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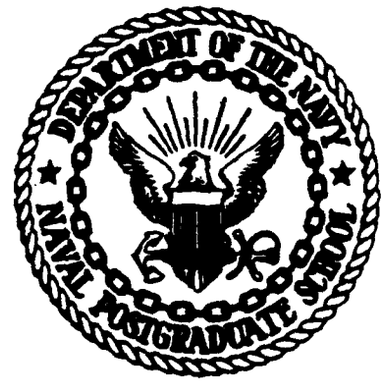

THESIS

MULTI-ATTRIBUTE UTILITY THEORY TO ASSIST TOP-LEVEL ACQUISITION DECISION-MAKING

by

Ran Goren

December 1981

Thesis Advisor: W. H. Cullin

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Multi-Attribute Utility Theory to Assist
Top-Level Acquisition Decision-Making

by

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requirements for the degree of

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ABSTRACT

Top-level acquisition decisions are complex and multi-objective. This implies difficulties in appropriately accounting for all relevant factors to select the best alternative. In addition, there are difficulties and deficiencies in the actual implementation of the decision process. The difficulties and deficiencies in the top-level acquisition decision-making are explored by this thesis. The thesis suggests improvements through intensive use of a quantitative, judgment-based decision technique derived from Multi-Attribute Utility Theory (MAUT). Emphasis is put on demonstrating MAUT's capability for incorporating subjective judgment, in order to reduce the existing doubts about its usefulness for top-level decision-making. The thesis recommends use of the MAUT procedure as the central tool for comprehensive evaluation of the decision alternatives. It argues that such use would solve some of the essential decision-making problems and in addition contribute to the quality and efficiency of the decision process.

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LIST OF ABBREVIATIONS

AFSARC	-	Air-Force Systems Acquisition Review Council
AFSEC	-	Air Force Secretary
ASARC	-	Army Systems Acquisition Review Council
ASH	-	Advanced Scout Helicopter
DAE	-	Defense Acquisition Executive
DCP	-	Decision Coordinating Paper
DOD	-	Department of Defense
DSARC	-	Defense Systems Acquisition Review Council
DSS	-	Decision Support System
IAF	-	Israeli Air Force
IPS	-	Integrated Program Summary
LCC	-	Life Cycle Cost
MAUA	-	Multi-Attribute Utility Analysis
MAUM	-	Multi-Attribute Utility Measurement
MAUT	-	Multi-Attribute Utility Theory
MAUT	-	Multi-Attribute Utility Technique
MOAT	-	Mission Operability Assessment Technique
OSD	-	Office of the Secretary of Defense
SECDEF	-	Secretary of Defense
SMART	-	Simple Multi-Attribute Rating Technique
(S)SARC	-	(Service) System Acquisition Review Council
SSRI	-	Social Science Research Institute
USD(R&D)	-	Under Secretary of Defense for Research and Engineering

I. INTRODUCTION

A. GENERAL

> The acquisition of major systems by the Federal Government constitutes one of the most crucial and expensive activities performed to meet national needs. Its impact is critical on technology, on the nation's economic and fiscal policies, and on the accomplishment of Government agency missions in such fields as defense, space, energy and transportation. [Circular No. A-109, p. 1]

The above quote clearly indicates how crucial, and complex the major systems acquisition decisions are. The quality of these decisions have long-run implications not only for the national defense capabilities, but for political and socio-economic issues as well.

The complexity of the major systems acquisition decisions stems from the scope and substance of factors such as:

(1) The variety of organizations and personalities with interests in the decision.

(2) The enormous resources committed to the decision.

(3) The technological and financial uncertainties involved in programs whose acquisition life cycle stretches over 7, 10, 15 or more years, and which exploit the leading edge of the technological state of the art.

(4) The large and complex organizations and management involved in running the programs through their acquisition life cycle.

During the acquisition life cycle there is a continuous decision-making process, involving various echelons, up to

the top decision-maker, which, for major systems, is the Secretary of Defense, or in some cases, even the President himself.

The decision-making process works in a hierarchical manner. As a decision issue ascends the decision-making ladder, it becomes more refined, the alternatives are better defined, and their number is reduced. At the same time another development takes place: As the decision moves up, emphasis changes, new considerations are added, and in addition to the measurable factors more and more intangible factors, which are subject to judgment, become involved.

Thus, top-level acquisition decision-making is distinguished by the problem of facing a broad spectrum of decision factors, of various scopes and natures, some of them technically measurable, and some of them more judgmental. Top-level decision-makers have the difficult task of intelligently consolidating all these factors and considerations into one final decision. The difficulty of such consolidation is amplified by the previously mentioned substantial implications of the acquisition decisions.

Because of their complexity and crucial implications, major systems acquisition decisions have always been subject to controversy, criticism and concern. Circular No. A-109 [Executive Office of the President, 1976] stated several years ago that "for a number of years there has been deep concern over the effectiveness of the management of major system acquisition." This thesis reveals that concerns and criticism about these

issues have continued to the present. In fact, there always should be concern about acquisition decisions, and there are no limits to striving for their improvement.

B. OBJECTIVES

The objectives of this study were to identify problems and deficiencies in the current methodology by which acquisition decision alternatives are evaluated, compared and presented for top-level decision-making, and to suggest use of a decision technique that should improve the way the ultimate decision is made.

C. SCOPE

The scope of this thesis is limited to the search for an evaluation framework or decision-making technique that can best serve top-level acquisition decision-making. The thesis does not directly address the major problems of acquisition decisions such as how to translate threat assessment into weapon systems terms, how to reliably predict cost, performance and schedule, or how to measure the political and socio-economic implications of the decision. These are beyond the scope of the thesis. Rather, the thesis concentrates on the question of how to best consolidate the above inputs to an ultimate decision, under the assumption that they are already given.

The thesis does not attempt to recommend specific changes in the formal acquisition decision process, the so-called "DSARC Process" (which is actually in the process of change). Rather, it does address the underlying approaches to

decision-making which are not necessarily attached to one formal process or another.

The study refers mostly to top-level decision-making. In this context, top-level acquisition decision-makers are defined as the highest acquisition authorities, such as Source Selection Board, (Service)SARC, (Service)Sec--at the Service Department level; DSARC and SecDef--at the OSD level.[1] But this definition is by no means strict. Any decision body that meets the thesis' principal assumptions may be considered as addressed by its analysis and conclusions.

D. SOURCES

1. The Questionnaire

a. General

At the center of the research work done for the thesis is a questionnaire which was distributed to a sample of high-level officials in the U.S. DOD and in the Israeli Air Force (IAF). The purpose of the questionnaire was to obtain inputs associated with the thesis theme from people who are actually involved in major system acquisition decisions. Addressing two different decision-making milieus--the American and the Israeli--provided a base for comparison, in which

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[1] As one can notice, no distinction is made here between decision authorities (such as SecDef or (S)Sec) and recommending bodies (such as DSARC, (S)SARC). The reason is based upon the assumption that in consolidating their recommendation, the latter should reach, in a sense, some sort of decision. In this respect the suggested technique may apply to them as well as to the formal decision-makers.

the American setting is emphasized, and the Israeli serves as a reference.

b. The Respondents Sample

The sample solicited was selected with reference to positions and estimated involvement in the acquisition decision process. The American sample consisted of 38 officials, of which 28 are military and 10 civilians. Those were spread among the DOD components as follows: OSD--13, Navy Department--16, Air-Force Department--9. Their positions distributed from medium-level staff, up to Under Secretary of Defense (R&E).

The Israeli sample consisted of 11 IAF officers, including two deputies to the IAF Chief of Staff, the IAF Chief of Maintenance and Logistics, IAF HQs department heads and staff members.

c. The Questionnaire As A Reference

The original questionnaire and its full analysis and numerical summaries are located in Appendix A, which is a complete and independent unit. Besides the direct analysis of the questions, Appendix A presents a variety of comments written by the respondents, some of which are unique. The analysis and numerical data of Appendix A serves as a supportive reference to the basic analysis of the thesis. For deeper insight intc the respondents perceptions, reading of Appendix A is recommended.

2. Interviews

In order to obtain additional and better insight into the acquisition decision-making issues than that permitted

by the questionnaire, several interviews took place. The interviewees were:

(1) Dr. Walter B. LaBerge, Ex-Deputy Under Secretary of Defense (R&E).

(2) Robert F. Trimble, Deputy Under Secretary of Defense (R&E) Acquisition Policy (acting).

(3) Dr. Robert J. Hermannn, Special Assistant for Intelligence to the USD(R&E), and until a week before the interview--Assistant Secretary of the Air Force for Research, Development and Logistics.

(4) BRIG. GEN Joseph H. Connolly, Director, Contracting and Manufacturing Policy, DCS/Research, Development and Acquisition, HQ USAF.

(5) Frederick G. Fellowes, Director, Tactical Air Surface and EW Development Directorate.

In order to discuss Multi-Attribute Utility Theory (MAUT)[1] implementation in the acquisition decision-making process, an additional interview took place. The interviewee was: Prof. Ward Edwards, Director of the Social Science Research Institute at USC, Los Angeles, Ca. Prof. Edwards is one of the leading theorists and practitioners of MAUT. His publications served as major references to this thesis.

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[1]In the literature, various names and acronyms applied to similar ideas are found. The acronym MAUT may be an abbreviation for Multi-Attribute Utility Theory, or Technology, or Technique. In addition, there can be found: Multi-Attribute Utility Measurement (MAUM), Multi-Attribute Utility Analysis (MAUA), or Simple Multi-Attribute Rating Technique (SMART).

3. Literature

The thesis also refers to various academic sources as well as to official publications.

E. ORGANIZATION

This thesis consists of six chapters. Chapter II explores the characteristics of the present acquisition decision-making process, and reveals its problems and deficiencies as reflected from the literature base, the official documentation and the perceptions of the people involved. Special emphasis is put on examining the attitudes toward usage of quantitative decision techniques, and the extent to which these techniques are actually used. Chapter II concludes with a list of criteria for a decision technique intended to improve the current process.

Chapter III examines the applicability of quantitative decision techniques for top-level acquisition decision-making. Emphasis is put on studying the capability of those techniques of handling subjective judgment. Among the decision techniques MAUT is found as most suitable for acquisition decisions.

Chapter IV provides the theoretical basis of MAUT, which is required for further discussion about the implementation aspects. The chapter also presents clarification of the various terms used interchangeably in MAUT-related literature and in this thesis as well.

Chapter V highlights the major issues associated in MAUT implementation as a tool for top-level acquisition decision-making. The chapter provides also a broader view on MAUT

procedure as a comprehensive, ongoing acquisition evaluation framework. The chapter demonstrates to what extent MAUT meets the criteria set in Chapter II.

Chapter VI gives the overall conclusions and general recommendations of the thesis.

Appendix A consists of a detailed analysis of the questionnaire.

II. EXPLORATION OF THE PRESENT SITUATION

A. THE GENERAL NATURE OF THE ACQUISITION DECISION-MAKING PROCESS AND ASSOCIATED PROBLEMS

1. Formal and Informal Process

> The formal acquisition process is well defined in various directives and instructions, but in fact is only a model from which individual programs deviate. The process guidelines represent an idealized scheme for selection development and procurement of products... Along with the formal and obvious decision-makers there are less conspicuous ones who are often more influential. [Fellowes, 1981]

In this respect, the formal acquisition decision-making process and documentation are those which are defined by DOD Directive No. 5000.1 (1980), DOD Instruction No. 5000.2 and the supplementary regulations within the Department of Defense (DOD) components. As an informal process are considered all meetings, discussions, influence exertions, writings, etc., which are not directly defined and required by the above mentioned documents.

Fellowes' perception is supported by several of the questionnaire's respondents. Moreover, some of them even doubt the value of the formal decision process and documentation in the "real world" decisions. Says one respondent:

> Acquisition process documentation is of limited value, if any. [Appendix A, p. 165]

This study addresses both the formal and informal decision-making processes. The suggested decision-making technique should serve not only as a decision tool for the formal decision events, but also resolve some deficiencies

caused by the informal process, although by no means cure them all. The informal process is considered as an inherent, inevitable part of the acquisition decision-making process, therefore no attempt is made to eliminate it, rather to better control and take it into account according to the "rules of the game."

Most of the references about the present situation are taken from the formal process, which is easier to identify. But that does not mean the formal process is the only one to be addressed. Nevertheless, in many cases the formal process situation is a genuine representative of more essential approaches to decision-making, which are not necessarily attached to specific current procedures. These approaches are addressed in this thesis. This is the reason why the recommendations for implementation of the suggested technique (see Chapter V) are stated in general terms, and suggestions for specific changes in the current directives and instructions are avoided. It is true also, as mentioned by some of the questionnaire's commentators [Appendix A, p. 164], that the "DSARC Process" is subject to continuing revisions. But since referring mainly to the underlying approaches, the conclusion may be valid in a new acquisition decision process as well.

2. Types of Major Systems Acquisition Decisions

The formal decision points in the acquisition life cycle are identified as the four Milestones. These SecDef's major decisions punctuate a continuous process of evaluations, consolidation of sub-decisions and recommendations. At each

Milestone an authorization to proceed to the next phase is approved or disapprove. At Milestones I and II, selection of system alternatives is done as well [DOD Dir. 5000.1, 1980, p. 4]. Although any decision is "selection of particular alternative(s) from set of feasible alternative courses for resolving a particular problem" [Krajewski, 1981, p. 5], the alternatives of the Milestones decisions are of variable nature. In Milestone I a selection should be made between alternative design concepts for development, and in Milestone II between contending specified systems. Since in most cases system selection and contractor selection are equivalent, it is Milestone II at which Source Selection is directed. Milestone III decisions usually do not deal with alternative concepts or systems, but rather with a single system. Here the alternatives are mostly variations in the acquisition strategy, i.e., trade-offs between performance, cost and schedule. All other factors are in most cases already determined. Milestones I and II type of decisions,[1] are those in which selection between different system concepts (e.g., MX missile vs. B-1 bomber) or between different systems of the same concept (e.g., F-16 vs. YF-17) is done, and a broad spectrum of factors may still affect the decision. These are the decision types which the suggested technique (which is later

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[1]The word "type" is emphasized since the statement relates to any decision at any level which meets the characteristics of Milestones I and II decisions. (Recall the author's approach to his analysis is not to relate it to any specific current decision process, which is subject to change.)

introduced) focus on. But, of course, it is by no means restrained only to this type of decision. Being a flexible and adjustable device it can handle other decision types as well.

3. Acquisition Decisions As Multi-Objective Decisions

The previous section related mainly to the multiple alternative nature of the acquisition decision. This section highlights the multi-objective nature of those decisions. A broad scope of objectives must be achieved by top-level decision-makers. Some of the major objectives are:

(1) Maximize[1] military effectiveness.

(2) Minimize cost.

(3) Maximize technical utility.

(4) Maximize internal and external political benefits.

(5) Maximize social and economic benefits.

These objectives are in fact subdivided through several levels in an hierarchical order, as presented in more detail in Chapter V. The complexity of the acquisition decisions is not measured solely by counting its objectives. An examination of the formal process reveals how many items, factors, and criteria may be taken into account. For example:

(1) The Decision Coordinating Paper (DCP) which provides the primary documentation for use by the DSARC in arriving at the Milestone recommendation [DOD Inst. 5000.2, 1980, p. 6]

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[1]The term "objective" is referred here as the "direction" in which one should strive to do better [Keeney and Raiffa, 1976, p. 34]. Consequently the words "maximize" and "minimize" indicate direction, and not specific levels of minimum or maximum as goals to achieve.

presents in its annexes a list of goals and threshold of 20 different items under categories such as cost, schedule, performance, supportability and manpower. In addition it includes a detailed table of different resources and life cycle cost (LCC) components.

(2) The Integrated Program Summary (IPS) which summarizes the implementation plan of the DOD component for the complete acquisition cycle [DOD Inst. 5000.2, encl. 4, p. 1] requires 5 mandatory annexes and 23 more issues to be addressed.

(3) A chart of major system acquisition life cycle [C&C Associate Consultants, 1980] counts 16 decision criteria for Milestones I and II.

(4) The USAF requires about 35 data items for its Milestone Reviews, consisting of a variety of areas (e.g., operational performance, technology, cost, etc., [Department of the AF, 1979, pp. 37-39]). Even if we assume that the principle of "management by exceptions" is valid here, as is the case in most top-level decision-making, still the examination of the various data items in light of the various criteria and objectives in order to reach the ultimate decision, is a very difficult task. The above examples relate to the formal inputs only. The task is much more difficult when informal inputs, influences, and pressures are taken into account.

The difficulties in top-level acquisition decision-making is observed not only by analyzing the formal documentation for the decision; it is also spelled out by the comments of the people involved. According to Connolly (1981),

> sometimes, when a program office comes in and gives a briefing, it is very difficult to really grasp the significant or distinguishing factors. You need your staff to be involved, to look into that in advance, to try to surface the discriminators.

But is not only a problem of grasping. It is in the first place a problem of including the relevant inputs for the decision, and according to one of the questionnaire commentators, "including all relevant decision factors is the tough part" [Appendix A, p. 200]. Muddling through the large number of pertinent factors leads to inefficiency in the DSARC process, while on one hand the reviews are not limited to key issues and many insignificant ones are raised. On the other hand, some essential issues do not get enough attention [Rice, 1978, pp. 33-34]. From the questionnaire we learn that although the respondents are moderately satisfied with the manner in which alternatives are represented and compared in the formal documentation, they indicate to a considerable extent the difficulty in making the final decision, despite the refining process prior to the top-level decision-making. According to Dr. LaBerge (1981),

> ...no serious comparison between alternatives can take place for most programs under the existing methodology.[1]

As a symptom of weakness in the decision-making, LaBerge points out that,

> In fact, the actual decision made by the senior defense officials is to approve or disapprove the

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[1]To soften this statement LaBerge comments that "there are exceptions for some major high visibility programs such as MX missile where top management can obtain an independent assessment from high level review groups such as the"Defense Science Board" [LaBerge, 1981].

alternative recommended by the Service, rather than select between alternatives.

This tendency, which is supported by the questionnaire findings [Appendix A, pp. 172-173] might be a wise decision tactic unless, as in many cases, it is caused by the fact that

> ...most people in the decision process neither have studied the problem in detail, nor had an easily understood impartial breakout of the issues. [LaBerge, 1981]

4. The Credibility of the Decision Alternatives Presentation

Problems of the present acquisition decision-making are not derived only from their complexity as being of a multi-objective nature. A severe criticism about the decision presentation objectivity, the alternatives credibility and the extent of the decision-maker real decision option repeatedly appears in the comments of the people involved. Some citations that illustrate the above mentioned notion include:

> ...the selection is never less than clear-cut...The Service assures this...The real alternatives generally do not appear--only strawmen.... [Appendix A, p. 170]

> The arguments and evidence are usually structured to support the Service selection and to present the decision in the most "clearcut" form permitted by the facts...By the time such reviews are held at the highest levels for all practical purposes the selection has been made and any other choice or selection is very difficult to affect... [Appendix A, p. 170]

> Alternatives other than the preferred alternative are evaluated to gain perspective on the preferred one. There is virtually no probability any other will be selected. [Appendix A, p. 172]

> In many cases alternatives besides the recommended one are presented to satisfy formality...The

process is too far committed to permit reversal of the Service position. [LaBerge, 1981]

These quotes clearly speak for themselves and do not require further interpretation. Even if we consider that they do not apply to all cases, and do not represent all views, still they are serious enough to be taken into account in searching improvement of the present situation.

B. THE DIAGNOSTIC APPROACH TO DECISION-MAKING: A DETAILED PROCESS ANALYSIS

1. The Diagnostic Approach--An Overview

The previous section examined the present acquisition decision-making situation from general aspects. The rest of the examination dealing with more detailed characteristics, will be done through the diagnostic approach to decisions. According to this approach, decisions are examined in terms of their process and structure [Keen, 1978, p. 61]. The examination of the decision process will be classified according to five main schools of thought which are found in the literature on decision-making. These are:

(1) The rationalistic view.

(2) The satisficing view.

(3) The organizational procedure view.

(4) The political view.

(5) The individual differences perspective. [Keen, 1978, p. 63]

Each of these schools suggests that its view should be the dominant aspect in examining a decision process, and any

suggested decision-making methodology should mainly apply to this aspect, and concentrate on resolving problems derived from it. But in fact, in complex decisions all those aspects play a significant role, and any decision methodology aimed to improve such complex decision processes should take into account requirements derived from all those views. That is the strategy to be used in our case as well. Thus, the coming sections will analyze the present acquisition decision process in light of the above mentioned five schools of thought.

2. The Rationalistic View

a. The Theoretical Definition

This is a normative view in which the decision-maker is assumed to select the most efficient alternative, that is, to maximize the amount of output for a given input. The decision criteria are predefined and the objective can be formulated in a quantitative manner. The rationalistic methods maximize the expected utility in situations where there is uncertainty of events and outcomes. In both instances there is an "objective" method of arriving at a solution: given a set of consequences and one's utility function, the choice is automatic. This approach assumes a rational, completely informed single decision-maker [Keen, 1978, pp. 62, 64-65]. As evidenced by Keen, proponents of cost-benefit analysis adopt this approach. The main shortcoming of this approach is that once one defined the "rules of the game", he is bound to their mechanical-computational results. Or as Simon (1957, pp. 241-260) put it, the logic and results of the optimal

choice remain, even where they are descriptively unrealistic. But even the opponents of this approach do admit that it is of value in highlighting central variables in the decision-making, and enabling good communication among the people involved [Keen, 1978, p. 64].

b. Quantitative Techniques in Use for Assisting Acquisition Decision-Making

At the foundation of the rationalistic approach rests all sorts of quantitative models. The questionnaire reveals relatively low propensity to use quantitative models, or techniques to support top-level acquisition decisions. If they are used, they are always severely limited, using very few factors as the only basis for comparison [Appendix A, pp. 174-177]. Quantitative techniques are hardly used as an overall evaluation means in the support of high level decisions. But they are broadly used in lower levels to calculate various complex but measurable unit-dimension factors, such as cost, performance, reliability, maintainability, manpower and the like. In his response to the questionnaire, a program manager writes:

> At the program level we tend to do little modeling outside the engineering domain, where we get good correlation factors. Objective modeling forces discipline but is not our tool in decision-making. [Appendix A, p. 181]

Among others, the specific technique that lies at the center of this thesis, the Multi-Attribute Utility Theory (MAUT), is used on some occasions in the acquisition evaluation and decision process. Moreover, it handles not

only measurable dimensions, but also subjective ones--however on a realtively narrow scope. It is used, for example, as one of the cornerstones of the Mission Operability Assessment Technique, (MOAT). This technique is an evaluation methodology that measures the operability of a system, or subsystem, in terms of operator tasks performed during mission. It is implemented in the test and evaluation of the F/A-18 [Pacific Missile Test Center, 1979]. But the results of this technique are obviously not an overall evaluation.

A broader scope of MAUT implementation is observed in the Source Selection procedure. Here the proposals are evaluated through a hierarchy of factors and subfactors, whose top-level categories consist of:

(1) General quality and responsiveness of the proposal.

(2) Organization, personnel and facilities.

(3) Technical approach.

(4) Cost. [Procurement Associates, 1972, pp. XVIII-13--30]

But this is also not comprehensive enough to base a major system selection on, as mentioned by the above source itself (p. XVIII-30):

> For large programs, the final choice may be made at the top of the agency level, or in the case of major weapons systems at the Department of Defense level, after evaluation by many subordinate groups. The technical and cost evaluation is only part of the consideration. The industrial mobilization requirements and the effect of the award of the contract on the cost of related Government contracts are only a few of the many factors that must be considered. [The underlines made by the thesis author, R.G.]

Another version of evaluation procedure for Source Selection is introduced in a newer source--the Navy Program

Manager Guide [Naval Material Command, 1980, pp. 2-27--2-33]. Here the top-level categories are:

(1) Life Cycle Cost,

(2) Contractor evaluation,

(3) Effectiveness.

(See Figure II-1.) But again, the scope is still too narrow for an overall evaluation since it excludes factors such as political, economic, social, environmental, etc., which undoubtedly have significant impact on major systems selection (though the extent depends on the case). The evaluation approach chosen by the Navy's Source Selection procedure fully correlates with the basic premise of this thesis. Its only "disadvantage" is that it is contract-oriented and not necessarily ultimate "in-house" (within the DOD top-levels) selection-oriented. Hermann (1981) emphasizes this notion by indicating that Source Selection evaluation procedure is needed primarily to conduct the relationships between the Government and potential contractors.

> It is a requirement of the contractual world to have a deterministic kind of means for choosing between competitors. But high levels, who look for the right thing to do, do not have this constraint.

Hermann means that top-level does not have to use the same procedure in their decision-making (he advocates not to use quantitative models at all). But the ultimate decision, using different evaluation procedures and more important, based on significant considerations which are external to the Source Selection evaluation, should not necessarily correlate

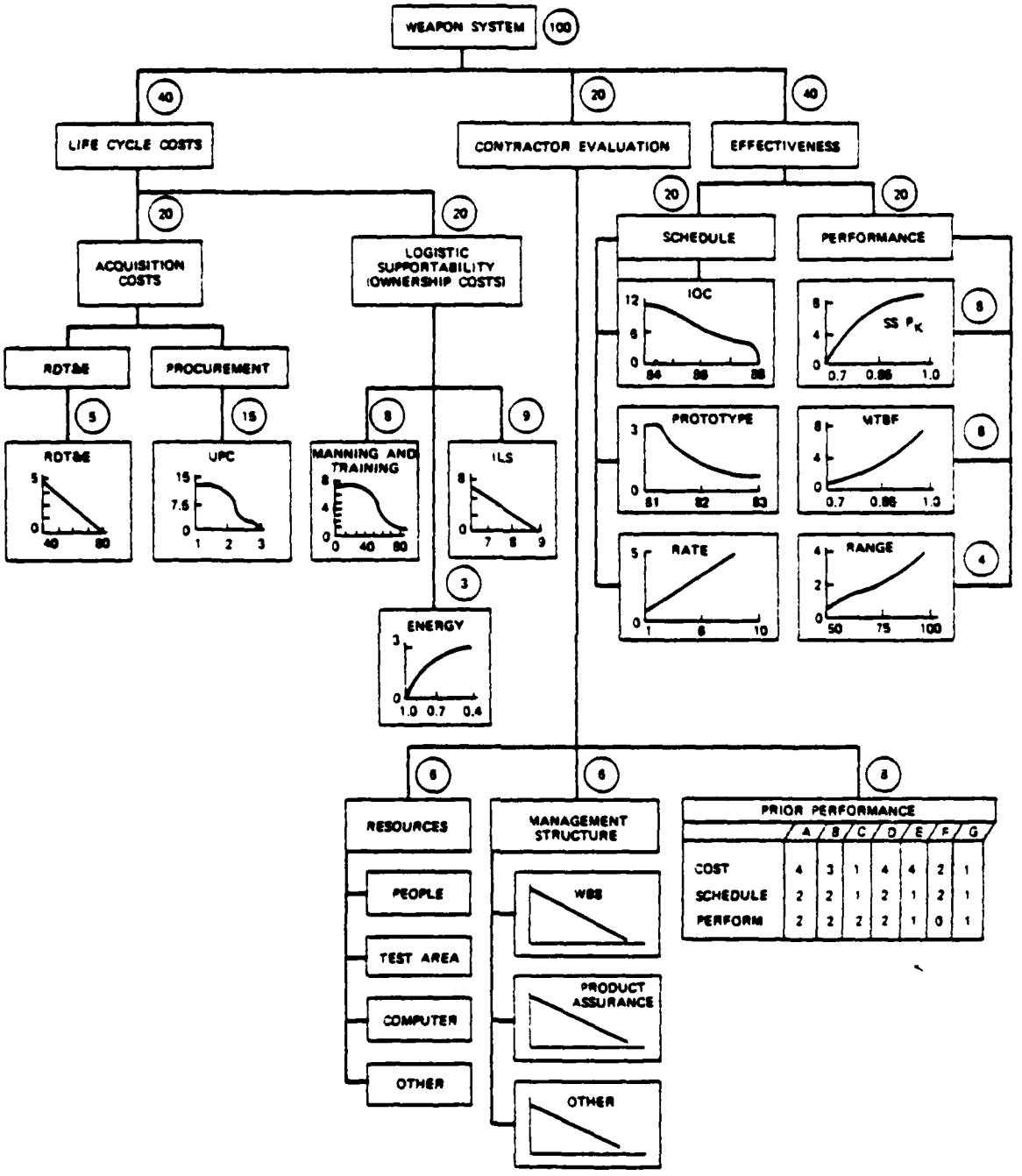

Figure II-1. Structuring and Weighting Evaluation Criteria for Source Selection (taken from Navy Program Manager Guide [Naval Material Command, 1980])

the Source Selection outcomes. That might be the case especially with major systems selection, in which political and similar factors play an important role. Since Source Selection procedure can be a basis for a legal suit, the possibility of conflicting ultimate decisions puts under question the very usage of this formal procedure for major systems selection. Thus, the existing Source Selection evaluation is not only short of being a top-level decision-making tool, but it also contains an inherent "catch," which questions its usefulness even as a Source Selection tool for major systems (at least for those which are politically or socio-economically sensitive).

