst should allow ample time in which to complete the entire decision analysis. A student carrying 12-15 quarter hours will require at least eight months to complete the decision analysis and write the results, if they are to be in thesis form. The process, by its nature, may be repeated as often as new information is added, or as long as the additional gathering of information is deemed profitable. Extra time may be needed for the establishment of the working relationships discussed above.

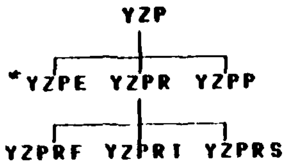
3. The analyst should make the best effort possible to assign monetary value to the outcomes in the value modeling. The use of utilities, while an acceptable substitute during the deterministic phase, was difficult to incorporate into the interpretation of the results (in the informational phase). In the value-of-information and the value-of-perfect-information calculations, the results were expressed in terms of utilities, and the results were more difficult for the analyst to examine. The use of monetary values would greatly ease results interpretation.

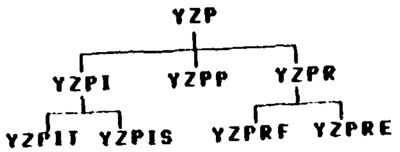
Appendix A: Deputy for Propulsion Organization Chart

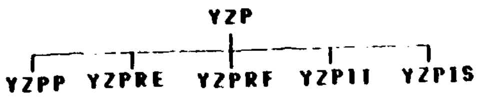


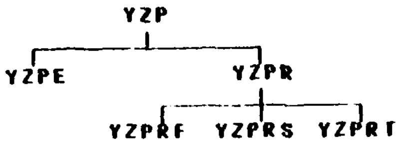
Appendix B: Six Organizational Alternatives Identified During Preliminary Interviews

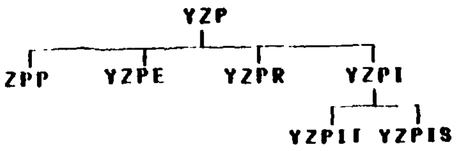












The following listing relates the letter representations to the potential organizational divisions and branches, potential and existing, within YZP.

YZPE -- Estimating Division (potential)
YZPES -- Scheduling Branch (potential)
YZPEE -- Estimating and Evaluation Branch (potential)
YZPI -- Engine Interface Division
YZPIT -- Tactical Engine Branch
YZPIS -- Strategic, Airlift, and Trainer Branch
YZPP -- Plans and Integration
YZPR -- Resources Management Division
YZPRF -- Financial Management Branch
YZPRE -- Estimating and Evaluation Branch
YZPRT -- Tactical Engine Branch (potential)
YZPRS -- Strategic, Airlift, and Trainer Branch (potential)

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VITA

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ABSTRACT

This study investigated the application of decision analysis to a problem involving choices between various organizational structures. The office involved in this study was the Program Control Directorate of the Propulsion System Program Office, Aeronautical Systems Division, Wright-Patterson AFB, Ohio.

The research goal was to evaluate different organizational structures and to determine the optimal alternative. The decision analysis methodology applied is comprised of three phases: deterministic, probabilistic, and informational. The deterministic phase structured the problem, the probabilistic phase incorporated the uncertainty associated with the decision problem and determined the optimal alternative, and the informational phase determined the associated utility of obtaining information to reduce uncertainty. Through this methodology, the decision-maker was assisted in determining a best logical alternative. The end product was a decision-maker that thoroughly understood the decision problem, knew his optimal alternative, and possessed a model that shows the logic by which the optimal alternative was determined.

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