A view from another angle on the use of quantitative decision techniques is noted by one of the questionnaire's respondents, referring to the (S)SARC's review sessions:

> The AFSARC does not use models for decision-making directly. We are, however, briefed on the use of decision aids and quantitative methods used by the staff in developing recommendations. [Appendix C, p. 179]

It seems that this is the case in most top-level decision-making occasions, in which no overall evaluation technique centers the decision-making, not to speak of any kind of interaction between the decision-maker and this assisting technique. In spite of all that has been said above, there are some "candles in the dark." One of them is found in the Navy Program Manager's Guide [Naval Material Command, 1980, pp. 3-22--3-25]. This guide does not only present MAUT model for Source Selection, but it also suggests using a similar model for risk management.

This tool is supposed to be used by the program manager and his staff in evaluating program alternatives which involve limited information and uncertainties. The suggested model includes a considerable element of subjective judgment. But no word is said about using that model for the major decisions, and no involvement of high-level decision-makers in the model construction or its parameters elicitation is mentioned. It is perceived as sort of an "in-house" tool. If one judges from the responses of the two program managers from the questionnaire sample, the actual use of such a mechanism in the program office is very limited [Appendix A, p. 181]. Another example is presented in the technical report "Decision Analysis of Advanced Scout Helicopter Candidates" [Decisions and Designs, 1980], ordered by the U.S. Army Aviation Research and Development Command to support its position at ASARC. This report contains an analysis of thirteen Advanced Scout Helicopters (ASH) candidates and some mixture of those candidates. The analysis evaluates the candidates on the basis of a wide scope of factors of which the top levels are: military worth; life cycle costs; attainability, force structure and personnel impacts, and RSI impacts [Decisions and Designs, 1980, p. 11]. This technical report uses MAUT as its evaluation methodology. It is based heavily on subjective judgments and refers sparingly to political and economic considerations, as expected from a model being developed for the Service level. But the basic approach is exactly the one this thesis advocates to be used also in

decisions made above the Service level. There would be no requirement for this thesis if such models were customarily used for top-level decision-making. But research done for this thesis indicates that they are not. Furthermore, there is considerable reluctance towards using such models. At the least, there is concern over improper implementation and biased models' construction. The remainder of the Advanced Scout Helicopter case illustrates the above statement. In a phone-talk to Michael Donnell (1981), one of the two authors of the referred-to report, the following facts were acknowledged:

(1) The analysis team worked exclusively with the program manager, a Colonel, and his staff, and did not interact with other higher levels of participants or the actual decision-making group members.

(2) The Colonel "knew exactly what he and his boss wanted," and, in some cases, determined the construct of the model that was in conflict with the analysis team's opinion. That caused some insignificant value-dimension to be located at the top of the hierarchy, while others, perhaps much more important, receive inappropriately low location. [The last comment is not a quote, rather the thesis authors' interpretation. R.G.]

(3) Eventually the decision that has been made was other than that recommended by the model "because of budget constraints that arose, and the 'politics' of the decision-makers who had strong prior views about the selection, which could hardly be affected by the model's analysis." In an answer to a question, Donnell said that in theory both elements--cost

changes and participants views--could be included in the model but (a) The analysis has been kind of a "one shot" type, and therefore, has not been up-dated according to, say, cost constraints that were not originally taken into account; (b) The analysis team had not, in fact, access to the decision-group members, and thus their views revealed only at late stages, when the analysis and its use got out of the teams control; (c) The analysis was supposed to be mainly cost-effectivess related, and, thus, intentionally did not put great emphasis on all kinds of politics-related aspects.

The deficiencies observed in this case can be summarized as follows:

(1) Improper representation of participants involved in the decision.

(2) Biased model structure.

(3) Although broader in scope than most models used, still limited for presenting comprehensive evaluation for the final selection.

(4) Discontinuity and lack of evaluation model updating. These deficiencies are repeated in many examples through the thesis. The conclusions of this case will be addressed among the rest in implementation, analysis, and recommendations (see Chapter V).

The questionnaire verifies the observation that models or other sorts of quantitative techniques are used only to a small extent to assist top-level acquisition decision-making, and whenever they are used, they are of limited scope

[Appendix A, pp. 174-178]. Furthermore, a considerable number of the respondents admit that they have never used a quantitative model for acquisition decisions of any kind at any level [Appendix A, p. 184].

c. Reservations of Quantitative Techniques as a Top-Level Acquisition Decision-Making Tool

The first and foremost reservation of quantitative techniques as an overall evaluation and comparison means for acquisition decisions, is the substantial doubt about their ability to handle subjective, intuitive, judgmental considerations. Trimble (1981) notes as an example the MX missile case, in which he points out the political, environmental and sociological impacts associated with its basing concept, as such, "do not lend themselves to any type of predictive quantitative model." But it is not only a matter of the issues under question, it is also a matter of the decision-makers themselves who, as described by Trimble, are "very capable and experienced people, but usually unstructured individuals, who do not follow 'a rule of bock'. How would they be willing to associate themselves with a structured decision process?" he asks.

Even more extreme in his aversion toward quantitative decision techniques is Hermann (1981), who says that a lot of subjective factors are not amenable to numerical treatment. Hermann says:

> I always found it difficult philosophically to understand, how a decision-maker could submit himself to a deterministic formula, in a decision which is fundamentally imbeded in highly subjective factors.

Part of this approach is supplemented in the literature. For example, Quade (1979, p. 10) in his book, Policy Analysis for Public Decisions, which basically advocates quantitative decision techniques, warns:

> ...there are always considerations that cannot be handled quantitatively, maybe not analytically, or even systematically, and there may be problems with no solution. In the end, politics and intuitive judgment must rule.

Question 10 of the questionnaire addresses this very issue, stating that "there is no use for a decision-making model to support top-level decision-makers, because they base their judgment mainly on subjective experience, perception and intuition, which cannot be rationally "managed." The opinions about this statement are split: 43% agree with the statement and 51% disagree, and 5% have no definite idea [Appendix A, pp.181-184].

Edwards (1981) agrees with the observation that acquisition decisions are fundamentally subjective, but he also thinks that there is a fundamental misconception with respect to quantitative techniques, at least as far as MAUT is concerned. His explanation of the deep reservations that the above quoted people have towards those techniques is that the standard kind of models they have been exposed to were either performance models, or cost-benefit models. While performance models deal with objective issues almost explicitly, the traditional versions of the cost-benefit models reduce everything to dollar units, which certainly takes the subjectivity out. According to Edwards, the respondents are just unfamiliar with techniques which are especially designed to

handle subjective judgment and intuition (though by no means to replace or generate them). To conclude, it should be stated that inspite of the reservations, all the interviewed officials and the questionnaire's respondents do see some degree of merit in a specified use of quantitative model as a decision aid. This premise will be introduced in more detail in the following chapters.

Another objection to quantitative techniques is attributed to the previously mentioned biased alternatives' presentation. As it is put bitingly by one of the questionnaire's commentators,

> ...use of such a model is phony as a 'three dollar bill! It's a travesty on honest quantification...The use of a model by the Service makes everyone feel better and maintain the area of 'objectivity'. It has nothing to do with the Service choice. [Appendix A, p. 184]

Others warn against the possibility of a model structured to support a previously selected alternative [Appendix A, p. 184].

Another worry about usage of decision models is expressed by the following quote:

> ...if a decision-maker embraced a model, but then disagreed with the model outcome he may be baring his belly to his foes. [Appendix A, p. 206]

But Edwards (1981) observation that, in most cases, decision-makers are not so insecure, is supported by the majority of the questionnaire respondents, who do not view this possibility severely enough to cause them to refrain from using decision models [Appendix A, pp. 206-211].

Finally, it should be emphasized that the purpose of this section has been to disclose problems, weaknesses and

difficulties in quantitative decision techniques. Therefore it addresses the criticism and apprehension towards them. But there were also positive reactions which are introduced later in this thesis.

3. The Satisficing View

a. The Theoretical Definition

This approach focuses on how a decision-maker can most effectively use limited knowledge and skills [Simon, 1957. pp. 241-260]. It highlights the constraints imposed by "bounded rationality," the emphasis on heuristic "rules of thumb," and searching for solutions that are "good enough." This approach is based, in most cases, on a descriptive model of the decision process. The goal is to improve the existing solution, "not to vainly seek for an optimum."

b. Application in the Acquisition Decision-Making

It seems that in many of the present acquisition decision-making the satisficing view is the prevailing approach. Connolly's (1981) description of his own pattern of thought during a decision event applies to a great extent to this approach. Hermann's (1981) clear preference of a descriptive decision model, "a clear logic in our natural language," corresponds to the satisficing approach as well. But some questions are raised: is the satisficing selection sufficient for critical decisions? Do decision-makers really reach the bounds of their "limited knowledge and skills"? The answer of this thesis to both of these questions is "no". There can be ways to achieve more than just "good enough" decisions.

There can be a technique with which decision-makers would be able to better exploit their own knowledge and skills to reach a decision based on the data presented to them.

4. The Organizational Procedure View

a. The Theoretical Definition

This concept of decision-making seeks to understand decisions as the output of standard operating procedures invoked by organizational subunits. The emphasis is on the formal and informal structure of the organization, its standard operating procedures and channels of communication [Keen, 1978, pp. 63,69-70].

b. Application in the Acquisition Decision-Making

It is clear that for major systems the final choice made by the SecDef is based on evaluations made by many subordinate groups [Procurement Associates, 1972, p. XVIII-30]. LaBerge (1981) says that,

> ...for most programs top-levels inevitably must rely upon evaluations done by their subordinates, and this is passed down to the middle levels of the Services, where the motivations are influenced much more by capability than by cost.

The reliance on lower levels mentioned by LaBerge, is challenged by the questionnaire's respondents in Q7 [Appendix A, p. 170] where 54% disagree with the statement that "the less the selection is clearcut, the greater is the decision-maker's tendency to rely on lower level analysis and recommendations." But yet, a significant portion of 35% think to the contrary. In any case, it is quite obvious that, as noted by one of the questionnaire respondents,

> ...staff members can be very influential in their principal's ultimate decision by carefully structuring and selectively presenting the alternatives. [H-2]

This brings us back to the notion of biased presentations and false alternatives ("strawmen") mentioned at the beginning of this chapter. This emphasizes a "fact of life," that through the inevitable organizational-hierarchical pattern of the decision process, interest groups may try to influence the decision to their side. That can be done in the worst case by "a hatchet job done on the alternatives" [Appendix A, p. 170], or by a genuine perception which does not necessarily correlate with that of the decision-maker. As an example of the latter can be taken LaBerge's observation that the services attribute much more importance to capability (performance) than to cost. This observation, although strongly rejected by the Services (for example, by Fellowes (1981)), is supplemented by a Report To The Congress by the Comptroller General (1979), stating that,

> ...there are many programs where extraordinary performance requirements have been the driving force behind high costs.

The controversy is further disclosed by a somewhat cynical comment made by one of the questionnaire respondents:

> ...quantitative rationale for the decision could be most useful in countering accountants budgeteers and other non-operationally experienced, but nonetheless influential decision-makers. [H-2]

This presentation of the problematics in the real life decision process correlates to the "classical" deficiencies attributed by the literature to decision procedures, as observed

through the organizational view. These deficiencies are:

(1) Parochial perceptions and group pressures.

(2) Inflexibility and adherence to routine procedures.

(3) Losing the overall picture by breaking decisions into small pieces.

(4) Sequential attention to goals, according to the organization's routine. [Keen, 1978, pp. 63,69-70]

These deficiencies should be addressed in any suggested improvement to current decision practice.

5. The Political View

a. *The Theoretical Definition*

According to the political view, decision-making is viewed as a bargaining process between the formal and informal organizational units and personalities. A premium is placed on understanding the realities of power and on the compromises and strategies necessary to mesh the interest and constraints of the "actors" in the decision process [Keen, 1978, p. 63]. Political aspects of a decision can be leveled in three tiers:

(1) The personal tier, in which personalities affect the decision. For example, a strong, charismatic person, equipped with good bargaining skills, confidence, and quick reaction may influence a decision towards his desired direction.

(2) The organizational tier, in which bargaining and power-play take place between organizations or groups of participants (e.g., the Services, OSD, Industry, Congress and others).

(3) The national tier, in which national political interests are involved.

b. Applications in the Acquisition Decision-Making

No doubt, all three tiers of the political view apply to the acquisition decision-making process. The role of the personalities involved is clearly described by one of the questionnaire's respondents:

> The personnel experience, and preferences of senior officials in key positions, plays heavily in the decision process...The skills of the program sponsor to communicate the value of his program has great impact on the decision. [Appendix A, p. 183]

Another respondent, referring the usage of models in review sessions, states:

> The review sessions are never so emotionless as to deal with a dispassionate review of alternatives... The model will be totally perverted. It is not an issue of models--it's a matter of power and emotion! [Appendix A, p. 177,183]

Fellowes (1981) describes the frustration feeling experienced sometimes at the Service level, while viewing a "pure," well-defined weapon system diverted from its original requirements as a result of political pressures. But he also agrees that there is no way to keep politics out, since it is an inherent component of the decision process. Trimble (1981) counts the politics as one of the three prominent considerations in top-level acquisition decisions, together with the need and the cost.

Hermann (1981) realizes the weight of the personal politics relative to the direct elements of the decision by defining the AFSec acquisition decision sessions as a "very

complex social event, but a very simple information event. The information conveys are very crude and primitive." The questionnaire resondents estimate out of 57 systems acquisition cases that on the average, the political and socio-economic issues weight about 50% of SecDef acquisition decision considerations. This weight, though gradually reducing to match the decision level, remains substantial even in lower levels [Appendix A, pp. 231-236].

The previous paragraphs reflect the impact of political considerations on the acquisition decision. These considerations are an integral part of a democratic process, and thus cannot and should not be taken out of it. The decision-maker should strive for an objective decision in the sense that it represents unbiased public values. A "public value" is assigned to an outcome by a public, usually by means of some public institution that does the evaluating. This amounts to treating "a public" as a sort of organism whose values can be elicited by some appropriate methods already in use to elicit individual values. From this point of view, the decision-making is associated with finding the appropriate adaptation of those methods--an adaptation that will take into account the individual (or grouped) disagreements, individual (or grouped) differences in relevant expertise, and the existing socio-political structures [Edwards, 1977, p. 248]. In other words, the political power play should affect the decision in a balanced, objective and ordered manner as much as possible. The various interests should be properly

represented, and differences variation in resulting decisions stemming from personalities should be reduced.

6. The Individual Differences Perspective

a. The Theoretical Definition

This perspective concentrates on the individual decision-maker and his, or her, probelm solving and information processing behavior [Keen, 1978, p. 63]. There have been two broad approaches in the individual differences perspective:

(1) The cognitive complexity, which argues that there is an optimal balance of information input for any one individual.

(2) The cognitive style, which emphasizes the style of the information and the decision process. For example, "systematic thinkers" tend to approach a problem by structuring it in terms of some method which if followed through leads to a likely solution (that corresponds to the previously mentioned rationalistic view). On the other hand, "intuitive thinkers" usually avoid committing themselves in this way; their strategy is more one of hypothesis-testing and trial and error [McKenney, 1974, p. 81].

b. Applications in the Acquisition Decision-Making

The cognitive complexity approach suggests that the amount of information presented is unique to any individual decision-maker. But dealing with top-level decision-makers, one basic need is almost common for all, and that is--simplicity. Edwards, for example, through years of developing his MAUT concepts puts a great emphasis on the simplicity of his technique (see for example Edwards (1971, pp. 119-129; 1977, p. 250) and

Edwards and Newman (1980, Executive Summary, p. 1)). While it lacks the theoretical elegance of techniques proposed by, for example, Raiffa (1968,1969) or Keeney (1972), it has the great advantage of being easily learned and used by a busy decision-maker or member of decision-making staff or organization. Keen (1978, p. 97) describes a desired managerial decision model as being "very simple and crude, rather than mathematically sophisticated. It is often based on heuristic rules and standard procedures for analysts."

Connolly (1981) requires a decision model to be uncomplicated and easy to understand. Hermann (1981) reveals a special aversion towards computerized decision models: "My own experience," he says, "is that a lot of computer models tend to destroy the intuition you have left." He is supported by one of the questionnaire's commentators, who says that "the structured decision process is a useful tool... but it must emphatically not be plugged into a computer..." [Appendix A, p. 227]. Thus, any decision presentation to top-level decision-maker(s) should be easy to grasp, even by people whose expertise is not necessarily in the very details of the system alternatives or in sophisticated modeling procedures. Models that have their logic "hidden" within a computer or can be understood only by the experts who built them, have a little value for top-level decision-makers, if any.

The cognitive style approach is reflected in several written comments to the questionnaire as well as in the interviews. According to those comments, any decision technique to

be used must not only be acceptable to the final decision-makers, but also be brought in at early stage in time to be modified by their comments, and to assure data base etc., is organized to their "taste" [Appendix A, p. 227, and Connolly, 1981].

C. CHAPTER CONCLUSION

1. General

As a conclusion of this chapter a list of requirements for a desired decision technique is presented. This may be considered as a guideline in searching for such a technique, or as a check-list in examining a proposed one. The list accumulates requirements from all views of the decision-making process in order to exploit their individual advantages, and avoid or reduce their weaknesses. In that sense, these are requirements for some hypothetical, ideal, and probably utopian decision technique because no technique can satisfy them all. Furthermore, not everyone would accept all these requirements as desirable. However such a list can serve as a good basis to start the search for improvement in the current decision process.

2. A List of Requirements from a Decision Technique

a. Requirements Elicited from the General Nature of the Acquisition Decision-Making

The decision technique should:

(1) Take into account the informal decision process and actors, as well as the formal ones.

(2) Be capable of handling multi-objective and multi-factor decisions.

(3) Focus on the significant issues, scan the less significant, and eliminate the irrelevant ones.

(4) Improve the decision-makers' capability to evaluate and select between the decision alternatives.

(5) Reduce biases in decision presentations, and increase objectivity of alternative presentation.

(6) Maintain continuity and evaluation model's updating.

b. Requirements Elicited from the Rationalistic View

The decision technique should:

(1) Be a comprehensive means for overall evaluation.

(2) Be quantitative by nature but maintain the capability of handling subjective, intuitive and judgmental considerations.

(3) Be implemented in such a way that will reduce the probability of the model being used to counter the decision-maker.

c. Requirements Elicited from the Satisficing View

The decision technique should:

(1) Use descriptive elements and "rules of thumg," especially for the judgmental components of the technique.

(2) Exploit to the maximum the knowledge and skills of the decision-makers.

d. Requirements Elicited from the Organizational Procedure View

The decision technique should:

(1) Reduce the dependence of top-level decision-maker on lower level evaluations.

(2) Spell out the importance-weights attributed to various factors at lower levels (and by that, perhaps, disclose some of the intentional and unintentional biases in the decision presentation).

(3) Exploit the organizational structure for partial and intermediate evaluations and decisions, but make sure that they are consolidated to an overall picture at the final decision phase.

e. Requirements Elicited from the Political View

The decision technique should:

(1) Give an "equal right" of representation to the various people and organizations who have stakes in the decision.

(2) Articulate political interests, including "selfish" ones.

(3) Compensate for personal differences in charisma, bargaining skills or presentation talents.

f. Requirements Derived from the Individual Differences Perspective

The decision technique should:

(1) Be simple and intelligible.

(2) Have sound and visible underlying rationale.

(3) Be acceptable to the decision-maker, and directed by him from the early stages.

These requirements will provide guidance in the search for an actual decision technique and its implementation in top-level acquisition decision-making.

III. SEARCH FOR DECISION METHODOLOGY

A. THE BASIC APPROACH TO THE SOLUTION

1. The Essential Dilemma

The essential underlying dilemma in the search for top-level acquisition decision-making methodology is whether or not the key approach should be quantitative. The reservations towards quantitative techniques as an overall top-level evaluation device have been introduced in detail in Chapter II.

At the core of those reservations rests the lack of confidence in the capability of quantitative techniques to incorporate subjective judgment. The ultimate conclusion is not to use quantitative techniques at all as a comprehensive decision basis. Hermann (1981) supports that idea:

> I am not favorably impressed with complex modeling as a basis for important weapons systems decisions. A clear logic in our natural language is the most important and preeminent need.

But there are opposing opinions as well, such as LaBerge's (1981), who says:

> The principal difficulty is that the selection of alternatives has little quantitative basis, which could be disputed...A quantitative decision tool is absolutely desirable, and might bring about an essential change in the quality of the acquisition decision-making.

Thus, it is this issue of whether or not quantitative techniques are compatible for top-level acquisition decision-making, which this section concentrates on. Special attention

is paid to the subjective judgment handling capabilities of those techniques.

2. The Role of Judgment in Acquisition Decisions

Keen (1978, pp. 86-87) divides decisions into three categories:

(1) Structured.

(2) Semistructured.

(3) Unstructured.

A similar term (well-structured, moderately-structured, and ill-structured) are used by Dunn (1981, pp. 103-105) in specifying public policy problems. It seems that acquisition decisions fall somewhere inbetween the second and the third categories of problems as defined by the two above mentioned authors. They fit Keen's definition for semistructured decisions very well, i.e., "decisions where managerial judgment alone will not be adequate, perhaps becuase of size of the problem or its complexity. On the other hand the model or data alone are also inadequate because the solution involves some judgment and subjective analysis." But the acquisition decisions and especially their political aspects, may fit as well Dunn's definition for ill-structured public policy problems, in which the main characteristics are "conflict among competing goals, and decision-making which involves high levels of conflict among competing stakeholders" [Dunn, 1981, pp. 104-105]. The acquisition decisions in many cases also fit Dunn's definition for moderately-structured problems, since they are usually involving one or few decision-makers, and a

relatively limited number of alternatives. Dunn's characteristic of moderately-structured problems, which views these problems as "reflecting consensus on clearly ranked goals" [Dunn, 1981, p. 104] can be achieved in some cases. Although the starting point is usually the conflicting attitudes upon values, after some iterations of interaction with stakeholders, an agreement or even consensus may be achieved. The last statement is approved by Edwards (1981) who reached in some practical occasions through face-to-face interaction, stakeholders' general recognition of a single "value tree"[1] as being a fair representation of their perceptions. In the acquisition decisions some of the factors are completely structured and objectively measurable, some require subjective judgment imposed on objective data, and some consist of pure judgmental, intuitive analysis. At the top-levels the latter have a considerable relative significance. Some people involved in the actual decision-making process emphasize this relative high significance of judgment by saying, "...Most decisions are fundamentally subjective..." [Hermann, 1981], or "...In my experience most, if not all, acquisition decisions are a matter of judgment" [Appendix A, p. 203]. The role of judgment in the acquisition decisions fits Keen's (1978, p. 97) observation about the role of judgment in semi-structured decisions:

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[1]This term will be defined in Chapter IV, p. 79 - 81.

> The judgement is necessary either to recognize or decide what constitutes the problem, or to create alternatives, or to choose a solution. The judgment may define the nature of the variables that are considered or the values that are put on the known variables.

3. Compatibility of Quantitative Techniques For Top-Level Acquisition Decision-Making

As a consequence of the previous section's analysis, the first thing to do is to look at the capability of quantitative techniques to handle judgment. Peck and Scherer (1962, pp. 543-580) approached the issue of weapon system performance evaluation empirically. They asked whether "it is possible to combine these diverse considerations into a single conceptual scheme which permits us to evaluate the overall effectiveness of a weapon program." Their analytical conclusion was that measurement in the conventional sense is impossible, but it may be possible to determine which program is better executed than others and thus to establish a ranking of programs from best to worst. They recognized that ranking poses a basic theoretical problem since weapon programs performance "is presumably multidimensional." Their answer was that "somehow the numerous dimensions underlying programs performance must be weighted and combined if a unidimensional ranking is to be obtained." Through their experiment Peck and Scherer proved that, based on judgment only, the individuals of the control group were able to express their preferences and importance weights consistently and to express them in numerical terms. Keeney and Raiffa (1976, p. 40) cite another example of a similar experiment done by Huber, Sahney and Ford

(1969, pp. 483-489), who concluded that the results strongly indicated professionals could develop and reliably use subjective evaluation models. This is not to say that every human intangible consideration involved in a decision can be quantified. Rather, the major consequences of these considerations may be quantified in terms of ranking order and relative impact on the decision. As mentioned by Keeney and Raiffa (1976, p. 40), "the literature in psychometrics is replete with examples that establish such scales of subjective index." The above mentioned experiments support Edwards' (1981) confidence in techniques especially designed for handling subjective judgment such as MAUT. His confidence is based on a considerable experience of himself and others. According to Edwards, letting the decision-maker create his own parameter estimates is appealing on an intuitive basis. It gives the decision-makers a feeling that they have more control over the process. Additionally, Dawes and Corrigan (1974) show that these estimates compare favorably to those derived empirically in regression models.

By ruling out the obstacle of the "prejudice" about quantitative techniques incapability of handling subjective judgment, the way is open to exploit the generally agreed advantages of those techniques, i.e., being a means for rigor, discipline and communication in complex decisions. Furthermore, Edwards and Newman (1980, Chapter 1, p. 3) emphasize that the willingness to accept subjectivity into evaluation, combined with the insistence that judgments be numerical,

serves several useful purposes: First it partly closes the gap between intuitive and judgmental evaluations and the more quantitative kind; it makes coexistence of judgment and objectivity measurement within the same evaluation easy and natural. Second, it opens the door to easy combination of complex concatenations of values. For example, it bridges over the distinction often made by researches between process evaluation and outcome evaluation. Third, it can greatly shorten the time required for an evaluation to be carried out.

But a question is still valid: assuming that quantitative techniques <u>are</u> capable of handling subjective judgment--are they really required and desired for top-level acquisition decisions? Recall LaBerge's response to this question which has already been introduced in the opening section of this chapter. His strongly *favoring* attitude is sound. Other interviewees like Trimble (1981), Hermann (1981) and Connolly (1981), in spite of their reservations, think that quantitative models may have merit, and can be helpful even to decision-makers such as the Defense Acquisition Executive (DAE) or SecDef. The questionnaire respondents, although far from being enthusiastic, lean towards recognition of quantitative models as a useful decision tool, including for top-level decision-making [Appendix A, p. 194]. The compatibility of such models to acquisition decisions is much more sound from the responses that refer to a specific example of decision technique, namely MAUT [Appendix A, pp. 186-188]. Many of the reservations relate to deficiencies external to the models

themselves, such as the decision environment ("The review sessions are never so emotionless to deal with a dispassionate review of alternatives" [Appendix A, p. 177). Others refer to the actual way models are currently implemented ("The scope of models limited," [Appendix A, p. 177]), as the main flaw in models' usefulness, rather than their inherent features [Appendix A, pp. 179-194].

An indirect conclusion about the contribution to decision-making of quantitative techniques can be drawn from the review of the Israeli respondents, who consistently indicated via the questionnaire a greater inclination towards usage of such techniques, compared to their American colleagues. At the same time they demonstrate a greater confidence in their ability to "close" decisions. The linkage seems to be clear.

Several citations from the literature may contribute to the recognition of quantitative techniques as being helpful decision-making tools. Cohen (1977), an Israeli Air Force high-level officer refers to the issue of overall evaluation of alternatives in his analysis of Headquarters decision-making. Cohen suggests two methods of decision-making, both based on breaking evaluation of the alternatives into factors. One consists of weighted scores assigned subjectively to factors and then aggregated to final preference (which is basically MAUT). Edelman (1965) provides an interesting comparison of the quality of managerial decisions in a competitive bidding situation, with and without the use of a

judgment based model. In seven tests managers-plus-model won the bid, while managers alone won only three. The model was extremely simple and did little more than to assist the managers' own estimating procedures.

England (1975, pp. 435-438), dealing with selection of an adequate source of supply states:

> ...the decision to place a certain volume of business with a supplier is always based on some rationale. The art of good purchasing is to make the reasoning behind that decision as sound as possible.

These phrases precede an introduction of various types of evaluations--some objective and others subjective, which are done by separate factors. Each factor is assigned an importance rate (weight), and each alternative is scored based on each factor. The overall evaluation is derived from aggregation of the products of weight times score for each alternative separately. (Again, this is basically MAUT.)

A similar method is suggested by Archibald (1976, p. 63) in referring to high technology project evaluation. Archibald's evaluation is done according to the following guidelines:

(1) Priority factors are listed for each project with a value of 1 to 10 assigned to each factor by several key managers. These scores are summarized and compared.

(2) Using the comparative scores and other information not easily quantified, the "Project Priority Review Board" meets sequentially and agrees on the relative priority to be accorded each project. Archibald does not mention specifically a usage of factor weights, but does mention that "the relative

importance of the factors will vary, depending on the organization and the type of project involved."

The Brandaid system, designed by Little (1975), is an interactive Decision Support System (DSS) that supports the decision process in commercial marketing, planning, and estimating overall profitability. The main feature of the Brandaid system is its emphasis on the role of judgment in the decision process. Little found that managers generally have a good understanding of the dynamics of the market, or at least of the interrelationships among its components, taken in pairs. But they are not capable of determining the full interactions of different components simultaneously. Little strongly recommends using judgment obtained in an organized way from more than one person. According to Little, using a quantitative technique Brandaid encourages managers to become more explicit and analytic in their problem solving, but it still strongly relies upon their experience, knowledge base and personalized judgments.

A major conclusion of LeGrow's thesis (1976, p. 2) is that judgmental scaling techniques are presently more valuable for measuring capability of weapon systems than more computerized procedures. According to LeGrow, among those judgmental scaling techniques the Multi-Attribute utility scaling affords the best opportunity for ratio comparisons of weapons capability, as being able to handle complex phenomena composed of both intrinsic performance characteristics

and external factors, like operating environment, operator proficiency or the technological capacity of the user [LeGrow, 1976, p. 44].

A similar approach is chosen Sherwin and Laurance (1979, pp. 377-387) in their search for better methodology for arms transfers and military capability evaluation. They find that the techniques generally known as "subjective measurement techniques" are the most suitable for the task and among them the MAUT is preferred. They emphasize the judgment handling capability of MAUT by saying:

> Basing a capability measure on multiattribute utility theory capitalizes on the notion that, to date, human insight remains the most reliable means for synthesizing the interrelations among a complex set of international relations variables, and that one means of indexing an otherwise intangible concept is to tap the collective judgments of human experts. According to this notion, humans, by developing an intuitive expertise, determine what factors are salient; they interpret relevant information; and by making weighted judgments, they differentially integrate several types of information to form subjective evaluations regarding key concepts.

Quade (1979, p. 48) recognizes that for public policy questions, where social and political considerations tend to dominate, models to be used to predict the consequences of choice depend more and more directly on judgment and intuition. According to Quade, an explicit model, scientific or otherwise, introduces structure and terminology to a problem, and provides a means for breaking a complicated decision into smaller tasks that can be handled one at a time. It also serves as an effective means of communication, enabling the

participants in the study to make their judgments in a concrete context and in proper relation to the judgment of others. Moreover, through feedback--the results of computation in an analytical model or the countermoves in a game--the model can help the analyst and the experts on whom they depend to revise their earlier judgments and thus arrive at a clearer understanding of their subject matter and of the problem.

All this variety of excerpts from the theoretical literature and the "real life" experience comes to support and strengthen the actual "actors'" somewhat hesitating recognition of quantitative decision techniques as a useful tool for top-level acquisition decision-making. The following are the summarized conclusions resulting from the above citations:

(1) There are in existence quantitative techniques which are capable of handling subjective judgment (but do not generate it; this is an exclusive task for human beings).

(2) For acquisition decisions, which are of semi-structured nature, judgment based quantitative techniques might be of great help.

(3) The secondary characteristics of the quantitative models, i.e., the separation of tasks and the provision of a systematic, efficient and explicit way to focus judgment and intuition--are of crucial importance. They provide a route for tracing out the major consequences of choice.

In addition to the above three major conclusions, many of the cited sources give some clues with respect to a

preferred decision technique by pointint out indirectly or explicitly the basic concept of MAUT.

B. MAUT--THE PREFERRED TECHNIQUE

1. Limitations of the Traditional Weapon-Systems Comprehensive Evaluation Techniques

The two most prevailing weapon-systems evaluation techniques were cost-effectiveness and cost-benefit analysis. Both meet the requirement of being quantitative techniques which are widely based on subjective judgment. But they still have some significant limitations that put their fitness under question as an overall evaluation device for top-level decision-makers.

Cost-effectiveness is a form of systems analysis in which alternative actions or systems under consideration are compared in terms of two of the consequences: dolar, or resource cost, and the effectiveness associated with each alternative. The effectiveness of an alternative is measured by the extent to which that alternative, if implemented, will attain the desired objective [Quade, 1979, p. 25]. Even the definition reveals the limited scope of cost-effectiveness models. Basically, they can handle one objective, which is usually for weapon systems--maximizing the combat (operational) effectiveness. As emphasized by Quade,

> Whereas we are often able to use cost-effectiveness to rank competing alternatives for the same goal, we cannot use it to compare alternatives that seek different goals--to decide, say, the best overall use of our money when we have several long-range objectives in mind.

But the latter is often the case in early stages of the acquisition decision (e.g., concept selection at Milestone I).

Dunn (1981, p. 251) also emphasizes the limited scope of cost-effectiveness approach by saying:

> ...cost-effectiveness analysis epitomizes technical rationality, since it attempts to determine the utility of policy alternatives, but without relating their consequences to global economic efficiency or aggregate social welfare.

But again, the latter, plus political considerations (which are not mentioned here explicitly), are in many cases very crucial considerations in the major systems acquisition decisions.

Edwards (1981) views the limited scope of cost-effectiveness from the cost aspect. According to Edwards, this technique aggregates all cost components to be a unit dimension (a single figure represents all costs). But in real life people attribute different importance to different cost components and, thus, are willing to consider them separately. (For example, one who is short of cash cares more about the down payment than about operating costs although both are components of the total life cycle cost (LCC)). Presumably, this is the type of model a commentator had in mind when he said:

> ...the model [used for acquisition decisions, R.G.] is always severely limited, for example, it might use acquisition cost as only basis for comparison. [Appendix A, p. 177]

Cost-benefit is a broader-scopedevaluation technique compared to cost-effectiveness. By expressing both the benefits and costs in monetary units, the cost-benefit technique allows evaluation and comparison of programs designed to accomplish widely differing tasks, on the same unit base [Quade, 1979, p. 26]. Quade points out that the great disadvantage of cost-benefit analysis is that it is very difficult to perform satisfactorily. It is really hard to express every human benefit in dollar terms, or as it is put by Prest and Turvey (1965):

> ...one can view cost-benefit analysis as anything from an infallible means of reaching the new Utopia, to a waste of resources in attempting to measure the unmeasurable.

Dunn (1981, p. 345) supports this criticism by emphasizing that dollar amounts are not perceived as equally significant by different persons, and therefore dollars are an inadequate measure of responsiveness. (This problem of limited interpersonal comparisons often means, for example, that income is an inappropriate measure of individual satisfaction and social welfare). Edwards (1981) thinks the reduction of everything to dollar units in the traditional versions of cost-benefit models "certainly takes the subjectivity out."

In conclusion, the traditional judgment-based, quantitative decision techniques have sound limitations when used for a comprehensive evaluation of major-systems acquisition alternatives. Thus, a better technique should be looked for, as is actually done in the next section.

2. MAUT as a Most Suitable Technique

So far throughout this thesis quite a few examples of various versions of the MAUT concept have been introduced. These examples cover various areas, but all of them have much in common with system acquisition decisions, although none of them precisely covers the whole scope of factors involved in those decisions. Here is a brief reminder of the examples:

(1) The formal Source Selection procedure (see Chapter II, p. 27).

(2) Peck and Scherer's weapon systems relative performance evaluation (see Chapter III, p. 51).

(3) Cohen's decision-making method in the Headquarters (see Chapter III, p. 54).

(4) England's selection source of supply (see Chapter III, p. 55).

(5) Archibald's high technology projects evaluation (see Chapter III, p. 55).

(6) LeGrow's weapon systems capability evaluation (see Chapter III, p. 56).

(7) Helm's mission operability assessment (see Chapter II, p. 27).

(8) Sherwin's arms transfers and military capability evaluation (see Chapter III, p. 57).

(9) Donnell's decision analysis of advanced scout helicopter candidates (see Chapter II, pp. 31-33).

(10) Navy Program Manager's Guide's risk management model (see Chapter II, p. 28-29).

In the literature MAUT is distinguished by its capability of handling a variety of factors such as technical, political, economic, social, or environmental, in various types of selections between similar and dissimilar, old and new, certain and uncertain alternatives. In order to stress MAUT's versatility, here is an additional list of MAUT actual applications. Some are practical applications, others are experimental. In all these cases MAUT has proven to be capable in circumscribing a complex decision. The examples are as follows:

(1) Airport development for Mexico City [Keeney & Raiffa, 1976, pp. 436-472].

(2) Selecting nuclear power plant sites in the Pacific Northwest [Keeney & Nair, 1977].

(3) Selecting dams sites around Phoenix, Az. [Edwards, 1981].

(4) Selection between future energy supply alternatives (nuclear, coal and combined geothermal and conservation package) for Southern California [Social Science Research Institute, 1981].

(5) Land use regulation on the Californian Coast [Edwards, 1977, pp. 256-265].

(6) Planning research program for the Office of Child Development (OCD) of the U.S. Department of Health, Education and Welfare (HEW) [Edwards, 1977, pp. 265-267].

Finally, MAUT was highly preferred by the questionnaire respondents over any other decision technique for

acquisition decisions. MAUT was selected by 50% of the Americans and 55% of the Israeli's, while none of the other contending approaches exceeded 15%. Furthermore, referring to a concrete MAUT example, the respondents demonstrated high confidence in the compatibility of this technique to acquisition decisions, including at top-levels. This time their attitude was much more favorable than their reaction to the general use of quantitative models for top-level decision-making [Appendix A, p. 186-188]. In addition, the respondents view several favorable side-effects of the MAUT procedure, some of them highly correlated to those already mentioned in citations from the general literature. These side-effects are:

(1) MAUT allows better communication and understanding among the people involved in the decision-making.

(2) MAUT has the potential to focus discussion on the important issues.

(3) MAUT assists decision-makers to consolidate their thinking, and forces rigor into discussions.

But the respondents also warned against some potential pitfalls in using MAUT:

(1) Including irrelevant data items.

(2) Overlooking significant issues.

From the positive side, the respondents expressed their confidence that MAUT does not suppress the decision-maker's intuition, bias his judgment or restrict his decision freedom. Finally, many of the respondents emphasized that

although it may serve as a comprehensive evaluation tool, and give a useful insight into the choice being made, MAUT procedure never would and never should be the ultimate determinant of the decision. It is, after all, only a tool, and thus should not dominate the decision. The responsibility always rests on the shoulders of the decision-maker, and no model can be used as an excuse when he has to account for his decision [Trimble, 1981, and Appendix A, pp. 202-212].

C. CONCLUSIONS

The conclusions of this chapter are the following:

(1) The acquisition decisions are of semi-structured nature, and combine objectively measured, structured data, with highly subjective judgmental considerations.

(2) For such kinds of decisions judgmental scaling techniques might be of great use. The judgment handling capabilities of these techniques are well-established through analysis, experiments and actual practice.

(3) Among those techniques MAUT is the preferred one. Its merits are recognized by a variety of authors, users, and--perhaps most important--by the questionnaire respondents who represent the defense systems acquisition decision-making community.

(4) MAUT has some limitations and potential pitfalls that should be noticed in its implementation.

These conclusions allow us to turn to a basic acquaintance with MAUT, which takes place in the next chapter.

IV. MULTI-ATTRIBUTE UTILITY THEORY (MAUT)

A. GENERAL

The purpose of this chapter is to provide the reader a basic acquaintance with MAUT, in order to understand its basic concepts. Since this thesis addresses mostly the simple forms of MAUT because it views simplicity as an essential requirement for top-level decision applications, no extensive introduction of MAUT has been undertaken. The user may, if necessary, turn to the branched literature written on MAUT, or consult with an expert practitioner (the latter is suggested in any case).

B. OVERVIEW

The most typical problem setting for MAUT applications arises when a decision-maker is required to make decisions among two or more alternatives, whose utility varies along several dimensions of value. As pointed out by Keeney (MIT, 1969, p. 16) and others, in reality there are only a few decisions which are based on just one measure of effectiveness. This realization has prompted the development of MAUT and other procedures which attempt to cope with more complex problems. Thus, MAUT is essentially a descriptive technique that processes information according to specific rules. Data processing is accomplished within a logical but flexible framework founded upon quantitative combinations of evidence. Evidence is brought to bear on the outcomes to be evaluated

by locating them on various dimensions of value. The located measures are then aggregated according to a combination rule which weighs the relative importance of each dimension. If the model is successful, it will present the outcome or alternative that represents the greatest worth to the decision-maker [Pacific Missile Test Center, 1979, p. 12]. The major building stones of MAUT are:

(1) The basic structural principle in MAUT is hierarchical decomposition. This means that the evaluation problem is broken down or decomposed from the general problem to specific components. The model provides the structure and rules necessary to investigate and integrate the interrelationships of all components.

(2) The selected value-dimensions are scaled, and utility functions are established.

(3) Global utility in a MAUT procedure is expressed by a single number. Thus multdimensional outcomes must be transformed into a single figure of merit such as utility, system worth or system effectiveness. This is done by means of some aggregation rules.

Finally, according to Winterfeldt and Fischer (1973, p. 1) and many others, MAUT combines a class of psychological measurement that can be applied to the evaluation of alternatives with multiple value relevant attributes. This notion, of MAUT's capability of handling psychological measurement, or in other words, subjective human judgment, is paramount in the appreciation of the method.

C. DEFINITIONS CLARIFICATION

Before the discussion proceeds further into more detailed presentation of MAUT, it is necessary to provide clarification of terminology that is used interchangeably in the literature and in this thesis as well.

The various names and acronyms used to identify MAUT in general have been already discussed in the Introduction (see footnote in Chapter I, p. 14), and therefore are not repeated here.

The type of decisions which are discussed in this thesis are referred to as multi-objective, multi-attribute or multi-criteria decisions. The three names represent three points of view on the same type of decision. "Objective" generally indicates the "direction" in which one should strive to do better. The characteristic phrasing of an objective can be, for example, "maximize air-to-air effectiveness." "Attribute" is the term by which the extent of achieving the objective is measured [Keeney and Raiffa, 1976, p. 34]. Therefore, attribute is also called "measure of effectiveness" (e.g., by Keeney and Nair (1977)). The attribute for the above objective can be, for example, "kill-ratio in air-to-air engagements." An attribute may be based on purely objective scale, or partly subjective scale (objective measurement is subjectively evaluated), or purely subjective scale [Edwards, 1977, p. 352]. "Criteria" is a required level of achievement. For example, one may establish criteria for air-to-air effectiveness such as: "ratios of 1:1 is poor, 1:5 is fair and 1:10 is very

good." Criteria corresponds to "goal" in the sense that goals clearly identify a level of achievement to strive toward. To continue the above pattern of examples, the goal might be, "strive to achieve 1:12 kill ratio."

The decisions are multi-objective-attribute-criteria because they have several, sometimes conflicting, objectives (e.g., "maximize air-to-air effectiveness," "minimize cost," "cause minimal environmental disturbance (such as noise and smoke)"). These objectives have corresponding attributes and a set of criteria for each (which are in fact some discrete consequences on a utility function scale).

As a consequence of the previous discussion, objectives, attributes and criteria, although distinguished from each other, all may be essentially interpreted as areas on which an evaluation of an entity is based. In defining these areas of evaluation two more terms are in use: "value-dimensions" (e.g., Edwards (1977)) and "factors." Thus, in the jargon, all five terms are used interchangeably to describe areas of evaluation, and in that sense they are considered synonymous.

As indicated by all decision analysts, objectives are characterized by an hierarchical nature. In fact, everyone who has seriously thought about objectives in a complex problem, has come up with some sort of hierarchy of objectives. The lower-level objectives can also be thought of as the means to an end, the end being the higher-level objective [Keeney and Raiffa, 1976, p. 41]. The hierarchical construct of the objectives is also called a "value-tree" (e.g., Edwards and

Newman (1980)). A value-tree can be a construct of objectives, of value-dimensions, of attributes, of criteria, or of factors. (In each case, of course, the various branches' definitions are differently phrased.) The upper level objectives (or value-dimensions, etc., of the hierarchical construct are also called "categories" (which are divided into "subcategories") or "branches" (of the "value-tree"). There is no strict definition at what levels these notations are valid. Usually, categories are used to describe only the highest level of objectives (only below the top, overall objective). Objectives at all levels below are referred to as subcategories. Branches usually consist of objectives at all levels except the bottom-level ones. Thus, while speaking about subcategories or branches, additional indications are required to know exactly at what level a specific objective is.

The bottom-level components in the tree are called also "twigs" (e.g., Edward and Newman, (1980)), or "entry-levels" (e.g., Decisions and Designs (1980)). In MAUT, as will be explained in more detail later in this chapter, the actual evaluation of alternatives is done only at the entry-levels. The weighted utilities at any higher level are an automatic outcome of "multiplication through the tree." Thus, attributes, i.e., evaluation tools are required only for the bottom-level objectives. Keeney and Raiffa (1976) are consistent in their definition of attribute, and thus refer to attributes only at the bottom-level items, while all the others

at higher levels are called objectives. The same way of notation appears in Stillwell's technical report [Social Science Research Institute, 1981] value-trees (see Figure IV-1). Edward and Newman (1980) are less strict and use attribute as synonymous with value-dimension, without identification of the level at which they are located, or how they are phrased. The broad meaning attributed by Edwards and Newman to the term "attribute" is reflected, for example, in the sentence "stakehold are sources of value-attributes. An attribute is something that the stakeholders care about..." [Edwards and Newman, 1980, Chapter 2, p. 2]. A "proxy attribute" is one that reflects the degree to which an associated objective is met, but does not directly measure the attribute [Keeney and Raiffa, 1976, p. 55]. Decisions and Designs (1980, p. 12) uses the term surrogate to express the same idea.

Several terms are used for the numerical evaluation of an alternative over a specific attribute. These are: "measure location," "utility location," "single attribute utility" (all the above definitions are found in Edwards and Newman, (1980)). Another term is "scores" (e.g., used by Donnell and Ulvila [Decisions and Designs, 1980]).

"Weights" are called also "importance weights," although the latter notation is rejected by Donnell and Ulvila [Decisions and Designs, 1980, p. 9] with the argument that they do not really express importance. Weights appear also as "scaling constants" (e.g., in Keeney and Nair (1977)).

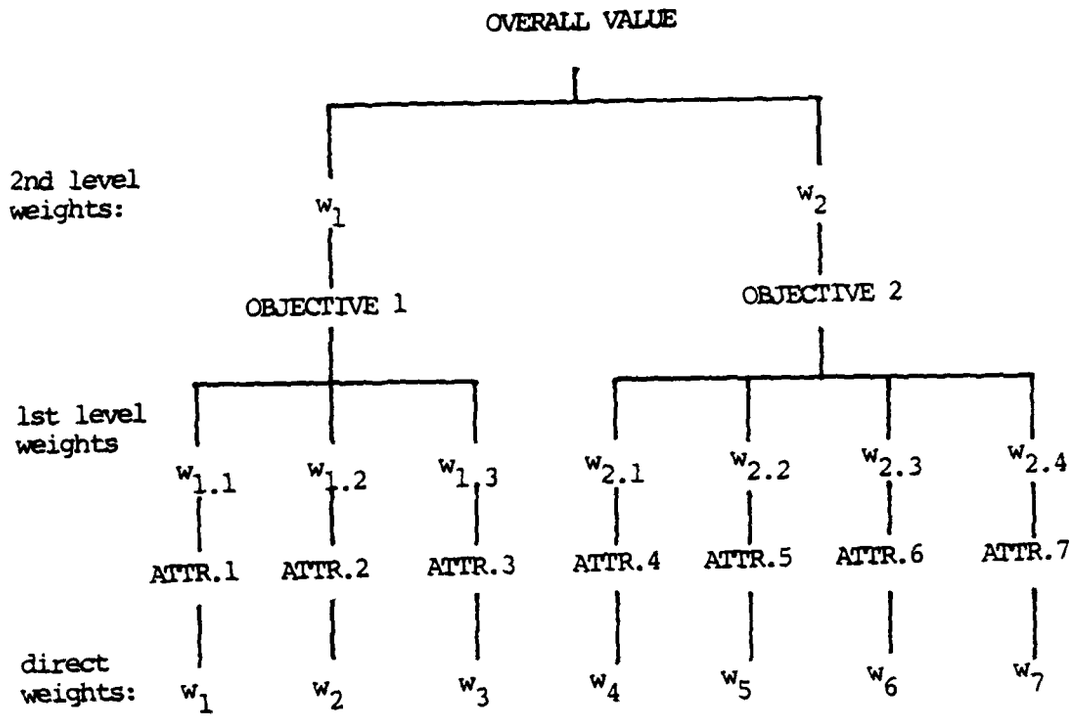

Figure IV-1. Schematic Value Tree (taken from Social Science Research Institute Technical Report SSRI 81-2)

The purpose of this discussion concerning MAUT terminology was to provide a background for subsequent text. The reader should be aware of the usage of some synonymous terms interchangeably used in this thesis.

D. THE BASICS OF MAUT

Let X_j be a set of possible values of attribute j and x_j be a particular value of attribute j. As an example, the j^{th} attribute could be the color of a car, which might be one of several attributes one might consider in buying a car. Let there be a total of n attributes under consideration (e.g., price, style, economy, etc.). Any one alternatives (e.g., car types) can be represented as a particular attribute combination:

$$\{x_1, x_2, \ldots, x_j, \ldots, x_n\}$$

The tendency to prefer one alternative over another can be represented by a construct called "utility" and denoted U. The utility of an alternative is a function of the particular values of the specific alternative over all attributes under consideration:

$$U_i = F(x_1, x_2, \ldots, x_j, \ldots, x_n)$$

where U_i is the overall utility of the i^{th} alternative. Most authors dichotomize the functions as being additive or multiplicative. The simplest and most prevailing form of additive models is the linear additive model:

$$U = w_1 \cdot u(x_1) + w_2 \cdot u(x_2) + \ldots + w_n \cdot u(x_n)$$

where:

- w_j is the normalized importance weight of the j^{th} attribute (such as $\sum_{j=1}^{n} w_j = 100$ or 1, as preferred);
- $u(x_j)$ is the normalized utility function (usually on a scale of 0-10, 0-100, or 0-1000) on the individual j^{th} attribute.

Let $u_{ij} = u(x_j)$, then

$$U_i = \sum_{j=1}^{n} w_j u_{ij}$$

where:

- u_{ij} is the utility of the i^{th} alternative over the single j^{th} attribute;
- U_i is the overall utility of the i^{th} alternative. [Edwards, 1977, p. 253]

Other types of additive models are those which include interactions [Pacific Missile Test Center, 1979, p. A-6]. Those will not be discussed here.

The multiplicative models are generally of the form

$$U = w_0 x_1^{w_1} . x_2^{w_2} \ldots x_n^{w_n}$$ [Pacific Missile Test Center, 1979, p. A-6]

Or in the form

$$1 + kU(\bar{X}) = \prod_{j=1}^{n} [1 + k\, k_j\, u_j(x_j)]$$

where:

$U(\bar{X})$ is a multi-attribute utility function,

k, k_j are constants with $k > -1$ and $0 < k_j < 1$, and

$u_j(x_j)$ is the utility function of the j^{th} individual attribute. [Giaque, 1972, p. IV-19].

In selecting among the various aggregation methods the authors have taken several approaches. One way of evaluating a model is to ask whether or not the model logically reflects the decision-making process in a valid and predictive sense, while the second way is to ask if the decision-making process can be approximated by a relatively simple model. The additive approach is less compatible with the value independence[1] assumption that is assumed by both additive and multiplicative versions. Consequently, Keeney (1974) has proposed use of a multiplicative rather than additive aggregation rule. But Edwards (1977), who consistently strove for model simplicity, indicates:

> ...in the presence of even modest amounts of measurement error, quite substantial deviations from value independence will make a little difference to the ultimate number U_i (the aggregate utility) and even less to the rank ordering of the U_i values.

---

[1]Roughly, value independence means that the extent of one's preference for location (score) x_2 over location x_1 of specific attribute, say, X_1, unaffected by the position of the entity being evaluated on dimensions $X_2, X_3, \ldots, X_n$, and so on [Edwards, 1977, p. 255].

Edwards concludes:

> ...the additive approximation will almost always work well if, for each dimension, either more is preferable to less or less is preferable to more through the range of the dimensions that is involved in the evaluation for all available values of the other dimensions.

Thus, Edwards and others conclude that additive models serve as good approximations in most cases and are the most appropriate in terms of practical usage [Pacific Missile Test Center, p. A-7]. But Edwards admits that when the assumption of value independence is unacceptable even as an approximation, much more complicated models and elicitation procedures that take value dependence into account should be used, like those presented by Keeney and Raiffa (1976). Edwards (1977, p. 250) ends up with the following conclusion:

> ...theory, simulation computation and experience, all suggest that weighted linear averages yield extremely close approximations to very much more complicated non-linear and interactive 'true' utility functions, while remaining far easier to elicit and understand.

(See, for example, Dawes and Corrigan (1974), and Einhorn and Magarth (1975).)

Most decisions involve uncertainties. These decisions are referred to as "risky decisions." Essentially, the consequence is using expected utilities rather than simple utilities. Edwards (1981) emphasizes that the expected values should be calculated on the natural values (i.e., performance measures) of the attributes, rather than on the normalized utilities resulting from them. When the probability function for the various possible outcomes is known, it should be used.

Otherwise, probabilities have to be estimated, and then utilities become subjective expected utilities. There is a variety of ways of how to elicit those subjective estimated probabilities. It starts from an extreme approach such as Bauer and Wegener's (1977, pp. 342-343) who found out (in a specific case) that probabilities are so difficult to estimate successfully, that it implies an assumption of equal certainty, or uncertainty, for all models output, and thus completely ignore the notion of risk. At the other extreme stands the sophisticated assessment of subjective probability estimates of utility, introduced by Raiffa (1968) and Keeney and Raiffa (1976). Besides the expected utility notion, uncertainties may be taken care of by sensitivity analysis, in which effects on the ultimate outcome resulting from deviations from the expected values are tested [Fisher, 1975, p. 74]. Another approach is using special value-dimensions for "risks involved" as done, for example, by Donnell and Ulvila in their ASH model [Decisions and Designs, 1980]. According to Edwards (1981), "this is theoretically inelegant, but definitely eligible."

E. EDWARDS' 7 STEPS OF MAUT PROCEDURE

1. General

There are many versions of MAUT in existence. While all refer to the same basic ideas, the details of implementation differ from one another. Edwards and Newmann (1980) introduce a 7-step MAUT procedure, which is a development of similar procedures introduced by Edwards in his older

publications [Edwards, 1971, 1977]. Edwards' approach has been selected for further discussion in this thesis because of the following reasons:

(1) Its framework applies almost to any MAUT procedure.

(2) It meets all six very important characteristics which Little (1970, pp. 466-485) defined as vital for a model to be useful. According to Little a model should be:

(a) Simple and easy to understand (though not simplistic).

(b) Robust: a user should find it hard to make the model give bad answers.

(c) Easy to control: a user should be able to make the model behave the way she or he wants it to behave.

(d) Adaptive: It should be easy to update in terms of both parameters and structure as new information becomes available.

(e) Complete on important issues: in conjunction with simplicity, this implies an optimal level of detail and complexity, which balances precision with scope. (According to Little, "An important aid to completeness is the incorporation of subjective judgments.")

(f) Easy to communicate with: a user needs to be able to change inputs simply, and obtain outputs quickly.

2. The 7 Steps[1]

a. Step 1

Identify the objects of the evaluation, and the function or functions that the evaluation is intended to perform. Determine the relevant alternatives (or options) to be evaluated. They can be defined as outcomes of some actions, or as the actions themselves.

b. Step 2

Identify the stakeholders. A stakeholder is simply an individual, group, or organization with a reason to care about the decision, and with enough impact on the decision-maker so that the reason should be taken seriously. The decision-maker is usually a stakeholder himself and not just a "judge." So he (or they) must be equally addressed at this step like any other stakeholder.

c. Step 3

Elicit from the stakeholders (or their representatives) the relevant value-dimensions and (often) organize them into a hierarchical structure called a "value-tree." Development of a value-tree is a phase of interaction between the analysis team and the stakeholders. Structuring of the value-tree is done in a top-to-bottom order. Judgment must be used to decide where to stop formalizing the hierarchy by considering

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[1]The introduction of the 7 steps are based mainly on three references: Edwards (1977), Edwards and Newman (1980), and Edwards (1981). Although these underly the whole section, they will be specifically referred to where necessary within the section. In some cases, the discussion expands beyond the scope of Edwards' 7 steps. In such cases, additional references will be cited.

the advantages and disadvantages of further specification. The more an objective hierarchy is subdivided, the easier it usually is to identify attribute-scales that can be objectively assessed. But of course, there are attributes which cannot be objectively measured at all. Moreover, by going down too far, not only the simplicity principle is violated, but the efficient tool of human judgment, which can "leap frog" many steps of elaborate "objective" evaluations is not fully utilized. (With this repect, recall Little's comment, saying that in the attempt to reach completeness and still keep the balance between simplicity and complexity, incorporation of subjective judgment is an important aid).

In many practical cases it is hard, if not impossible, to reach objectively measured attributes. For example, Donnell and Ulvila's [Decisions and Designs, 1980, pp. 31-32] model of the Scout Helicopter evaluation, although relatively elaborate, still ends up with most of the bottom-level attributes that are not readily quantifiable on an underlying scale.

A means to reduce the number of attributes is mainly to combine some of them, what is in fact equivalent to stop formalizing at a higher level of the attributes hierarchy, or to eliminate the unimportant ones. Here one can use the "test of importance," introduced by Ellis (1970), in which the decision-maker is asked whether he feels the best course of action could be altered if a specified objective was excluded. An affirmative response would obviously imply that

the objective should be included. Edwards (1981) mentions that it is desirable to get the stakeholders' common acceptance of the value-tree, although, he indicates, "you can never satisfy them all."

Donnel and Ulvila [Decisions and Designs, 1980, pp. 7-8] count the important benefits the hierarchical decomposition provides as follows:

(1) It breaks the elicitation process up into "chunks" of manageable size.

(2) It organizes the presentation of the final results, highlighting the most important factors without losing the ability to retrieve details when desired.

(3) It limits the required assessments to comparison among attributes that are closely related in meaning, and therefore relatively easy to weigh against one another.

d. Step 4

For each stakeholder group assess the relative importance of each of the value-dimensions. Since values change over time, the weights should be re-elicited in situations in which the program is periodically re-evaluted. As emphasized by Helm [Pacific Missile Test Center, 1979, p. 12] "MAUT is especially appropriate for the applied setting, since in addition to its flexible structure it incorporates interactive methodology for data manipulation." Consequently, as new data are gathered, existing information is revised in the light of the new data. This process can be repeated as often

as required. That feature protects MAUT from the fate of many static models, which quickly reach obsolescence.

Step 4 is the second of the only two steps in which- according to Edwards, stakeholders are involved. (The first one is, as recalled, the value-dimensions elicitation.) Obviously, it is desired and in most cases even possible to reach a common stakeholders' agreement to both the value-tree construct and the weights. The recommended way to reach such agreement is through a face-to-face open discussion. If agreement is not reached, the ultimate decision-maker may judge and decide about the final value-tree construct and weights. Another option is to use more than one set of weights (although the value-trees must be identical) for parallel comparative evaluations. According to Edwards (1981) in many practical cases, the ultimate outcome of different weight sets was selection of the same alternative. That is explained by the fact that in practical cases, weight sets which are determined by reasonable people, usually only differ moderately, thus the dominant discriminator is score rather than weight. Edwards and Newman (1980) prefer the weighting method called "ratio weighting." The procedure for this method is as follows:

(1) Place the attributes in rank order of importance.

(2) Assign a value of 10 to the least important attribute.

(3) Assign to the next attribute a value according to your evaluation of how much it is more important than the least important one. For example, if it is twice as important as the least important attribute, it should be assigned the value

of 20. Go up the rank order and assign relative values to all attributes. Ties are permitted. Normalize the values assigned to a scale of 0-1, 0-100, or as desired. This is done by summing up all important values, and dividing each individual value by the sum. The result is the attribute's importance weight on a sacle of 0-1. For 0-100 scale, multiply by 100. When you have a value-tree, use it to ease the weighting: instead of generating weights for all attributes together, do the same procedure for each level separately, and within the levels--for each group of attributes (which are under a common upper-level attribute) separately. Start the procedure from the top and proceed to the bottom. The final weight of each attribute is the multiplication of his original weight by the weights of all attributes which are above it, in its branched pattern up to the top. (A detailed example can be found in Edwards and Newman (1980, Chapter 4, pp. 12-14). This is called "multiplying through the tree."

While Edwards and Newman (1980, Chapter 4) present some additional weighting methods which are even simpler than the ratio weighting, there are also more complicated methods (see for example Keeney and Nair (1977, pp. 310-312)), which are essentially based on exploring trade-off ratios of scores among the various attributes.

e. Step 5

Ascertain how well each object of evaluation serves each value-dimension at the lowest level of the value-tree. This is expressed in terms of location-measures (or single attribute utilities, or scores). Those numbers can be

purely subjective or some sort of transformation on objective measures. Edwards (1977, p. 252) distinguishes between purely subjective value-dimension, partly-subjective--in which the units of measurement are objective but the location-measures are subjectively evaluated, and purely-objective--in which location-measure can be measured unjudgmentally in objective units before the decision.

An important part of the location measuring procedure is to construct a utility function in which the location-measure of each alternative can be evaluated. While some of the users prefer a sophisticated development of dimension-by-dimension utility curves (like Keeney and Raiffa (1976)), Edwards, who consistently strives for simplicity, is a great advocate of using linear ("straight line") utility functions. According to Edwards (1981), in most cases preferences are described basically by a straight line, or by a bi-linear function with only one interior maximum (or minimum). Edwards and Newman (1980, Chapter 5, p. 8) point out that the use of linear and bi-linear location measures is an enormous simplification, "which is very much out of the traditional spirit of formal decision analysis." But they emphasize that "if one's desirability or utility function increases steadily, or decreases steadily, or has one interior maximum, then this approximation will work so well that there is little point in using anything more sophisticated." Donnell and Ulvila [Decisions and Designs, 1980, pp. 10-21] distinguish among

three methods of scaling: relative scales, ratio scales and absolute scales. All three methods assume linearity. The absolute method requires determination of range of performance that starts at some very low "true zero" level, and ends at some theoretical maximum level of performance. The advantage of this method is that it indicates not only the relative preference order between alternatives, but it also indicates to what extent an alternative is "good" or "bad" relative to some acceptable absolute reference scale. The disadvantages are that it is hard to define the scaling range, and because the true zero is so low, the spread in the alternatives' scores is relatively small and hard to distinguish. In the ratio scale the analyst can avoid the problem of defining "perfect" capability, and the best alternative on each dimension serves as the upper limit of the range. Other alternatives are evaluated relative to the best. But this method still requires defining an "unacceptable" point of zero value as in the absolute scale method. The relative scale does not require definition of end points at all. The best alternative at each dimension is used as the upper limit of the scale, and the worst as the bottom limit. Other alternative evaluations are located in-between according to their estimated (or objectively measured) location relative to both limits. The main advantage of this method is its simplicity and its "modest" information requirements. The disadvantage is that it does not indicate whether an alternative is "good" or "bad," only "better" or "worse" are meaningful. All three methods, if

properly implemented, provide the same rank order of alternatives and even the same ratio of preferences among them. In most decisions relative order is sufficient, and if there is no specific need for evaluation in absolute terms, according to Donnell and Ulvila [Decisions and Designs, 1980, p. 7] the relative scaling method, whose advantages outweigh its problems, is preferred.

Edwards (1981) views the scoring process as done essentially by experts. In any case, he recommends to avoid letting stakeholders do the scoring because that is a potential source of biased outcomes.

f. Step 6

Aggregate the location-measures with the importance weights into an overall utility for each alternative.

As mentioned before, Edwards, and many others prefer the additive aggregation rule to the multiplicative one.

Another issue that may be recalled is execution of several aggregations (but not too many!) using different sets of weights. Those can be presented concurrently for decision-maker's judgment. Such presentations may convey to him in a visible manner, controversies among groups of stakeholders, if they are really significant [the word significant refers to both controversies and stakeholders. To be worth separate aggregations both should be significant. R.G.].

An issue which has a great practical significance that is suggested by Edwards and Newman (1980, Chapter 6, pp. 11-12) is subaggregation. As they say, aggregation need not be an all-or-nothing affair. If value-trees have been developed, one can select an appropriate level of higher order value, and aggregate up to it. Then MAUT scores on each branch separately can be presented as a "value profile"--an aggregate but still informative summary of how objective evaluation stands with respect to each of the higher-level values considered relevant to its assessment. That gives information at whatever level of detail seems to be just right for the purpose on hand.

g. Step 7

Perform sensitivity analysis. As true for any sensitivity analysis, the underlying question at this step is whether a change in the various inputs or input-evaluations will lead to a different conclusions. According to Edwards and Newman (1980, Chapter 7, p. 1), the most important kind of sensitivity to look at is sensitive to weigths. This is important both because weights are the essence of value judgment, and because weights, being purely subjective numbers about which people disagree, are more likely to be in dispute than location measures, which may be objective, may depend on the judgment of experts--or may be in some cases also matters of intense controversy. If there is some debate about whether a branch or an attribute belongs in the analysis

at all, it can be in effect eliminated in the sensitivity analysis by giving it a weight of zero, or almost zero.

F. CONCLUSIONS

This chapter attempted to provide the reader a basic acquaintance with MAUT. As noted, MAUT has variety of versions. In this context, the simpler ones were addressed, with several references to the more complex ones. But it should be emphasized that the simplest versions of MAUT, like the one introduced by Edwards and Newman (1980), may not be adequate to handle the more complex acquisition decisions. Edwards himself admits that he has not had experience with such complex problems [Edwards, 1981]. For example, Donnell and Ulvila's [Decisions and Designs, 1980] value-tree used for the Advanced Scout Helicopter evaluation is much more complex than the "trees" exhibited in Edwards' examples. On the other hand, Donnell and Ulvila's linear utility function assumption, their usage of relative scale, their preference for additive linear aggregation rule, or the way they treat uncertainties, corresponds more to Edwards' approaches, than to the more sophisticated ones suggested, for example, by Raiffa (1968), Keeney and Raiffa (1976), or Keeney and Nair (1977). In any case, the selection of the approach depends a great deal on the object of evaluation and on the preferences of the decision-maker. Nevertheless, many approaches and techniques--the simple and the more complex--are available for use as required. The conflict between the simplicity

desired and the complexity required for acquisition decisions will be addressed in the next chapter.

V. IMPLEMENTATION OF MAUT FOR TOP-LEVEL ACQUISITION DECISION-MAKING

A. GENERAL

The purpose of this chapter is to highlight some of the implementation-related issues, in applying MAUT to top-level acquisition decision-making. No doubt, acquisition decisions are of the most complex kind. Although MAUT was originally geared to complex decisions, there are still some important problems, stemming mainly from the complexity of the acquisition decisions. These problems should be resolved in order to make it more likely that MAUT be used in acquisition decision-making. Many of the implementation problems may be associated with each individual decision. Those, of course, cannot be addressed in this context. Only the issues which are common to most cases will be mentioned here.

Neither the thesis in general, and this chapter in particular, pretend to cover all implementation aspects, nor are they supposed to be a complete "user's manual." Thus, a preliminary recommendation is that the user should be helped and consulted by MAUT's skilled field practitioners. According to Edwards (1981), although there are many who deal with MAUT, "there are only a few real skilled practitioners around." This is by no means to say that those practitioners will do the evaluation by themselves. It is to say that their help is vital. Basically,

the MAUT procedure[1] is managed at staff level by a team of MAUT's experienced practitioners, usually externally hired, and combined with staff members. (The combined group, hereafter, will be called "the analysis team"). The analysis team works in close interactions with the various stakeholders, experts, and, of course, the decision-maker(s). Those interactions, which are paramount for MAUT procedure scuccess, will be discussed in more detail later in this chapter.

A final comment, which is preliminary to any further discussion of the implementation issues, is that MAUT procedure must be acceptable to the final decision-maker. This notion has been raised by several of the people involved, by means of the questionnaire and the interviews (e.g., Connolly (1981) and also see Appendix A, p. 227). Furthermore, one of the questionnaire respondents emphasizes the potential contribution the decision-maker's experience and intuition may offer to models by steering them from the early stages. According to this commentator, "'Good' decision-making is enhanced by bringing them [the models, R.G.] in early, so that data base, etc., is organized to their [the decision-makers', R.G.] 'taste'" [Appendix A, p. 227].

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[1]The words "procedure," "technique," and "model" are used interchangeably in this chapter to refer to the implementation form of MAUT. There are practitioners such as Edwards (1981) who have reservations about using the term "model" in this context, since model is some representation of real phenomena, and MAUT is merely an analysis and communication mechanism. ("Algebra is also not a model.") But in the prevailing jargon the MAUT framework for specific analysis is called a "model" (see for example Decisions and Designs (1980). Thus, this term will be used in that sense in this chapter as well.

The various implementation issues will be addressed by their order of arrival according to MAUT's 7 steps.

B. IMPLEMENTATION ISSUES

1. Step 1

As recalled, at this step the scope of the decision is determined and alternatives defined. That brings about the question: what type of acquisition decisions is the MAUT procedure applicable? Edwards (1977, p. 248) says:

> I don't understand the differences among evaluations of plans, evaluations of ongoing projects and evaluations of complete projects; all seem to me to be instances of the same kind of intellectual activity. MAUT can, and I believe, should be applied to all three; the only difference is that in ongoing or complete projects there are more opportunities to replace judgmental estimates of locations on value dimensions with utility transforms on actual measurement--still subjective, but with firmer ground in evidence.

A similar attitude is taken by Hermann (1981) who says:

> I am not sure that there is such a clear distinction between source selection decision and status review decision session [i.e., Milestone session, R.G.].

In fact, there should not be a clear distinction. As mentioned in Chapter II, Milestones I and II are designated to approve the alternative(s) and authorize the acquisition process to proceed into the next phase. Apparently, the approval of the alternatives is based on their status review. But from another aspect, each alternative system is usually identified with a specific contractor. So that is in essence the linkage between the system/contractor Source Selection

and the Milestones decisions. The above mentioned notion contradicts some people's arguments (such as Trimble (1981)) that the DSARC is not supposed to make any kind of comparison between alternative systems since that is exclusively the Services' business. According to Trimble, DSARC's basic job is to recommend to approve or disapprove the Service selection. Thus, with this pattern of logic Trimble concludes that MAUT procedure might be most useful at the Department level, and especially for Source Selection (which, in fact, already uses such procedures). One of the questionnaire respondents, a program manager, concludes his lengthy written analysis with four conclusions which essentially match Trimble's perception. These are:

(1) Models are good tools for evaluating two basically 'technically equal' systems, i.e., Source Selection.

(2) Models are useful for prototype evaluation.

(3) They are of limited use in the A-109 process, even when comparing similar systems.

(4) They are of no use in unlike alternatives (e.g., TOW missile vs. A-10 aircraft, to kill tanks).

While it absolutely agrees with the first two conclusions, the thesis analysis disagrees with the last two. In response to the third conclusion, as explained before, it argues that there should not be a difference in essence between "Circ A-109 process" (or "DSARC process," or any similar new process) decisions, and top departments decisions, such as Source Selection for major systems. If, in fact,

there is a difference, it stems partly from weakness of evaluation capability of the DSARC process decision bodies, rather than from principle. Secondly, the flexible nature of MAUT may allow its use in assisting top-level decisions, even when they change shape while moving up the ladder of the "DSARC Process" hierarchy. The fourth conclusion raises a set of questions with respect to how to compare unlike alternatives or old or with new ones. According to Edwards (1981), it is harder, because the range of value dimensions to be considered is greater, but it is possible. "In fact," he says, "we were able to generate value trees [to such evaluations, R.G.] never-the-less." In the case of unlike alternatives there might be many low level attributes which are not common to all alternatives. On the other hand, since all alternatives aim to achieve common upper-levels objectives, the upper levels value dimensions are probably shared by all. Thus, a value tree may consist of bottom level attributes accumulated from all alternatives, while each alternative is actually evaluated only on those attributes which are relevant to it, and is scored 0 on the irrelevant ones.

A more concise option is to construct different value trees for each alternative, which includes for each alternative, just the relevant attributes, and thus may differ at the entry-levels, but be identical at the upper levels. Old vs. new alternatives differ mainly in to what extent objectively measured attributes are used, and in the degree of uncertainties. In such a case it is possible to use a specific

value-dimension subjective scale for one alternative (probably the new, yet "unknown" one), and more objectively-based scale, for another (probably for the old, well-known one).

Uncertainties are taken care of by expected value computation (or estimation) and sometimes by applying special value dimensions of risk (see more detail--this chapter, p. 110). Thus there is no fundamental problem in applying MAUT to "old vs. new" evaluation context. Some examples of MAUT actual implementation for "old vs. new" evaluations were mentioned in Chapter III (see p. 63) such as: Airport for Mexico City, Energy supply for Southern California, or Advanced Scout Helicopter selection. All of them deal, and manage well, with mix of "old" and "new" alternatives.

Scoping the decision might be a problem when the MAUT procedure is expected to serve some levels of decision-makers, whose scope of decisions are not the same. In such a case, the procedure should refer initially to the broadest scope, which is usually determined by the highest decision-maker. The scope is expressed by the range of value-dimensions included in the model. The construct of the value-dimensions, namely, the value-tree should be modular, so complete branches would be eligible for elimination as a unit. Lower decision levels would be presented only by these models' branches which are relevant to their scope of decision. In most cases this is not difficult to do, since usually the structure of the objectives correlates the hierarchy of the decision-makers.

The generation of alternatives is usually a straightforward task in the acquisition decision. Cases of variation on the same basic alternative, which differ by various combinations of some components (for example, those resulting from trade-offs between performance cost and schedule), should be referred to as separate contending alternatives [Edwards, 1981]. Such trading-off processes can be continuous with an infinite number of alternatives; but some discrete alternatives selected from the reasonable range might be good enough to represent the real life selection options.

2. Step 2

As recalled, at this step stakeholders are identified. In the acquisition context, besides the DOD visible stakeholders, they may also be found in Congress, at the states' level, or in industry. Naturally, in a real case there can be too many stakeholders to permit a reasonably "managed" evaluation model. So the list must be refined, organized in a more or less homogeneous groups of individuals and organizations, and representatives for the actual interaction should be identified.

As mentioned before, the decision-maker is usually a stakeholder himself and as such, may be addressed at this phase like any other stakeholder. Although he has the authority to dominate other stakeholders, he is wiser not to exert this authority at this early stage, because he may lose inputs generated by others--inputs which may be of importance to his own later-on decision. Authority to dominate the process is

suggested not to be activated until the final decision phases. On the other hand, any decision-maker's directive which is a condition of his acceptance of the methodology in the first place, should be implemented immediately.

3. Step 3

As recalled, at this step elicitation of relevant value-dimensions from the various stakeholders takes place. Usually the hierarchy of the value-dimensions correlates with the natural hierarchy of the stakeholders. It is not so difficult to generate a global list of value-dimensions. There might be some difficulty in eliciting subjective "political" value-dimensions; on one hand, as suggested by Edwards (1981), a stakeholder should be told that "it is OK to be selfish." But it is questionable whether a Congressman would openly expose himself by articulating his "selfish" interest to provide his constituency a multimillion dollar contract. Edwards (1981) suggests the use of proxy attributes in such cases. For example, the Congressman's objective to select the systems' alternative that means contract awarding to his constituency can be considered under the "legitimate" lable. "Inter-regional balance of labor force" or, "inter-regional balance of income allocation", or even more indirectly-- "Prospects for Congressional Approval."

A harder task is to organize the value-dimensions into a value-tree. This is mainly the analysis team's job. They have to make sure that all important value-dimensions are in there, and "including all relevant decision factors is a tough

part" [Appendix A, p. 200]. An effort should be made to make the value-tree as concise as possible. Some possible ways to do so have been already mentioned (see Chapter IV. p. 80). In cases where the tendency is to reach objectively measurable attributes because the subjective scale seems to be inadequate, attributes in addition to those elicited from stakeholders are required. This attributes' generation is done by experts. But to avoid too elaborate a value-tree, a compromise is suggested as an option by Keeney and Raiffa (1976, p. 45]. They say that,

> ...the vertical depth of the proliferation of the hierarchy does not necessarily force us to quantify our preferences down to this level of detail. The hierarchy after a given level may serve merely as a qualitative checklist for items to consider.

But even when there is an effort to limit the level of detail of the value-tree, it still turns out to be fairly elaborate. Figures V-1--V-9 exhibit an example value-tree for a selection between several hypothetical advanced fighter aircraft types, in order to proceed with one (or two) into Phase II (Demonstration, Validation) of the acquisition life cycle. It should be emphasized that this value-tree has not been generated through the procedure recommended here (which requires a lot of manhours of a professional t[illegible] It has been constructed by the thesis author just as an illustration tool.[1] Thus

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[1]In constructing this value-tree the author was assisted by two sources:
(1) The value-tree used by Donnell and Ulvila [Decisions and Designs, 1980, pp. 21-34] in their Decision Analysis of Advanced Scout Helicopter Candidates.
(2) The questionnaire input [Appendix A, pp. 237-239].

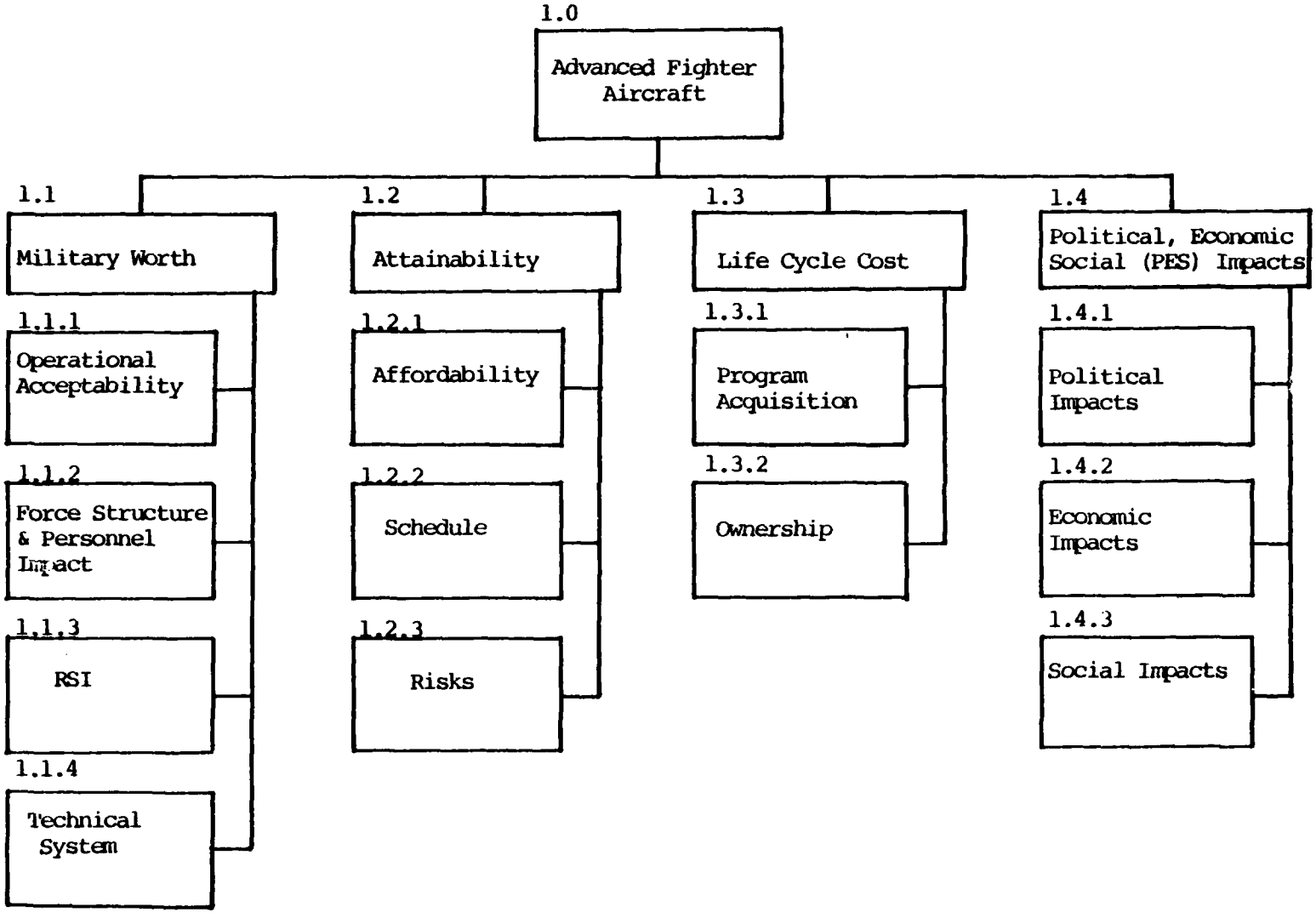

Figure V-1. Top-Levels Structure of AFA Evaluation Model

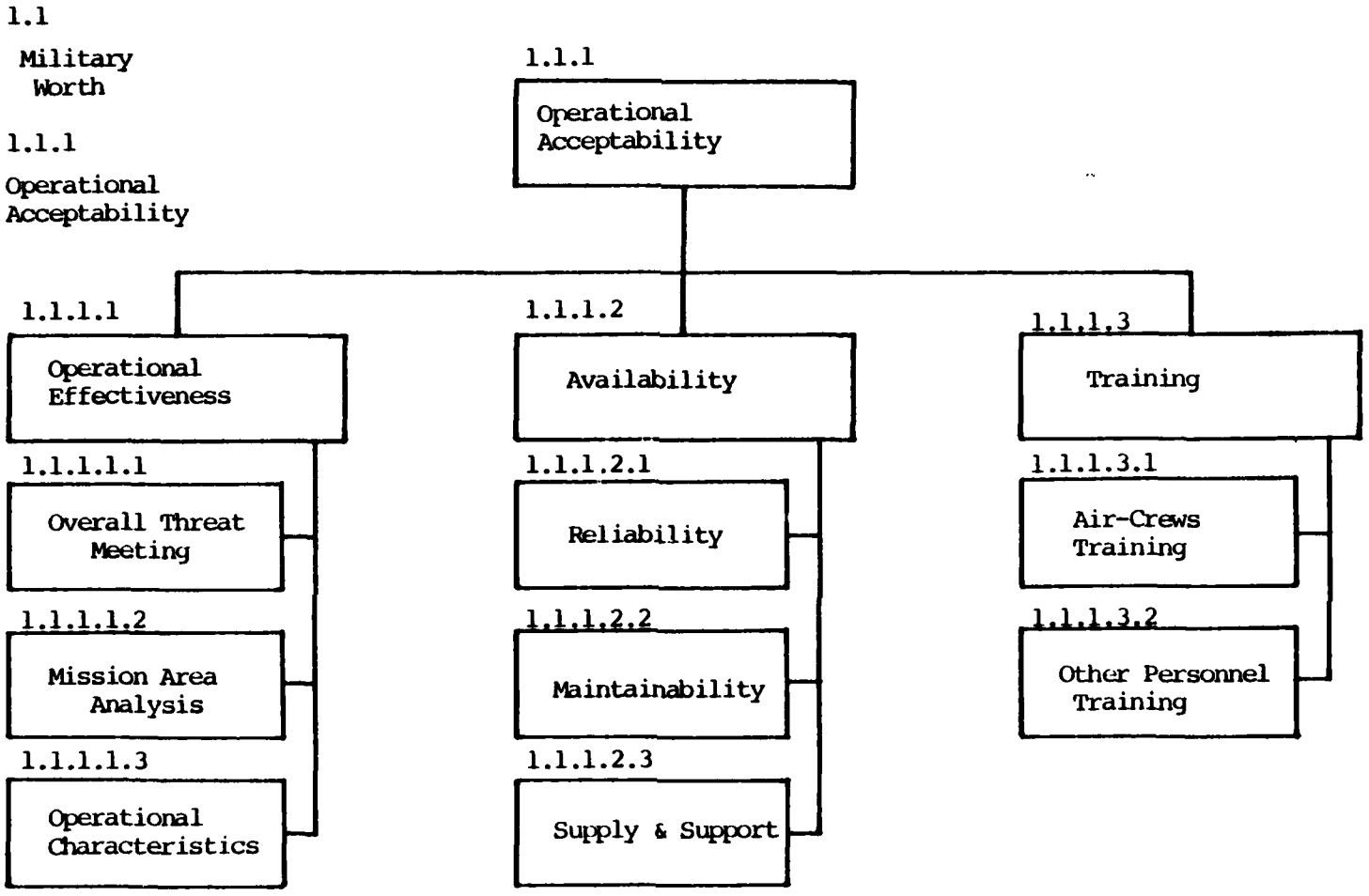

Figure V-2. Subdivisions of Operational Acceptability

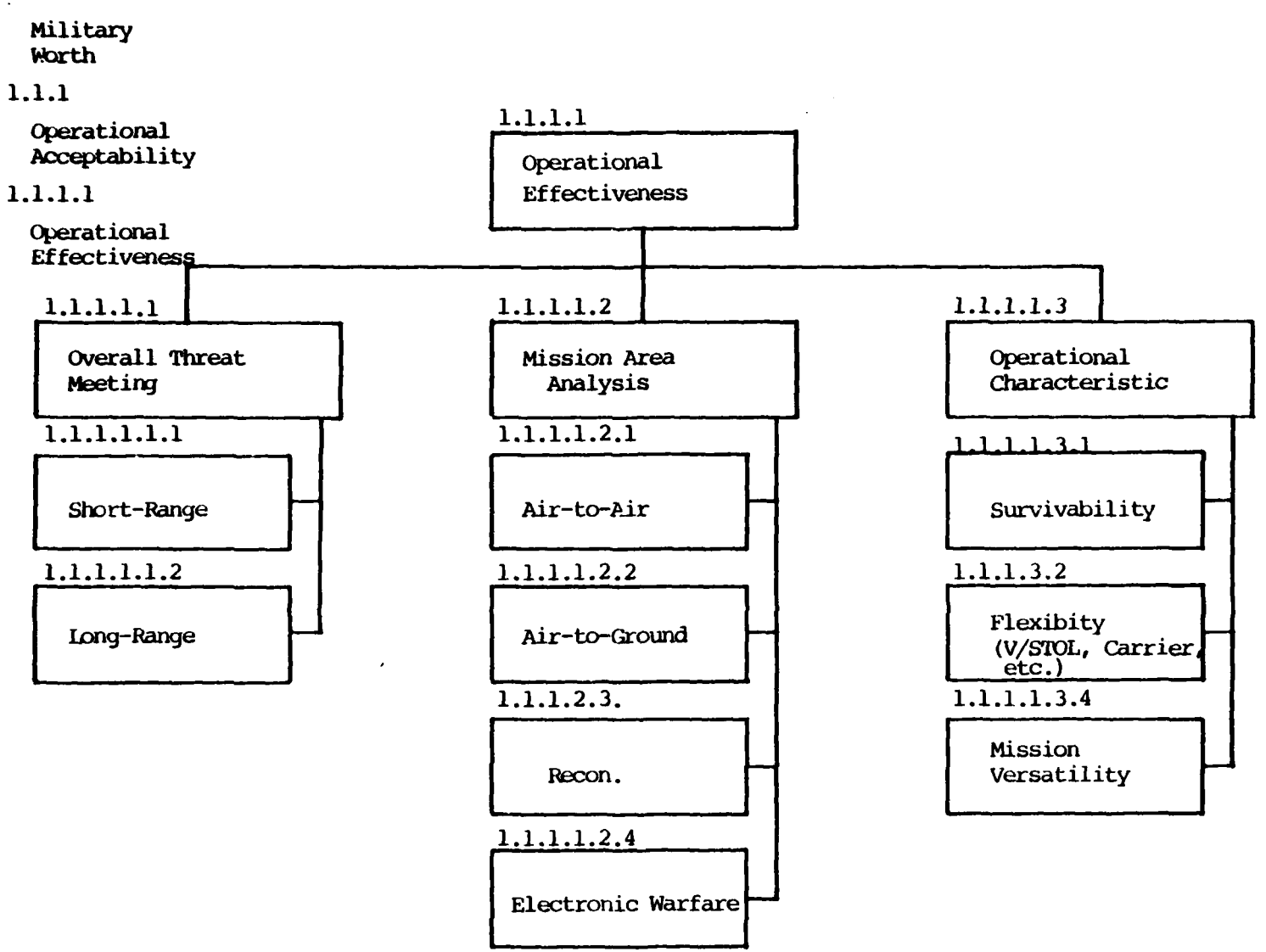

Figure V-3. Subdivisions of Operational Effectivness

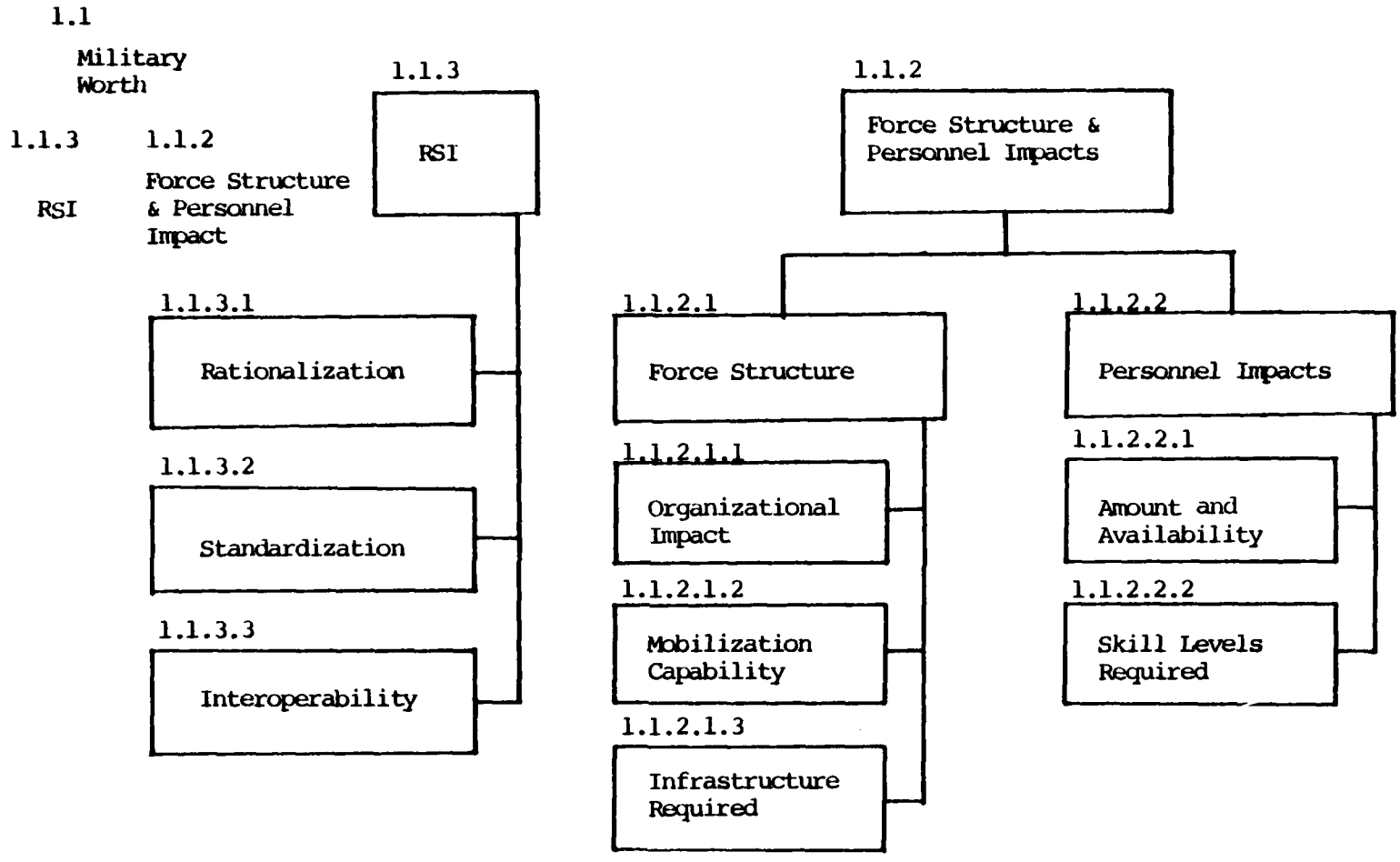

Figure V-4. Subdivisions of RSI and Force Structure & Personnel Impacts

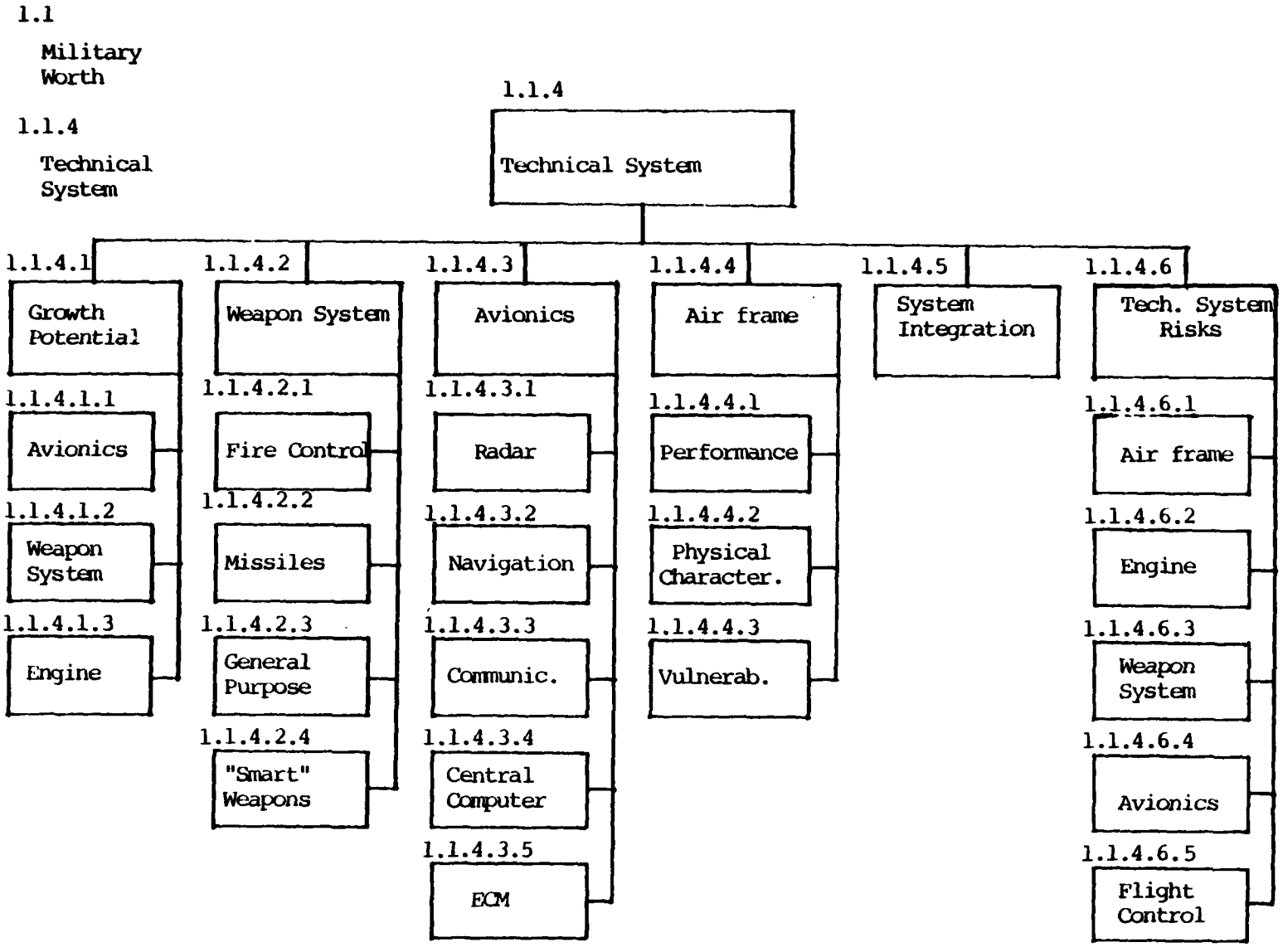

Figure V-5. Subdivisions of Technical System

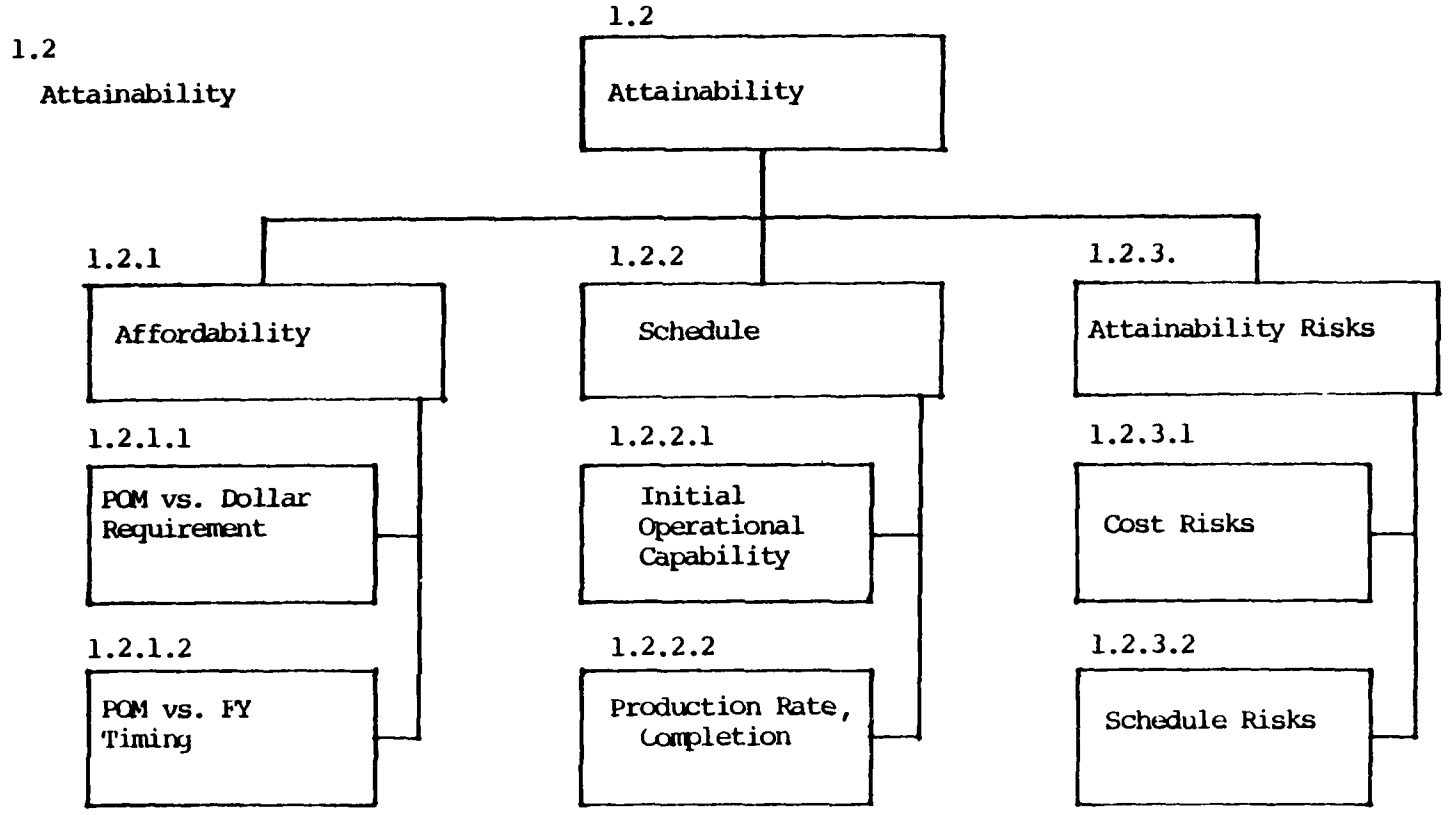

Figure V-6. Subdivisions of Attainability

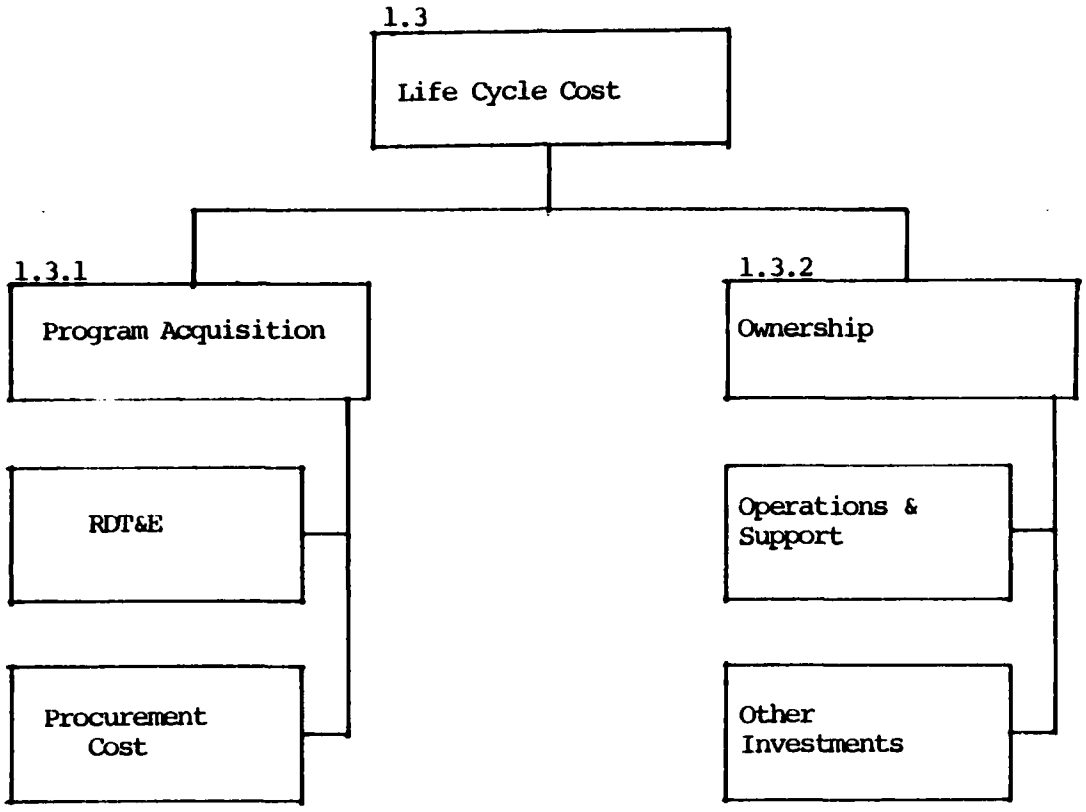

Figure V-7. Subdivisions of Life Cycle Cost

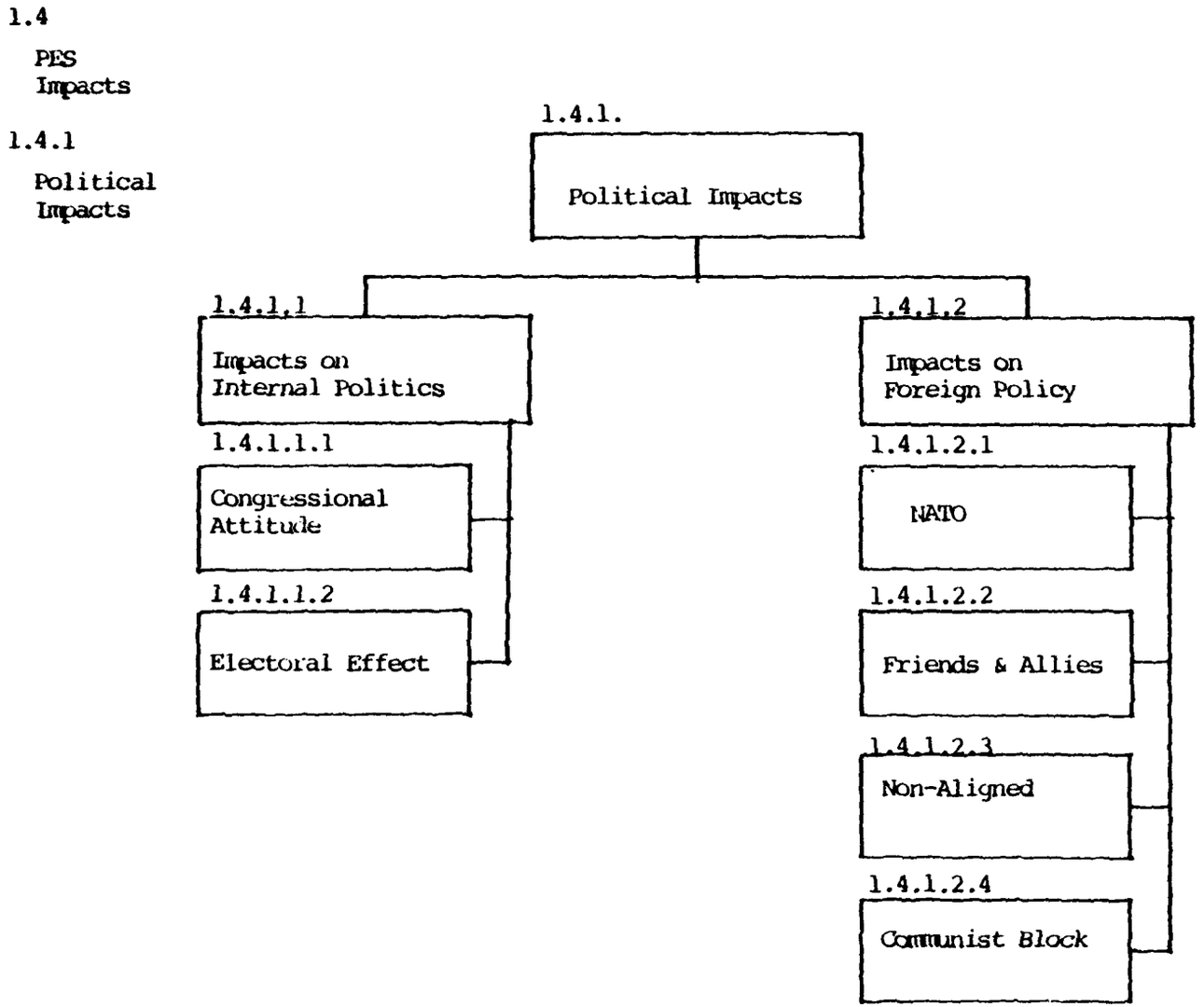

Figure V-8. Subdivisions of Political Impacts

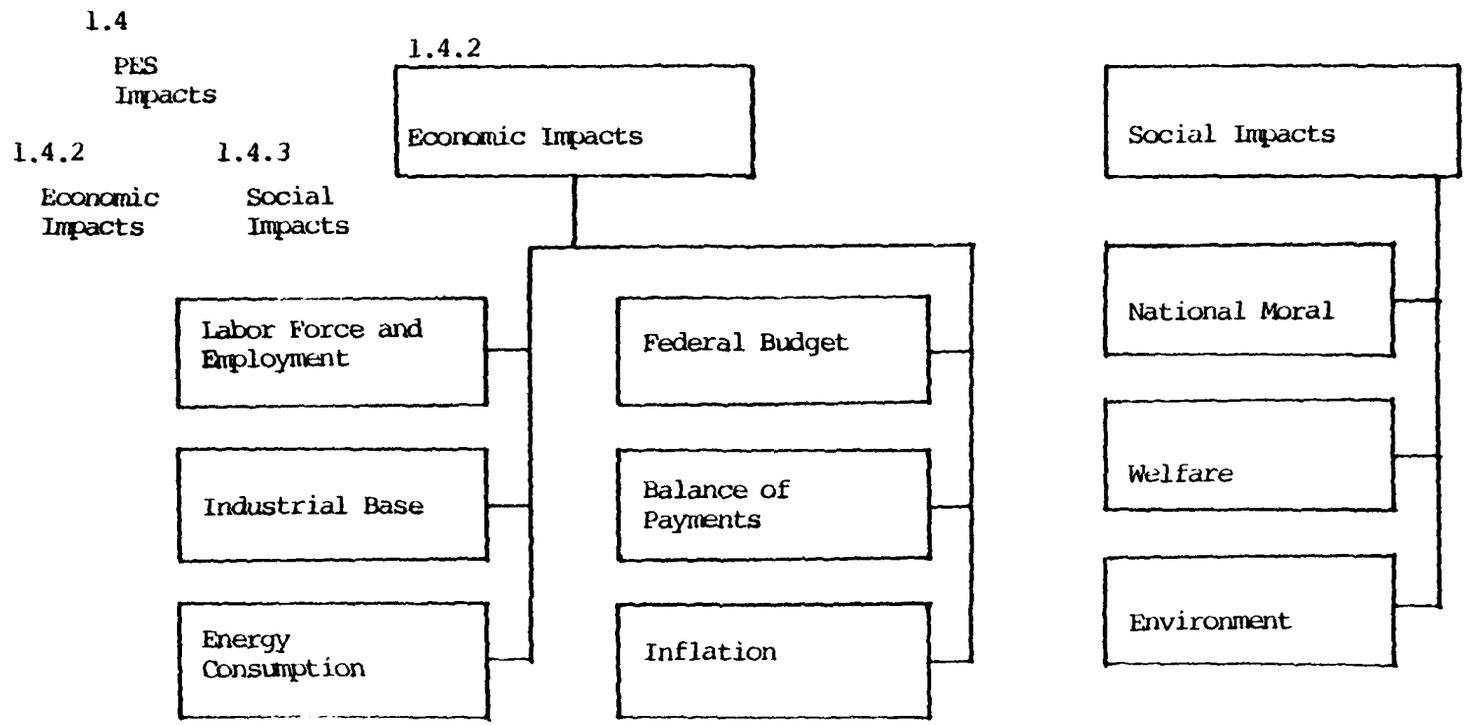

Figure V-9. Subdivisions of Economic and Social Impacts

the details of its construct are not subject to discussion or critique (which would be difficult anyway, since there are no real specified alternatives behind this value-tree which can be referred to). As one can notice, the tree is quite elaborate. (As a matter of fact, Donnell and Ulvila's [Decisions and Designs, 1980] Scout Helicopter model goes even further in its attribute division.) The complex structure of the illustration value-tree stands in conflict with the principle of simplicity that is emphasized throughout this thesis. Two basic approaches to cope with inevitable model's complexity can be recognized:

(1) To refer to only the upper levels as the formal tree, while all other levels serve as a checklist for judgmental location measures.

(2) To retain the existing construct, but adjust the model's complexity to the level of decision-maker whose decision the model serves.

Between the two, an intermediate approach is selected. With respect to the first approach, the object of the decision requires, and permits, subdivisions down even to 6^{th}, 7^{th} or 8^{th} levels. That is required in order to reach an objectively measured data base for some of the utility functions. This is considered unreasonable. Thus, in most attributes, and even at the lowest subdivisions, judgment should be applied in partly-subjective or purely-subjective evaluations. Thus, the question is what should be the optimal level at which to stop the attributes division. The complex acquisition

evaluations require at least 4-6 attribute levels. That can be acceptable if the second approach, namely, adjusting the model's complexity to the decision-maker level, takes place as well. That will be addressed in more detail later in this chapter.

Another feature of the value-tree is its modular structure. For example it separates the political category (see 1.4 in Figure V-1) from the others, and enables the ranking order of alternatives to be based on military related grounds only. The political, economic, and social analysis can be done separately, and be added to the rest with suitable weights for the final conclusion.

As one can notice, cost is evaluated through the four main subcategories of the life-cycle-cost, which are at the entry-level of the cost category (see Figure V-7). This stands in conflict to many prevailing analysis approaches which discount costs to present-value and then refer to them as a unit dimension. The approach presented here offers a more realistic handling of cost, since in real life, cost's present-value minimization is not the only, or major consideration. ("As if the only thing one is worried about is the rate of interest" [Edwards, 1981].) In many real life cases one may be willing to accept smaller initial costs, even if they mean eventually greater costs through time. Thus the way cost is handled in the example provides a less mechanical approach, and greater emphasis of the cost over time factor. Later on, at step 5, the cost will be assigned a negative

utility which is subtracted from the aggregate utility. That would cause the model as a whole to be, in a sense, a cost-effectiveness model, that measure the difference between the negative utility of cost, and the positive utility of other factors (effectiveness here is synonymous to global utility).

Another issue that stands out in the example is the existence of specific value-dimensions for risks in various areas (see for example Figure V-5, Technical Risks, 1.1.4.6). Those appear in addition to the expected-value calculation (or estimation) that should take place in any case for the uncertain location measures. The approach of having specific attributes for risks is also selected by Donnell and Ulvila [Decisions and Designs, 1980, pp. 25-,32] in their Advanced Scout Helicopter model. Edwards (1981) refers to this approach as "conceptually inelegant," though acceptable. As a matter of fact, it suits very well the basic logic, suggesting that once you've calculated an expected-value, you deal with a single specific location-measure for each alternative at each attribute. But there can be, for example, two alternatives of which one is an existing system with well known parameters, and the other still on the drawing board with highly variable possible parameters. Both alternatives may have equal measure location over a specific attribute, and thus considered utility-equal with respect to that attribute. But in fact, they are not perceived equivalent since one involves high risks and the other does not. A prudent decision-maker would like to

take into account the possibility that the new system would not perform as well as the expected value suggests. The risk dimension allows an explicit consideration of the uncertainties involved with the various alternatives in the value-tree. Another way to cope with the above problem is through sensitivity analysis, while mainly the variable and risky attributes are checked for their impact on the ultimate outcome if location measures are different from the expected value. Without overlooking the need for sensitivity analysis, it seems that the special attributes for risks spell out the risks involved to the decision-maker more clearly. It meets the requirement raised by one of the questionnaire respondents who stated:

> A range of subjective values and numerical estimates needs to be presented to top decision-makers, with uncertainties clearly spelled out. [Appendix A, p. 224]

4. Step 4

As recalled, at step 4 important weights are assigned to the value-dimensions at the various levles of the tree. Weights, as well as the value-dimensions, are elicited from the stakeholders. As mentioned before, stakeholders are usually arranged in some sort of a hierarchy that correlates the hierarchy of the value-dimensions. This feature suggests that specific weights are elicited from specific stakeholders. Not all stakeholders are supposed to refer to all weights of all value-dimensions. The use of the value-tree construct for the weighting procedure (see Chapter IV, p. 83).

provides a convenient framework for weighting by small groups of weights distinguished by their horizontal belonging to specific attributes levels, and by their vertical relationships to specific branches. Like in the attributes elicitation, the weights for many of the entry-level attributes in the acquisition case should be done preferably by experts rather than by stakeholders.

The questionnaire respondents give priority to the decision-maker in weights determination. It seems that they are not aware of the possibility of elicitations from stakeholders (and the questionnaire itself did not provide it). Even with a broader weighting source, the decision-maker should retain the last word in resolving unsettled disputes over the value-tree construction and weighting.

The notion of disagreements over weights brings about the issue of using several weight sets. As revealed by the questionnaire [Appendix A, pp. 231-236], there are different sets of relative weights for different decision-makers levels. Those differences are very natural. It is quite obvious that SecDef, for example, would assign higher weights to political value-dimensions than the Service. While the modular structure of the value-tree may provide resolution for different scopes at the various levels, it does not provide a resolution for differences in weighting of the same spectrum of value-dimension. In fact, the same factor areas considered at DSARC or SecDef level are considered also at the top Service Department levels, though not with identical importance weights.

For example, the questionnaire indicates that political and socio-economic aspects are also considered at the Service level, although by different importance weights compared to OSD top-levels. As mentioned, these differences cannot be resolved by the modular structure. Another approach should be selected: First, weights should be reduced to very few sets. Agreements within the main groups involved such as OSD, Service, or Industry may be reached. After all, as said by Edwards (1977, p. 248), "Every boss has a boss, and every one attempts to take the values of his superior into account in his own decisions." And really, the questionnaire reflects only reasonably moderate deviation between the weight sets of the four DOD top-level acquisition decision-makers (see Appendix A, p. 233). Then, as previously mentioned, there is an option to present separate evaluation outcomes as developed by using several major weight sets, while each represents a major group of stakeholders. The judgment between them is left for the ultimate decision-maker.

5. Step 5

As recalled, at this step utility functions are constructured, and each alternative is evaluated as to how well it performs at each of the value-dimensions. The construction of utility functions is a complex process and each of them should get individual treatment, using a suitable approach. Naturally, the utility functions for objectively measured technical attributes should be constructed by different methods, consulting different experts than the purely subjective ones. There is no intention to describe in detail these

methods, whose use should be considered on a case by case basis. In general, there must be a striving for linear functions, as suggested by Edwards and many others (see Chapter IV. p. 84). For the purely subjective attributes an even simpler way may be appropriate. Instead of a continuous linear function, some 5 or 10 discrete points on it can be selected, stated in terms of "excellent," "very good," etc., or by a broader verbal formulation of quality grades (for example, see Larichev, (1977, p. 199)). Each such verbal utility grade has an associated numerical value over the utility function scale, so it enters the model mathematical procedure.

In constructing the utility functions, the notion of thresholds arises. Several of the questionnaire respondents require the procedure to maintain a provision for handling thresholds. If the relative scaling method recommended by Donnell and Ulvila is selected (see Chapter IV, pp. 84-86), no inherent threshold handling capability is provided. According to Donnell (1981) the solution for that problem is to test the alternatives for meeting thresholds external to the model. Only those who pass the test enter the formal evaluation. But since a threshold is not usually an absolutely unchangeable entity, interesting alternatives may get lost. For example, Keeney and Nair (1977, p. 299) decided, in their Nuclear Power Plant Sites analysis, not to exclude areas merely because they failed just under or over cutoff level on one criterion. Using the threshold as a "true zero" point in the

absolute or the ratio scaling methods, enables implementing what Edwards and Newman call "outside-the-range objects scoring," i.e., scores that below zero are legal, "so long as the meaning of the ranges is kept clearly in mind" [Edwards and Newman, 1980, Chapter 5, p. 5]. Thus, the strong requirement for thresholds in real life cases weakens somewhat Donnell's strong support for relative scaling. But as indicated by Donnell (1981) himself, different scaling methods can be used in the same model, as long as a complete branch (or category) uses the same scaling approach. Thus, for threshold-sensitive value-dimensions such as cost, the absolute scaling is preferred, while in other cases the relative, or ratio, scales are good enough.

Another issue associated with step 5 is the question of who should evaluate the alternatives and determine their individual scores over the various utility functions. According to Edwards (1981) that is an experts' job. Truely, looking at the nature of the entry-level attributes, almost none of them are separately a subject for high-level judgment. Furthermore, Edwards warns against letting stakeholders do the scoring. According to Edwards, models are more sensitive to scores than to weights, and if there is a place for biasing a model, scoring is that place. The questionnaire respondents reveal clear reservations towards experts' evaluations [Appendix A, p. 219]. (The Israelis are much more open to experts' aid.) In general, the respondents would like to see extensive involvement of the decision-maker in the scoring process, but

this is not very practical. In any case, the message is clear: they don't want the evaluations of some medium or low-level experts (those can be operational people as well as technical ones) to be the only input to the procedure. It is not acceptable that once the low level evaluations take place, they are pluged into the model and automatically run to the final outcome. The feeling is that some sort of higher level reviews of the model are required before it is presented to the ultimate decision-maker. Two ways are suggested to meet this requirement.

(1) Limit the value-tree to some relatively high-level of value-dimensions. Then the evaluation, naturally more subjective, will be done by higher level evaluators.

(2) Review the evaluations done by "experts" by higher-level "judges." Each will take care of a specific branch that is in his area of expertise. Those higher-level "judges" will be eligible to override evaluations that they do not accept. The question, of course, is who are these "judges?" It is hard to imagine such an evaluation process accomplished completely independently of the stakeholders, by some "objective evaluators." No doubt, the Service should be the major evaluator for any military related aspects. To counter possibility of biased evaluations there are, after all, some "insurances" while the MAUT procedure is used. The procedure cannot be completely bias-proof, but it reduces such possibilities, by its following features:

(1) The very fact that "subdecisions" are done separately for each value-tree module (or branch) reduces the possibility of overall bias.

(2) The procedure forces people to articulate their importance weights, preferences, evaluations, and hence automatically increases transparency of the alternatives presented [Edwards, 1981]. This notion is supported by the Navy Program Manager Guide [Naval Material Command, 1980, pp. 3-25], which views the achievement of a much greater degree of objectivity in the evaluation process than might otherwise be expected, as one of MAUT's greatest advantages:

> When opinions are displayed and critiqued, narrow minded orientations give way to more balanced outlook.

This is true at any level of decision-making. While the sub-decision-makers or the "experts" for specific categories are in most cases inevitably associated with one or another party of stakeholders, it is important that the analysis team, which runs the procedure, be independent or report directly to the top decision-maker office. That can be another safeguard for objectivity. All this is unnecessary in an environment of greater mutual credibility than the one described by the questionnaire comments. In environments in which the danger of biased evaluations is not sc significant, the program office is the natural home for running the MAUT procedure.

6. Step 6

As recalled, at step 6 the weighed location measures are aggregated into a single figure of merit, i.e., an overall

utility figure for each alternative. The one with the highest figure is the preferred alternative (according to the MAUT procedure only, of course). The aggregation rule recommended here is the additive rule, as preferred by most MAUT practitioners (see Chapter IV, p. 76). The aggregation, by itself, is a relatively simple calculation, but it is not yet a decision. It is the decision-making process that will be addressed, rather than the mathematical computation of the aggregate utility. Some highlights of the decision-making process associated with the MAUT procedure implementation are presented here.

As mentioned in the previous section, various branches of the model may be reviewed by separate sub-decision-makers that are authorized to do so. But when the decision reaches top-levels such as (S)SARC, Service's Source Selection Board, (S)Sec, DSARC or SecDef, the presentation should include all the model's major categories. However that might be an exhausting presentation, unless the model's complexity, or in other words--level of detail, is adjusted to the position and the personal preferences of the decision-maker involved (recall Chapter V, p. 108). The actual meaning of this adjustment is the model's presentation that starts from some selected level of attribute subdivision and up. The lowest level presented should not necessarily be uniform at all branches. It depends on how deep the decision-maker is willing to go down at each of them. In some instances he may be willing to go down to the entry-level in order to examine the utility functions, and

in another he may be satisfied by reviewing to only the second or third level. The model's presentation should be supplemented by subaggregation output for each desired level of attributes (see Chapter IV, p. 87). In addition, the decision-maker should be verbally briefed about the underlying data, and the rationale behind the model's construct. In such a way, the decision-maker has a good picture of the main objectives or value-dimensions of his interest and their relative weights; the relative location of each alternative over the major categories (by the subaggregations); and a more general idea about the construct and the utility functions at those levels which are not presented.

The notion of presenting the basic data, how the evaluation was generated, and the MAUT procedure construct rationale, as a supplement to the model's numerical parameters, is strongly recommended by the questionnaire respondents [Appendix A, pp. 224, 226]. Another questionnaire input is that subaggregations should not replace the presentation of the single figure aggregated global utility. The latter is definitely required, as reflected in the answers to Q28 of the questionnaire [Appendix A, p. 214]. That is different from methods found in the literature, which recommend listing the characteristics and impacts of the various alternatives, and leave the task of ranking to the judgment and intuition of the decision-maker. Those methods, such as "Goeller Scorecard," sometimes supplemented with "color coding," have been suggested for cases where "classical" approaches like cost-benefit were not able to prepare unambiguous

ranking of alternatives [Quade, 1979, p. 59]. But that is not the case with MAUT, which overcomes many of the "classical" analysis method's weaknesses.

Some of MAUT's advantages noted in the literature were also pointed out by the questionnaire respondents. According to the questionnaire [Appendix A, p. 211-212], the following benefits might result if MAUT is used in the acquisition decision sessions:

(1) It allows better communication and understanding among the people involved.

(2) It has the potential to focus discussion on the important issues.

(3) It assists the people to put rigor into their line of thinking.

Of course, as in any discussion, these points can be missed if the discussion is badly managed. As a consequence, some of the questionnaire respondents are reluctant to use MAUT because of the worry that the procedure may shift a discussion to unnecessary arguments on weights and scores [Appendix A, p. 203]. The answer to this worry is very simple: "don't mismanage" [Edwards, 1981].

An interesting issue is the case that the procedure would result in an outcome which the decision-maker is not willing to accept, whatever the reason--"gut feeling," or more explainable reason. However, some of the questionnaire's respondents say, "then he may be baring his belly to his foes" (by agreeing to use the procedure, R.G.) [Appendix A, p. 206].

There are several ways to avoid this problem. First, the preliminary acceptance of the procedure by the decision-maker reduces the probability of the outcome being rejected later in the process. If the decision-maker participates in the model's construction and guides, or even overrules parameters decisions, that probability is even smaller. Thus, it is essential for the MAUT procedure success to have the decision-maker's involvement from its early phases. Second, it should be recognized that it is perfectly legal for the decision-maker to change the model's parameters according to his own perception. After all, he is the one that should make the ultimate decision, and the responsibility is always on his shoulders [Trimble, 1981]. The questionnaire responses strongly support the decision-maker's authority to change the model's parameters [Appendix A, p. 214]. That is also acceptable by practitioners such as Edwards (1981). In the worst case, the decision-maker would adjust the model "brutally" to fit his own selection. Even in such a case, the model usage has been probably contributed to the decision-making: first, it served as an input that after all cannot be ignored. Second, in changing the model's parameters the decision-maker is forced to articulate his own parameters in terms of weights and scores, which puts rigor into the decision-making. But in real life, the decision-maker interaction with MAUT model is not so brutal. A more "diplomatic approach" is suggested by one commentator:

> Usually, I don't think the decision-maker will openly or overtly change weights and scores. To do so at the "end" only invites allegations of improper rigging of selection. [Appendix A, p. 218]

Edwards (1981) adds that the decision-maker should challenge the analysts if he thinks the models outcomes are incorrect. As a consequence, a wise decision-maker would not allow a model to provide a "wrong" result in the first place. By following its preparations he may affect it in the early stages. But if a conflict arises with his own attitudes at the final stages after all, he would probably send the analysts back for a "second guess" while pointing out what he thinks is wrong. That should be the real meaning of interaction between the decision-maker and the MAUT procedure. True, in some instances time constraints do not allow the full interaction as suggested here, but some level of interaction must exist if the procedure is selected as the decision tool. The acquisition decisions are important enough to justify several iterations of the evaluation model presentation to the top decision-makers, in order to obtain their acceptance of the evaluation, and the procedure's outcome.

Finally, it has to be emphasized, as noted by some of the questinnaire respondents [Appendix A, p. 202] and the interviewees (for example Trimble (1981) and Edwards (1981)) that the MAUT procedure should never dominate the decision. The final decision is the exclusive responsibility of the decision-maker, and no model's outcome should be an excuse for a bad decision. He should exploit wisely whatever available

from the MAUT evaluation procedure, but he should never let it replace him. In that sense, the MAUT procedure is only a "tool," as defined by many of the respondents [Appendix A, p. 202]. Truely, it does no more than provide a mechanism whereby proposed alternative concepts can be evaluated [Navy Material Command, 1980, pp. 3-25]. Though accepting this view as noted above, the thesis analysis suggests that this mechanism should be used as the major framework for the evaluation process and decision-making.

7. Step 7

As recalled, step 7 involves a sensitivity analysis. This is an important part of MAUT's implementation, and its results should be an integral part of the model presentation to decision-makers at the various levels.

As mentioned in Chapter IV, the most important kind of sensitivity to look at is sensitivity to weights. Sensitivity analysis of weights can replace or complement presentation of several weight sets in order to represent separately the major groups or stakeholders involved in the decision. Instead of several weight sets, only one is used, serving as a basis on which changes of weightings are tested and analyzed. The ranges of weights to be tested may be reduced by applying some "rules of thumb," which define the relationships between weight perceptions of groups or organizations. Such relationships between weights sets made at several decision levels within the DOD are presented and analyzed in Appendix A (pp. 231 - 236).

C. MAUT PROCEDURE AS AN ONGOING PROCESS

The basic ideas of the MAUT procedure as an ongoing process have been, in fact, introduced by means of the detailed comments about its implementation in the acquisition decision-making process. This section attempts to combine those ideas into a complete concept. The idea is to use MAUT procedure not only as a "one shot" evaluation tool, but as an ongoing framework for evaluation through the whole acquisition life cycle. The value-tree's various branches may be used as independent evaluation models for various aspects of the program. When combined altogether, they would provide the over-all evalaution. The model as a whole or its separate modules may serve as the major tool for any current review or decision-making session, and not necessarily for top-level decision-makers. It should be updated and changed in both construct and parameters as more information accumulated through time. Consequently, it should be maintained currently by a suitable team. (After procedure initiation, its maintenance should not be a full time job for the team members.) The natural home for such a team might be the program office. But the team's nucleus should consist of independent personnel who report essentially to the top decision-maker. That is required as a safeguard against biased evaluations.

In such a way, an up-to-date evaluation and comparison between program alternatives can be provided at any time, and not only towards Milestone decisions. From the methodological aspect, MAUT, as a modular easy-to-update procedure fits

the function of an ongoing evaluation and comparison framework very well.

D. CONCLUSIONS

1. The Chapter's Conclusions

The major conclusions of this chapter can be summarized as follows:

(1) In any case of using MAUT for major acquisition decision-making, skilled practitioner's consultation is required.

(2) The decision-maker's acceptance of MAUT procedure as the major evaluation and presentation tool should be assured in early phases of the implementation.

(3) MAUT procedure is very versatile and fits various types of acquisition decisions such as Milestones decisions (mainly I and II), source selection, and other status reviews and sub-decisions at the various decision-making levels.

(4) MAUT procedure is applicable to the evaluation and selection between unlike systems (such as missile vs. aircraft) or between "old vs. new" systems. Though such comparison raises some practical problems, they should be and can be resolved.

(5) The modular construct of MAUT's value-trees permits implementation of separate, partial evaluations for components of the overall decision.

(6) Value-dimensions should be elicited from all major stakeholders, including the decision-maker himself. Value-dimensions should also include "selfish" political factors, perhaps, in the shape some surrogate (proxy) attribute.

(7) Inspite of simplification efforts, value-trees for major acquisition decisions inevitably turn out to be quite elaborate.

(8) Adjustment of model complexity to top-level decision-maker levels can be done by a partial presentation of the model, starting at some value-dimension level and going up to the prime objective. Such a presentation is supplemented by subaggregations, underlying data and methodology rationale briefings.

(9) There might be differences in weighting between stakeholders or levels of decision-maker. When they cannot be resolved, several aggregations, using several weights sets, can be presented, being subject to the decision-maker judgment.

(10) To avoid leaving the scoring of the alternatives only to "experts," various branches of the model should be reviewed by sub-decision-makers, who would be authorized to exert their judgment in overruling the experts' evaluations.

(11) The scaling method should meet the requirement for threshold inclusion for some of the attributes.

(12) While "experts," evaluators and sub-decision-makers are inevitably identified with some stakeholders' organizations (e.g., a Service), the analysis team should report to the final decision-maker, as a safeguard for unbiased evaluations.

(13) The decision-maker is eligible to change the model's construct and parameters according to his own subjective judgment. A "wise" decision-maker should interact with the

model during its development to assure that conflicts would not be exposed only at the final stages of the decision process. If there is a conflict between his preference and the model's outcome, he had better challenge the analysts to find out what was wrong, rather than "brutally" change the model, or worse, just ignore it.

(14) The MAUT procedure is, after all, a decision "tool," although as suggested here--a central one, and should not replace the decision-maker who always has the ultimate responsibility for the decision.

(15) MAUT procedure is suggested to serve as an ongoing comprehensive evaluation base through the whole acquisition life cycle.

2. A Check for Meeting the Required Criteria

At this stage, after having introduced MAUT's characteristics in general, and its implementation issues for acquisition decisions in particular, it is appropriate to go back and check how well the sugtested methodology meets the criteria set at the conclusion of Chapter II (see pp. 45-47). This check provides the following observations: (Comment: Order of items here correlates the order of the requirements in Chapter II.)

(1) MAUT takes into account the informal decision process by identifying the informal stakeholders and by eliciting from them value-dimensions and weights.

(2) MAUT by its very nature is a multi-objective decision technique.

(3) The value-tree construct allows sorting of the factors, focusing on the important ones, and eliminating the irrelevant ones. The partial presentation described in this chapter enalbes any desired level of detail of presentation for decision.

(4) The concise but comprehensive alternatives' presentation through the MAUT procedure makes the decision-maker more capable to evaluate and select alternatives.

(5) The rigor and discipline imposed by MAUT procedure inherently increases model transparency and by that counter biased presentation tendencies.

(6) The suggestion that MAUT be an ongoing evaluation framework provides the element of evaluation updating.

(7) MAUT can serve as a comprehensive evaluation tool including political, economic and social issues.

(8) MAUT is a quantitative technique which is capable of handling subjective, judgmental consideration.

(9) The "wise" interaction of the decision-maker with the model may reduce the possibility of conflict between his decision and the model outcome, and thus reduce the possibility of using the model against his decision.

(10) The subjective evaluations involved in MAUT include also "rules of thumb" and descriptive elements, but putting them into order causes a better exploitation of the decision-maker's skills.

(11) Although top-level decision-makers remain highly dependent on their subordinates evaluation, the comprehensive

decision presentation allows them better evaluations of their own.

(12) The modular construct of MAUT model enables working through the organizational functional and hierarchical structure.

(13) The MAUT procedure provides fair and ordered representation of political powers and their attitudes.

(14) The framework of the procedure's presentation compensates, to a certain degree, personal differences of charisma, presentation skills and alike.

(15) The modular construct of a MAUT model enables adjustment of the presentation complexity to the individual decision-maker.

(16) The implementation recommendations of this chapter meet the requirement of the model's early acceptance by the decision-maker, and the latter's interaction with the model through its various phases.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The major concern driving this research has been the desire to improve top-level acquisition decision-making. The following major problems, deficiencies, and difficulties of the present acquisition decision-making situation, have been identified:

(1) Difficulties in circumscribing the decision factors and consolidating them all for a final decision. This stems from the complex, multi-objective nature of the acquisition decisions.

(2) Lack of balance of political impacts of individuals, groups and organizations, imposed upon the decision-making process. Disorder in the representation of those who have stakes in the decision.

(3) Existence of phenomena such as biased decision presentation, which is amplified by the inevitable reliance of top-level decision-makers on their subordinates' evaluations.

(4) Aversion to the usage of quantitative techniques as top-level decision aids which stems mainly from the lack of confidence in the capability of these techniques to incorporate intuitive, judgmental issues.

In the search for decision techniques that may improve the above deficiencies, the thesis concludes that there are in existence decision techniques which are capable of incorporating

subjective, judgmental issues, and of combining them with objectively measured data. After analyzing the nature of the acquisition decision, a conclusion is drawn that the above-mentioned techniques might be of great help to these decisions. Among the decision techniques MAUT stands out as the most preferred by theoreticians, as well as actual users.

After a review of the basic concepts of MAUT, recommendations for implementation of the procedure are suggested. The major conclusions for implementation are:

(1) MAUT, as a versatile method, is compatible with a broad spectrum of acquisition decision types.

(2) MAUT's model for major system acquisition decisions is inevitably complex, but its modular construct allows "vertical" and "horizontal" cuts, in order to adjust the model's scope and level of detail to the decision-maker's position and personal preferences. Ways to do it are suggested.

(3) A "fair" representation of stakeholders can be achieved by their substantial involvement during the model's construct process (value-dimensions and weights elicitations) and during the model's presentation (by presenting several aggregations with several weights sets).

(4) The ultimate decision-maker should "interact" with MAUT procedure from the beginning by preliminary acceptance, participating in the value-dimensions and weights elicitations, guiding the model's construction and interacting with the model in the presentation for the decision.

As explained at the end of Chapter V, the MAUT procedure satisfies to a great extent the criteria established in Chapter II, and thus, offers solutions to many of the deficiencies and difficulties of the present decision process. However, MAUT is by no means a "magic prescription" for all the existing decision process' weaknesses: First, there are still questions of how to generate reliable data for its various inputs. Second, its success is sensitive to the quality of the implementation process in each individual case. Third, although capable of incorporating subjective judgment, it cannot generate it. It also cannot express and represent all the delicate components of human thought. The above mentioned issues imply an important conclusion: MAUT is, after all, a "tool," and should never dominate the decision. It is the decision-maker who has the responsibility and the authority to make the decision, and he is accountable for it.

The message of this thesis is that usage of MAUT procedures as the major evaluation framework and the center of the decision presentation for the highest decision levels, would improve the efficiency of the process, increase objectivity, contribute to top-levels decision-making capability, and consequently bring about better decisions.

B. RECOMMENDATIONS

(1) The MAUT procedure should be used as the major tool for presenting and evaluating alternatives for acquisition decisions at the top levels. The procedure should include political, economic and social factors in addition to the

directly relevant factors such as military worth or cost. It should provide fair representation of the major stakeholders involved in the decision.

(2) For each major system MAUT should serve as comprehensive, ongoing, updated evaluation framework through the whole acquisition life cycle. On the base of this evaluation framework, major decisions as well as sub-decisions would be made. This ongoing evaluation framework should be constructed, maintained and reviewed by staff members and sub-decision-makers through the functional and hierarchical organizational structure. At the nucleus of the evaluation framework would be an analysis team that may be located at the program office, but would be formally subordinate to the ultimate decision-maker.

For more detailed description of implementation issues, reference may be made to the conclusions as presented in Chapter V.

C. AREAS FOR FURTHER RESEARCH

(1) The implications of the model's "vertical" and "horizontal" decompositions should be further explored. That includes modifications suggested by the thesis such as:

(a) Presenting only the upper level value-dimensions to the decision-maker.

(b) Reviewing issues and making sub-decisions referring the separate branches of the model's value-tree and only as a later step integrating them into the overall model.

(2) The approaches and methodologies for constructing utility functions for major systems should be further

researched. Some of them may have general application, while others, presumably, are unique to the system under question.

(3) The specific procedural and organizational adjustments required for MAUT implementations should be further examined. That should be the duty of the authorities actually responsible for the major systems acquisition decision-making process.

APPENDIX A

THE QUESTIONNAIRE

TABLE OF CONTENTS

A-I. Introduction to the Questionnaire

A. GENERAL

As a part of the research work for this thesis, a questionnaire was distributed to various high-level officials in the U.S. DOD, and in the Israeli Air Force (IAF).

B. PURPOSE

The purpose of the questionnaire was to obtain inputs associated with the thesis theme from the people who are actually and personally involved in the major systems acquisition decision-making.

There were two main reasons why two decision-making communities--the American and the Israeli--were addressed:
(1) It provided the basis for comparison between two different disciplines, dealing with the same issue, while one is not bound by the perceptions, tradition and procedures of the other.
(2) The special interest of the author in both communities as being an Israeli officer and currently a student at the Naval Postgraduate School.

C. THE QUESTIONNAIRE OBJECTIVES

The main objectives of the questionnaire were:

(1) To examine the current practices of top-level acquisition decision-making processes and find out to what extent quantitative decision models are in use, and whether a further use of such models might be helpful.

(2) To find out the respondents attitude toward a specific model (or rather, a procedure) based on the Multi-Attribute

Utility Technique (MAUT)[1], and its compatibility to assist top-level acquisition decision-making.

(3) To explore the respondents ideas about the actual implementation of the above mentioned procedure in the decision-making process.

(4) To examine the possibility of constructing a general "value tree", i.e., to define value dimensions (or, attributes, factors) and arrange them in hierarchical structure, which, with some inevitable modifications would apply to any major system acquisition decision-making process.[2]

D. THE RESPONDENTS POPULATION

1. General

As mentioned before, the questionnaire was distributed to people from two decision-making communities: the U.S. DOD and the Israeli Air Force. In both cases no purely random selection of the sample respondents took place. They were arbitrarily selected according to their positions and estimated involvement in the "real life" acquisition decision-making process. On the other hand, the sample was selected from the DOD Phone Book and the author had no prior idea about the

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[1]Also called in its various versions Multi-Attribute Utility Theory (MAUT), Multi-Attribute Utility Measurement (MAUM), Multi-Attribute Utility Technology (MAUT), Multi-Attribute Utility Analysis (MAUA), or Simple Multi-Attribute Rating Technique (SMART).

[2]Originally, the questionnaire was supposed to concentrate mainly on fighter aircraft acquisition decisions. Later on, the scope of the thesis has been broadened to apply to more general cases. The questionnaire well served this broader scope as well.

respondents attitudes, and in this sense there was some extent of "randomality" in the selection, as reflected in the deviation of the answers.

2. The American Distribution

a. The questionnaire was distributed to 73 American officials of which 42 have responded (57.5%). 4 claimed they did not feel eligible to fill in the questionnaire ("new in the job," "unfamiliar with the subject," etc.). Thus 38 filled-in questionnaires came back, which accounted for 52% of the initial distribution. This can be considered as an excellent rate of response, taking into account that the questionnaire answers required about 2-3 working hours from very busy high-level personnel.

b. The American respondents' population accounted for 28 military personnel and 10 civilians. The ranks of the military officers were distributed as follows:

(1) LT. GEN -- 2
(2) V. ADM. -- 4
(3) MAJ. GEN. -- 1
(4) R. ADM. -- 7
(5) BRIG. GEN. -- 1
(6) CAPT (Navy) -- 5
(7) COL -- 4
(8) LT. COL -- 3
(9) LT. CDR -- 1

10 American civilians responded to the questionnaire. The civilians were all of relatively high levels, from GS-15, SES IV, and above.

c. The respondents, spread according to their DOD components, were as follows:

(1) OSD -- 13

(2) Navy Department -- 16

(3) Air Force Department -- 9

d. The respondents were from a broad range of positions in the OSD and the Service Departments, starting at the level of staff members, executive assistants and program managers, and up to the level of Under Secretary of Defense. The common denominator for all respondents was involvement in the major systems acquisition decision-making process, within the OSD and the Services.

e. The Israeli respondents population consisted of 11 officers of the IAF. Their ranks were distributed as follows:

(1) BRIG. GEN -- 4

(2) COL -- 3

(3) LT. COL -- 2

(4) MAJ. -- 2

Having in mind that the rank of the IAF Chief of Staff is "only" MAJ. GEN., the level of the Israeli respondents were considered as equivalent to the Americans. Thus, the Israeli respondents population included two ex-deputies to the IAF Chief of Staff (the second position in the IAF hierarchy), the IAF Chief of Maintenance and Logistics, IAF HQs department heads, etc.

A-II. Example of the Questionnaire

A. GENERAL

This appendix presents the American version of the questionnaire, with the escort letters attached to it. As one can notice, the title of the questionnaire speaks about "Methodology for Aircraft Acquisition Decision-Making." This is not identical to the thesis title. The reason for this discrepancy is that according to the material accumulated through the research for this thesis, the author has decided to broaden the scope of the thesis theme. Nevertheless, this change does not affect the substantial application of the questionnaire in providing insight into the top-level acquisition decision-making. The Israeli version of the questionnaire is not introduced in this context since it is similar to the American one. On the other hand, because of some natural differences between the two responding populations, and because both questionnaires were not distributed in the same time-frame, there were some substance and format differences, especially in Part V, which made the answers' consolidation sometimes difficult. The differences are addressed specifically where necessary.

B. THE QUESTIONNAIRE

Dear Sir:

First, I would like to introduce myself. I am Colonel Ran Goren, a pilot in the Israeli Air Force. I have about 4000 jet flight hours, and 250 operational sorties. I did a variety of jobs at the field and Headquarters, among them squadron commander, vice wing commander, and head of a department in the

ISAF Headquarters. Currently, I am a student at the Naval Postgraduate School, Monterey, California.

As a requirement for the master's degree, I have to submit a thesis. As a theme for my thesis, I have chosen "The Methodology of Decision-Making in Aircraft Acquisition." The completed thesis will be available to the DoD acquisition community through the NPS and the Naval Center for Acquisition Research.

I am definitely aware of how big and complex the issue is and therefore, I have limited myself as follows:

1. To deal only with the top-levels of decision-making (in American terms--(S)SARC, (S)Sec, DSARC and SecDef--or equivalent to those).

2. Not to deal in detail with the whole acquisition life cycle process. The process would be referred to only in terms of the inputs it should provide for the milestone decision-making.

3. To analyze mainly milestones I (demonstration/validation) and II (full scale development).

I thought that getting the personal perception of people involved in this decision-making might be a vital contribution to my work. In order to obtain this perception, I am distributing the enclosed questionnaire.

Although the questionnaire is voluntary, I would like you very much to respond.

If you find it too long, please answer personally the first half (Parts I, II, III) only.

Since the distribution of the questionnaire is very small, it will be analyzed by simple percentages, and ANOVA (Analysis of Variance).

I am not going to quote any respondent by name. Names and positions are needed just for relating the responses to the respondents viewpoints. But, if you prefer not to fill in your personal information--please leave it blank or put just an indication of your level.

I will be grateful if you return your response up to the end of July. At any rate, after August 31st, the questionnaire will be longer be administered. Please return the completed questionnaire form to the following address:

Colonel Ran Goren
Naval Postgraduate School
SMC #1183
Monterey, CA 93940

Thanks a lot for your cooperation.

Sincerely yours,

Dear Sir:

As you may know, I recently moved from being the Principal Deputy Under Secretary of Defense to Dr. W. Perry to being an Adjunct Professor here at the Naval Postgraduate School. As part of this way for me to finish the last few months of my civil service, I have been writing down, for the new Under Secretary Dick De Lauer, things which may otherwise be lost in the transition. One of these areas of interest to both Dr. De Lauer and myself has been how best to improve the acquisition process.

The purpose of this note is to introduce the request made of you to assist in an important study of one facet of our acquisition process being done by Colonel Ran Goren, IAF, as part of his thesis work at the Naval Postgraduate School, Monterey, California.

The study will survey an important aspect of the acquisition process, namely whether there exists an adequate review of alternatives before selection of hardware for development or acquisition. Colonel Goren will also present, for comment a potential qualitative technique for aiding in this selection.

His thesis, when published, will be available to you and to others in the acquisition community. It should provide an especially pertinent insight into an important acquisition question. It is for that reason I ask, as a favor, your consideration of his request to put down your thoughts through the media of his questionnaire.

W. B. LaBerge

A Questionnaire

Methodology for Aircraft Acquisition Decision-Making

1. Respondent Information:

_____ _____ _____ _____

rank first name middle last

Address _____

_____

Present Job _____

Main Past Jobs Connected With Acquisition

_____

_____

_____

2. Preface

-- Part IV of the Decision Coordination Paper (DCP) requires: "Summarize system and program alternatives considered and the reasons why the preferred alternative was selected."

-- Part VI of the DCP requires: "Identify and assess issues affecting the SecDef's milestone decision," which presumably are political and socioeconomic issues.

-- The DCP is supplemented by a list of various goals and thresholds, costs and resources.

-- The Integrated Program Summary (IPS) addresses 23 different topics.

-- There can be defined 16 decision criteria for milestone I and II decisions.

-- The AF (as an example) requires about 35 decision data topics to base on in its milestone review.

The milestone decisions might be a very complex task, even after the analyses, data collection, refinements and eliminations that have been done through the preceding process.

This questionnaire attempts to explore some aspects of the above problem as background for the thesis decision model development.

3. General Instructions

a. Ignore questions which do not apply to you.

b. While answering the question refer as much as possible to cases of:

   1) Milestones I and II decisions.

   2) Selection between two or more different types of weapon-systems (aircraft type A vs. aircraft type B, and not a selection between alternative acquisition strategies of the same system).

   3) If possible, refer to aircraft or airborn weapon systems (although other systems are ok too).

c. Although the questions aim at top-level decision-making, you may use your experience in other levels, as long as multicriteria selection between acquisition alternatives is involved.

Part I

Instructions:

For each question select one answer. Please, circle the number to the left of the selected answer.

1. Are the evaluation of alternatives and the explanation for recommendations in the DCP made in a sufficiently descriptive manner to be useful?

    1. Never
    2. Seldom
    3. Sometimes
    4. Usually
    5. Always

2. Are the evaluation of alternatives and the explanation for recommendations in the DCP supported by sort of a quantitative model?

    1. Never
    2. Seldom
    3. Sometimes
    4. Usually
    5. Always

3. In the milestones review sessions (DSARC, (S)SARC)--how often is the evaluation of alternatives supported by a normative--quantitative model?

    1. Never
    2. Seldom
    3. Sometimes
    4. Usually
    5. Always

4. If you ever used a model for overal evaluation of acquisition alternatives (not necessarily at milestones decisions), which one did you find the most useful?

    1. Scores and weights assigned to factors
    2. A decision tree
    3. A computerized model
    4. Another (which one?)
    5. Never used a model

Part II

Instructions:

In each question there is a statement. For each statement select your degree of agreement.

5. There is no problem in selection of an alternative at the milestones reviews, since the pre-DSARC process leads to refined, clear and explicit recommendations.

    1. Decidedly agree
    2. Moderately agree
    3. Perhaps agree
    4. Moderately disagree
    5. Decidedly disagree

6. After hearing (or reading) the detailed evaluation of the alternatives by individual areas (i.e., cost, performance, etc.), it is difficult to determine which alternative was preferred.

    1. Decidedly agree
    2. Moderately agree
    3. Perhaps agree
    4. Moderately disagree
    5. Decidedly disagree

7. The less the selection is clear cut, the greater is the decision-maker's tendency to rely on lower level analysis and recommendations.

    1. Decidedly agree
    2. Moderately agree
    3. Perhaps agree
    4. Moderately disagree
    5. Decidedly disagree

8. In cases where the overall preference is unclear, a quantitative model might be helpful.

    1. Decidedly agree
    2. Moderately agree
    3. Perhaps agree
    4. Moderately disagree
    5. Decidedly disagree

9. In fact, top level decision-makers do not select between alternatives, but approve or disapprove the recommended alternative.

    1. Decidedly agree
    2. Moderately agree
    3. Perhaps agree
    4. Moderately disagree
    5. Decidedly disagree

10. There is no use for a decision-making model to support top level decision-makers because they base their judgement mainly on a subjective experience, perception and intuition which cannot be rationally "managed."

    1. Decidedly agree
    2. Moderately agree
    3. Perhaps agree
    4. Moderately disagree
    5. Decidedly disagree

Part III

Instructions:

Recall 2 cases of aircraft acquisition. (If you wish you may relate to systems other than aircraft, or even to an unspecified general case. Please, note what kind of a system you are relating to.) Evaluate the relative weights of three main categories;--direct, socioeconomical and political factors--in the evaluation. Express weights by percentage. Please, make different evaluations for some different levels.

	Case 1			Case 2		
Level of decision	Dir.	SE.	Polit.	Dir.	SE.	Polit.
(Example)	35%	15%	50%	60%	20%	20%
SecDef	____	____	_____	____	____	_____
DSARC	____	____	_____	____	____	_____
(S)Sec.	____	____	_____	____	____	_____
(S)SARC	____	____	_____	____	____	_____
Below	____	____	_____	____	____	_____

Part IV

Instructions:

This part contains a simple evaluating model example. Questions in the following parts of the questionnaire refer to this example. The example is a submodel of an overall model, which evaluates the alternatives in one category (change in the Air-Force capability). Scores assigned relative to a specified benchmark (i.e., acceptable criteria, threshold) according to a key:

0 - under threshold (or minimal criteria).
1 - poor
2 - fair
3 - good
4 - very good
5 - excellent

Significance weights express the impact of the factor on the evaluation within the category (they should sum up to 1).

Change in the Air-Force Capability - Example Model

Evaluation Factor	Weight	Score		Weighted Score	
		Alt. 1	Alt. 2	Alt. 1	Alt. 2
Effectiveness (with respect to MENS)	.30	5	3	1.5	.9
Cost-Effectiveness	.25	2	5	.5	1.25
Timeliness	.15	3	1	.45	.15
Manpower and Training	.15	3	2	.45	.30
Maintainability and Reliability	.10	4	2	.4	.2
RSI	.05	2	4	.1	.2
Overall evaluation				3.4*	3.00

*Alternative 1 is preferred.

Comment: Scores and weights are arbitrarily assigned. I refer to the model to illustrate the principle ideas and not to the specific selection of factors, weights and scores.

Part V

Instructions:

This part contains a list of statements with respect to using such a model. Please, indicate your degree of agremeent to the statements by circling a number according to the following key:

Decidedly agree - 1
Moderately agree - 2
Perhaps agree - 3
Moderately disagree - 4
Decidedly disagree - 5

11. Such a model may be used only if supplemented by representation of the detailed data for each topic.

1 2 3 4 5

12. The decision-maker himself has to determine weights and scores.

1 2 3 4 5

13. The model is supposed to be objective therefore may not be changed. (The decision-maker is not bound, of course, by the model outcomes)

1 2 3 4 5

14. The model is prepared by an analytical process through the different levels, but the decision-maker may change weights and scores (interact with the model) according to his judgement:

1 2 3 4 5

15. Such a model is not for acquisition related decisions.

1 2 3 4 5

16. Such a model may be useful in most cases of acquisition selection decisions.

1 2 3 4 5

17. Such a model is not useful for top-level decision-making.

1 2 3 4 5

18. Such a model is useful for all levels except SecDef, since political aspects can't be handled by the model.

1 2 3 4 5

19. Evaluation by separate factors is not appropriate, since the appropriate evaluation is derived from the complex interrelations among factors.

1 2 3 4 5

Key

Decidedly agree - 1
Moderately agree - 2
Perhaps agree - 3
Moderately disagree - 4
Decidedly disagree - 5

20. The model leads people to manage their judgement in a logical manner, which helps the decision-making.

1 2 3 4 5

21. Such a model leads people to refer to the really important issues in the decision.

1 2 3 4 5

22. Such a model suppresses the natural intuitive judgement.

1 2 3 4 5

23. Such a model may bias the decision-makers good judgement.

1 2 3 4 5

24. Such a model may somehow bind the decision-makers freedom.

1 2 3 4 5

25. Such a model enables better communication among people involved in the decision-making.

1 2 3 4 5

26. Such a model may be used as a tool to criticize the decision (e.g., by Congress), and therefore undesirable.

1 2 3 4 5

27. Such a model is a very good way to reach a decision in a multicriteria case.

1 2 3 4 5

28. There is no need for weights and total score. A score for each factor separately is sufficient. The rest should be left for pure judgement.

1 2 3 4 5

29. Such a model may shift the discussion from the significant issues to unnecessary arguments on scores and weights.

1 2 3 4 5

30. Weights and scores should be assigned independently from each other at a different time, and perhaps, by different people.

1 2 3 4 5

Key

Decidedly agree - 1
Moderately agree - 2
Perhaps agree - 3
Moderately disagree - 4
Decidedly disagree - 5

31. The weights are the main ingredient in the model outcome, therefore they should be determined by the decision-maker himself.

1 2 3 4 5

32. Weights and scores should be determined by a common work of a group of experts.

1 2 3 4 5

33. Weights and scores should be determined by summing up assignments made individually by people involved in the decision.

1 2 3 4 5

34. Add additional remarks with respect to the model.

Part VI

Instructions:

Based upon your knowledge and experience of two recent cases of selection between acquisition alternatives - evaluate the following list of possible factors which affect the decision-making.

a) For each factor assign the degree of impact on your evaluation of the alternatives.

b) For each case note:

1) the nature of the weapon system under discussion (aircraft, missile, ship, etc.)

2) the phase in the acquisition life cycle you refer to.

Rate the degree of impact using the key:

No impact	- 0
Weak impact	- 1
Medium impact	- 2
Strong impact	- 3
Very strong impact	- 4

	Case 1	Case 2
Weapon System	_____	_____
Phase of Decision	_____	_____

Factors	Impact on Evaluation	
1) Effectiveness (relative to MENS)	_____	_____
2) Cost-effectiveness	_____	_____
3) Timeliness	_____	_____
4) RSI	_____	_____
5) Maintainability and reliability	_____	_____
6) Manpower and training	_____	_____
7) Vulnerability	_____	_____
8) Life cycle cost	_____	_____
9) R&D costs	_____	_____
10) Production costs	_____	_____

Key

No impact - 0
Weak impact - 1
Medium impact - 2
Strong impact - 3
Very strong impact - 4

Factors		Impact on Evaluation Case 1	Case 2
11)	Initial investment (procurement and infrastructure)	_____	_____
12)	Operating and support costs	_____	_____
13)	Funding resources	_____	_____
14)	State of the art (implemented in the system)	_____	_____
15)	R&D current status	_____	_____
16)	Feasibility and risks	_____	_____
17)	Critical components	_____	_____
18)	Maturity (experience with the system)	_____	_____
19)	Contractor performance (technological achievements, cost control, timeliness)	_____	_____

Please, add more factors that you think deserve to be evaluated at high-levels (except political and socioeconomical).

20)		_____	_____
21)		_____	_____
22)		_____	_____
23)		_____	_____
24)		_____	_____

Part VI

Instructions:

In this part I'll appreciate any of free comments with respect to the questionnaire subjects.

End of the questionnaire.

Again, thanks for your cooperation.

Ran Goren
N.P.G.S. SMC 1183
Monterey, CA 93940

A-III. Introduction to the Analysis of the Questionnaire

A. GENERAL

The following chapters include the analysis and the summaries of the numerical results of the questionnaire. It is emphasized that the analysis in these chapters refers to the questionnaire only, and attempts to represent objectively the aggregate attitudes of the respondents. Any broader view of the thesis theme based on additional sources is left for the body of the thesis.

B. SAMPLE CHARACTERISTICS

The responding sample was not purely randomly selected. Thus, from a pure scientific viewpoint, the results and the analysis cannot be considered as an unbiased representation of the total population of people involved in top-level acquisition decision-making. In the worst case the results may be considered as representing the responding sample only. But the responding sample has a great significance in its own right. As mentioned in Appendix A, it consists of 38 DOD personnel, 28 military and 10 civilians, of which 23 are at high ranks (Generals, Admirals and the equivalent civilian ranks), up to USD (R&E). It represents, by more or less equal portions, the OSD, the Navy Department and the Air Force Department. The Israeli responding group consists of 11 Air Force officers including 4 Generals of the highest positions concerning acquisition. Consequently, though not taking for granted any statistical result, the responding sample may well

represent opinions, attitudes and trends within the top-level acquisition decision-making communities of both the US and Israel.

C. GENERAL METHODOLOGY

The numerical summaries and the analysis are presented in 6 chapters (IV to IX). In each chapter the numerical summaries and the analysis associated with the subject under discussion are attached together for the reader's convenience. The subjects of the chapters follow the underlying questionnaire surveying purposes, but not necessarily create a complete logical continuity.

The questions are referred to in these chapters according to the issues they inquire, and not according to their order of appearance in the original questionnaire. This is also the rationale of the numerical summaries presentation order.

The subjects of the chapters are as follows:

(1) Examination of the present situation in top-level acquisition decision-making.

(2) Competability and usefulness of quantitative decision-making techniques for top-level acquisition decision-making.

(3) Advantages and disadvantages of MAUT as a top-level acquisition decision-making tool.

(4) Implementation of MAUT procedure in major system acquisition decision-making process.

(5) Relative importance of acquisition decision-making attribute categories.

(6) Identifying acquisition decision-making attributes (value dimensions).

The responding sample is referred to three categories:

(1) Low levels--Colonels, Captains (Navy), GS-15, and below.

(2) High levels--Generals, Admirals and the equivalent civilian ranks.

(3) Total--all levels together.

The rationale behind this division rests on the assumption that the "low" levels are mostly staff members while the "high" levels are personally involved in the decision-making. Although such distinction is oversimplified, it has been selected for convenience reasons, under the assumption that no major error will result.

D. METHODOLOGY OF THE NUMERICAL SUMMARIES

The numerical summaries are done on a single question basis, i.e., each question has a separate summary. Interrelations among questions are addressed in the verbal analysis.

As a result of the small sample size, no complex statistics are developed. Rather, a simple frequency distribution is the most common tool for this analysis. The frequency distribution is introduced in three shapes:

(1) Absolute amount.

(2) Relative frequency (expressed as percentage)

(3) Relative frequency histogram.

Some differences between the American and the Israeli questionnaire versions do not allow a consolidation of the data. As a matter of fact, such a consolidation is not desirable since

a comparable analysis is preferred. Thus, the Israeli summaries appear separately. Because of the small Israeli sample size, only the total frequency distribution is exhibited, although the data about the separate distributions of the Israeli "high" and "low" levels does exist, and it is referred to in the discussion of the analysis when necessary. In the Israeli questionnaire there are only four alternative answers for each question, compared to five in the American version. This requires some adjustments for comparison needs. Part V of the Israeli questionnaire is structured differently from the corresponding part in the American version. Therefore the summary of this part for the Israeli answers only is located separately at the end of the associated chapters.

E. METHODOLOGY OF THE ANALYSIS

The analysis refers to the questionnaire answers and written comments only. Neither the analysis of the questions, nor the chapters' summaries are supposed to represent the final conclusions of this thesis. That is the reason why there are no conclusions to the analysis. The conclusions are deliberately left for the body of the thesis.

To facilitate the analysis, the five answer alternatives are usually grouped into three categories:

(1) The "agree" category includes the "decidedly agree" and "moderately agree" answers.

(2) The "disagree" category includes the "decidedly disagree" and the "moderately disagree" answers.

(3) The "middle" category includes the "perhaps agree" answers.

The division is equivalent where frequency type answers (never, seldom, etc.) or others are concerned. Obviously, where necessary, the full fine distinction through all five alternative answers is used.

For a common language, four types of distributions are defined:

(1) The "uniform" distribution--the answers are more or less uniformally distributed through the various answer alternatives, as illustrated in Figure A-III-1.

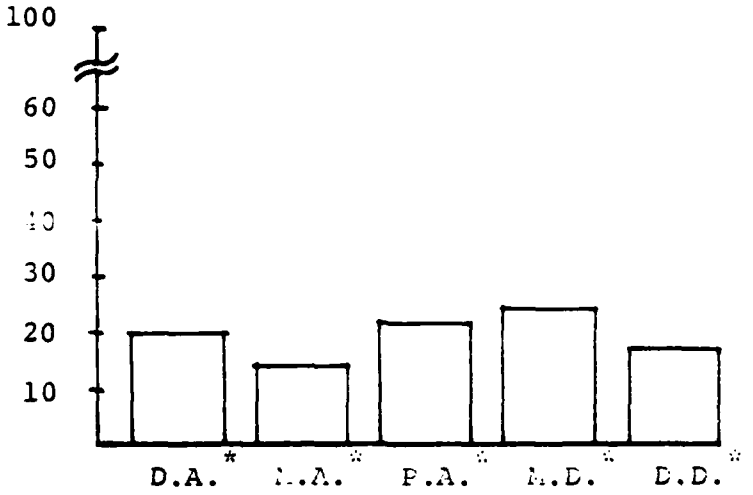

Figure A-III-1. "Uniform" Distribution

(2) The "split" distribution--the answers are divided categorically on both sides, while very few are in the middle

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*In this and all future exhibits, the following abbreviations are used to label the entries along the x-axis: D.A. = Decidedly Agree, M.A. = Moderately Agree, P.A. = Perhaps Agree, M.D. = Moderately Disagree, D.D. = Decidedly Disagree. See above sections of this appendix for a fuller discussion of the categories.

column. That means that people have clear opinions about the subject, and they are either pro or con. Figure A-III-2 illustrates this distribution.

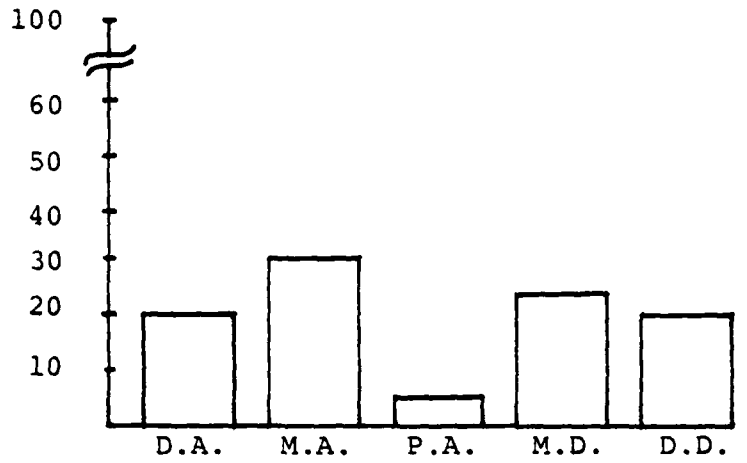

Figure A-III-2. "Split" Distribution

(3) The "middle" distribution--This is the case where the largest column is the one at the middle, i.e., the group of people who do not have definite opinions about the subject is dominant. Usually the two next in size are the columns on both sides of the middle--the "moderately agree" and "moderately disagree" columns. Figure A-III-3 illustrates:

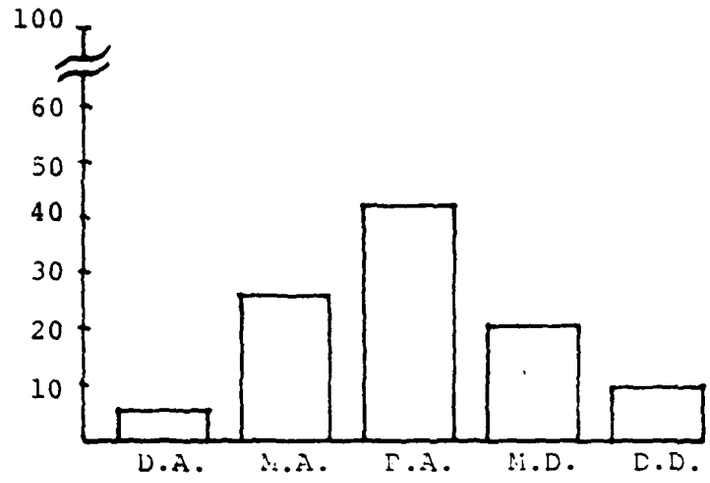

Figure A-III-3. "Middle" Distribution

(4) The "one-sided" distribution--The answers tend to be concentrated on one side of the histogram, i.e., the majority of respondents clearly favor one attitude to the subject. Figure A-III-4 illustrates:

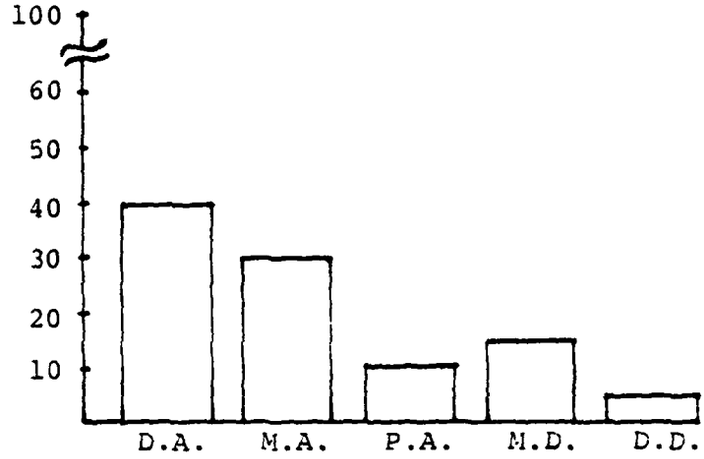

Figure A-III-4. "One-sided" Distribution

Some of the questions appeared in different shapes in the Israeli questionnaire. Instead of having five degrees of agreement for each question, the Israeli respondents were presented a list of statements from which they had to select only those which they think are true. The statements themselves are almost identical to those appearing in the American version. Thus, the numer of respondents that picked up a statement is the number of those who agree with the statement. Those who did not pick up a specific statement probably disagree or don't have a determined mind about it. A concentration of that type of question appears at the end of each chapter, consisting of the questions corresponding to the chapter's theme.

Generally, each question is treated separately. But where necessary, interrelations among questions, mostly within the chapters, are addressed--verbally and statistically.

The American questionnaire serves as the analysis base, while the Israeli one--since quantitatively small--is used as a reference and comparison mean.

Another notation which appears in this analysis relates to the quotes from the written comments to the questionnaire. On one hand, there is a commitment not to identify commentator by name. On the other hand, it is important to recognize that a set of, say, very critical comments, came from the same person, and they do not necessarily represent a wide range of respondents. Therefore, commentators are assigned an arbitrary notation which appears in brackets following the quote or

reference citation. The notation distinguishes between high-level personnel and low-level personnel (see definition on p. 157) as follows: H-1, H-2, etc., for high-levels, and L-1, L-2, etc., for low levels.

A-IV. Examination of the Present Situation

A. PURPOSE

The purpose of this section and the corresponding questions is to reveal what are the real difficulties the decision-makers face when they reach a decision point.

B. DISCUSSION ABOUT THE BASIC APPROACH OF THE ANALYSIS

The questionnaire addresses mostly the formal decision sessions and documentation. The assumption underlying the above approach is that the formal decision sessions (e.g., Milestones DSARCs) or documentation (e.g., DCP) do reflect or should reflect the alternative system evaluating techniques used throughout the decision process. Obviously, they do reflect the decision and evaluation tools offered to the decision-makers themselves for their decision-making.

The questions deliberately refrained from touching the underlying essential acquisition decision-making difficulties, mainly stemming from uncertainties, such as how to make a realistic cost estimate, how to predict the performance of a system that has not been born yet, or how to define the real mission needs, based on a projected threat assessment. These warrant a treatment beyond the scope of this thesis. However, the assumption is that better evaluation and decision-making techniques have significant impact on the essence of the decision. Several commentators write that dealing mostly with the so-called "DSARC Process", or "A-109 process" is inappropriate since it is subject to continuing revisions, including expected

near-term substantial change [H-1,L-1]. Others mention that the "acquisition process documentation is of limited value, if any..." [H-1]. They emphasize the informal decision process that takes place parallel to the formal one, and the "less conspicuous decision-makers, who are often more influential than the formal and obvious ones" [H-2].

While admitting that the issue is obviously more complex than the questionnaire will permit, several points can be made to stress the value of the data that this part of the questionnaire does provide. These points are:

(1) Decision-making tools are not attached to a specific formal decision process. Change of the present process, say, to a greater extent of decision authority granted to the Services, less DSARC Milestone sessions, or more pages allowed in the DCP, does not necessarily change the extent to which decision-making tools are used. The present decision difficulties and decision-making tool usage are symptoms of basic approaches and not attached to a specific decision process.

(2) Correcting the weaknesses of the formal process may reduce the informal powers affecting the process.

(3) The formal sessions and documentation have, after all, a significant value. For very busy top-level officials who do not deal with the acquisition issues on a day-to-day basis, the formal sessions and the documentation they receive represent a significant part of the input for their decisions.

C. DIFFICULTIES IN THE DECISION MAKING

According to Q1 (see Exhibit 1), 46% of the American respondents think that the evaluation of alternatives and the explanation for recommendations in the DCP are made in a sufficiently descriptive manner to be useful. The preference here is clear as compared to only 14% who think that it is so, seldom or never. However, no less impressive is the percentage of those who think that only sometimes are the descriptions in the DCP good enough to serve as a decision basis. Thus, a considerable percentage are not generally satisfied with what is presented in the DCP. Q6 (see Exhibit 2) reveals very clearly, with 69% at the "disagree" region ("moderately disagree" plus "decidedly disagree"), that after the alternatives demonstration (presumably with the current techniques), there is no difficulty in determining which alternative was preferred. This question might have been misinterpreted because of inexplicit wording. The question was aimed at the decision-maker's difficulties in determining his <u>own</u> preferences based on the alternatives presented, and not on his ability to recognize which alternative was preferred by the program sponsor. This possible confusion is, perhaps, disclosed by the corresponding Q5 (see Exhibit 3) which deals with the same issue of preference or selection of alternatives. Here, 47% of the respondents think that a problem does exist in the selection of alternatives while 29% think that there is no problem, and 24% are inbetween. This is supported by the Israelis, who express their reservation with 64% of "Sometimes true" answers.

Exhibit 1

Question No. 1 (Q1)--Numerical Summary

The Question's Phrasing:

Are the evaluation of alternatives and the explanation for recommendations in the DCP made in a sufficiently descriptive manner to be useful?

Table A-IV-1

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Never	1	-	1	7.1	-	2.7
Seldom	2	2	4	14.3	8.7	10.8
Sometimes	4	11	15	28.6	47.8	40.5
Usually	7	10	17	50.0	32.5	45.9
Always		-	-	-	-	-

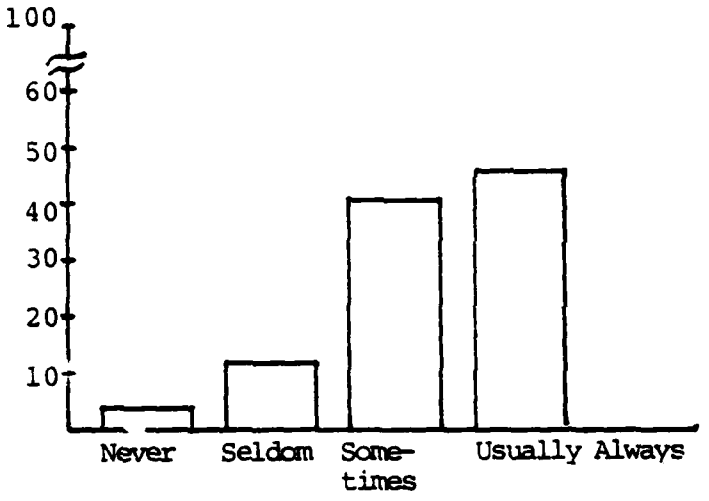

Figure A-IV-1. American Responses Distribution Histogram

Table A-IV-2

Israeli Responses Distribution

	Distribution (Amount)	Distribution (Percent)
Never	1	12.5
Sometimes	2	25.0
Usually	5	62.5
Always	-	-

Exhibit 2

Question No. 6 (Q6)--Numerical Summary

The Question's Phrasing:

After hearing (or reading) the detailed evaluation of the alternatives by individual areas (i.e., cost, performance, etc.), it is difficult to determine which alternative was preferred.

Table A-IV-3

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	1	1	2	7.7	4.3	5.5
Moderately Agree	2	2	4	15.4	8.7	11.1
Perhaps Agree	1	4	5	7.7	17.4	13.9
Moderately Disagree	6	9	15	46.1	39.1	41.7
Decidedly Disagree	3	7	10	23.1	30.4	27.8

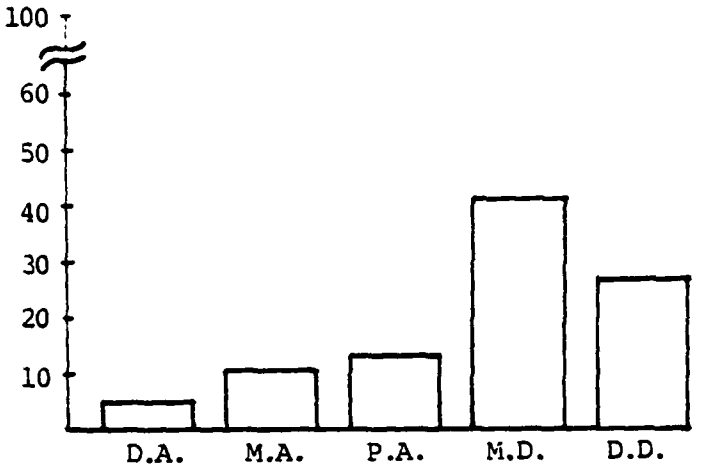

Figure A-IV-2. American Responses Distribution Histogram

Table A-IV-4

Israeli Responses Distribution

	Distribution (Amount)	Distribution (Percent)
Decidedly Agree	-	-
Moderately Agree	1	9.1
Perhaps Agree	8	72.7
Decidedly Disagree	2	18.2

Exhibit 3

Question No. 5 (Q5)--Numerical Summary

The Question's Phrasing:

There is no problem in selection of an alternative at the milestones reviews, since the pre-DSARC process leads to refined, clear and explicit recommendations.

Table A-IV-5

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	1	2	3	6.7	8.7	7.9
Moderately Agree	2	6	8	13.3	26.1	21.0
Perhaps Agree	2	7	9	13.3	30.4	23.7
Moderately Disagree	6	5	11	40.0	21.7	28.9
Decidedly Disagree	4	3	7	26.7	13.0	18.4

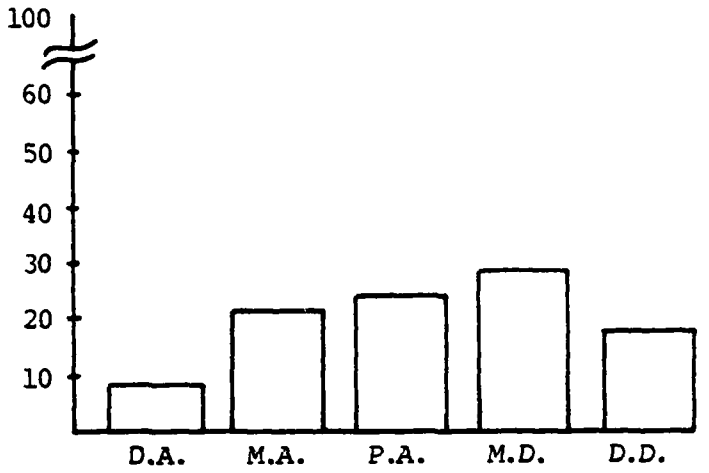

Figure A-IV-3. American Responses Distribution Histogram

Table IV-6

Israeli Responses Distribution

	Distribution (Amount)	Distribution (Percent)
Decidedly Agree	-	-
Moderately Agree	4	36.4
Perhaps Agree	7	63.6
Decidedly Disagree	-	-

Several respondents' written comments disclose a new factor which on the surface makes the selection easier, but not as a result of objective alternatives presented or usage of efficient decision-making tools. The following quotes express these observations:

> ...The real alternatives generally do not appear--only strawmen... [H-3]
>
> ...By this time the deck is so stacked that the viable alternatives either do not appear or have had a hatchet job done on them. [H-3]
>
> ...The selection is never less than clear-cut... the Service assures this... [H-3]
>
> ...The arguments and evidence are usually structured to support the Service selection and to present the decision in the most "clearcut" form permitted by the facts... [H-4]
>
> ...By the time such reviews are held at the highest levels, for all practical purposes the selection has been made, and any other choice or selection is very difficult to affect... [H-4]

Thus, even if these comments should be taken with some reservations, they can't be ignored. The question to be asked is how to make decision sessions more effective and system presentation more objective. This question is addressed in the body of the thesis, at least as far as decision-making techniques are concerned.

Another group of difficulties in decision-making is revealed by Q7 (see Exhibit 4). The answers distribution is of the "split" type, where people either agree or disagree, while very few are in the middle. 54% disagree with the statement that "the less the selection is clear-cut, the greater is the decision-makers tendency to rely on lower level analysis

Exhibit 4

Question No. 7 (Q7)--Numerical Summary

The Question's Phrasing:

The less the selection is clear cut, the greater is the decision-maker's tendency to rely on lower level analysis and recommendations.

Table A-IV-7

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	3	3	6	21.4	13.0	16.2
Moderately Agree	4	3	7	28.6	13.0	18.9
Perhaps Agree	3	1	4	21.4	4.3	10.8
Moderately Disagree	2	10	12	14.3	43.5	32.4
Decidedly Disagree	2	6	8	14.3	26.1	21.6

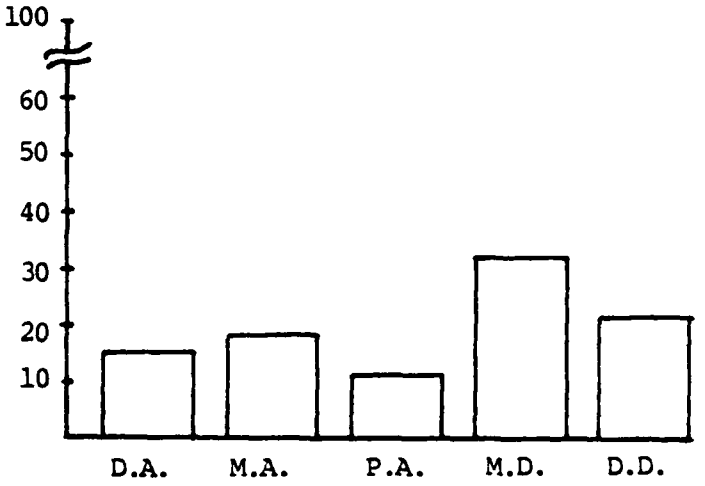

Figure A-IV-4. American Responses Distribution Histogram

Table A-IV-8

Israeli Responses Distribution

	Distribution (Amount)	Distribution (Percent)
Decidedly Agree	1	10.0
Moderately Agree	1	10.0
Perhaps Agree	5	50.0
Decidedly Disagree	3	30.3

and recommendations." 22%--a relatively high amount for an extreme answer--even decidedly disagree. But yet, a significant portion, 35% think on the contrary.

It is interesting in this case to observe the differences between high and low levels: while high levels apparently reject the statement with 70% disagreeing and only 26% agree (the remaining 4% are inbetween), low levels agree by 51% and only 28% disagree. Whose observation is more accurate is hard to tell. The Israeli rejection of the statement is more definite, with 80% in the "disagree" category, with a similar distribution for both high and low levels. Perhaps that points out a higher confidence in their ability to make a decision in a difficult selection. This feeling gets support from Q9 (see Exhibit 5). Here 54% of the American respondents agree that "in fact, top-level decision-makers do not select between alternatives, rather, approve or disapprove the recommended one." 35% objected to the Q9 statement. Furthermore, among the high levels, the degree of agreement is even higher than the total, with 65% that agree! On the Israeli side the disagreement is obvious with 73% disagreeing. Moreover, all four Israeli Generals decidedly disagree to the statement! The reasons for the American observation might be one of the following two, or both:

(1) The top level decision-makers do not have sufficient tools, data or expertise to allow selection between alternatives.

(2) As quoted from one of the respondents: "Alternatives other than the preferred alternative, are evaluated to gain

Exhibit 5

Question No. 9 (Q9)--Numerical Summary

The Question's Phrasing:

In fact, top level decision-makers do not select between alternatives, but approve or disapprove the recommended alternative.

Table A-IV-9

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	3	7	10	23.8	30.6	27.0
Moderately Agree	2	8	10	14.3	34.8	27.0
Perhaps Agree	2	2	4	14.3	8.7	10.8
Moderately Disagree	5	4	9	35.7	17.4	24.3
Decidedly Disagree	2	2	4	14.3	8.7	10.8

Figure A-IV-5. American Responses Distribution Histogram

Table A-IV-10

Israeli Responses Distribution

	Distribution (Amount)	Distribution (Percent)
Decidedly Agree	1	9.1
Moderately Agree	2	18.2
Moderately Disagree	1	9.1
Decidedly Disagree	7	63.6

perspective on the preferred one. There is virtually no probability any other will be selected" [L-2].

D. EXTENT OF QUANTITATIVE MODELS USAGE IN THE PRESENT DECISION-MAKING PROCESS

The purpose of Q2 (see Exhibit 6) was to reveal the extent quantitative models are used to support the recommendation in the DCP. The major observation on the responses' distribution is the high amount of the answer "sometimes", which accounted for 38%. The "seldom" and "usually" answers share about an equal percentage--30% and 27%, respectively. One can wonder why there is any distribution at all, since the question deals with tangible facts. The answer, of course, is that none of the respondents have complete knowledge about all the DCP's issued. Thus people just estimate. In this respect, it is interesting to notice that perhaps the only respondent who is connected with the DCP's on a day-to-day basis, and reviews all DCP issues, is the only one who answers "never", with the simple verbal explanation that a "10 page DCP is too short for this" [L-3]. Similarly to the American answers, the Israeli response to this question reveals a clear majority of 63% who estimate the frequency of quantitative model use in presentations to the Minister of Defense as occurring only "sometimes".

A similar picture is observed in the answers to Q3 (see Exhibit 7) which asks about the frequency quantitative models are used to support alternatives evaluation in the Milestones review sessions (DSARC, (S)SARC). Again, there is a "middle" distribution with the largest portion selecting the "sometimes"

Exhibit 6

Question No. 2 (Q2)--Numerical Summary

The Question's Phrasing:

Are the evaluation of alternatives and the explanation for recommendations in the DCP supported by sort of a quantitative model?

Table A-IV-11

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Never	1	1	2	7.1	4.3	5.4
Seldom	3	8	11	21.4	34.8	29.7
Sometimes	5	9	14	35.7	39.1	37.8
Usually	5	5	10	35.7	21.7	27.0
Always	-	-	-	-	-	-

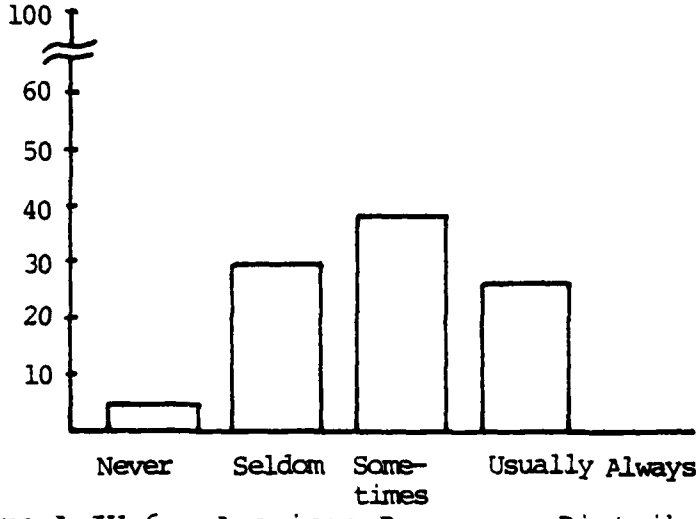

Figure A-IV-6. American Responses Distribution Histogram

Table A-IV-12

Israeli Responses Distribution

	Distribution (Amount)	Distribution (Percent)
Never	-	-
Sometimes	5	62.5
Usually	3	37.5
Always	-	-

Exhibit 7

Question No. 3 (Q3)--Numerical Summary

The Question Phrasing:

In the milestones review sessions (DSARC, (S)SARC)--how often is the evaluation of alternatives supported by a normative-quantitative model?

Table A-IV-13

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Never	-	2	2	-	9.1	5.6
Seldom	5	7	12	35.7	31.8	33.3
Sometimes	6	8	14	42.9	36.4	38.9
Usually	2	5	7	14.3	22.7	19.4
Always	1	-	1	7.1	-	2.8

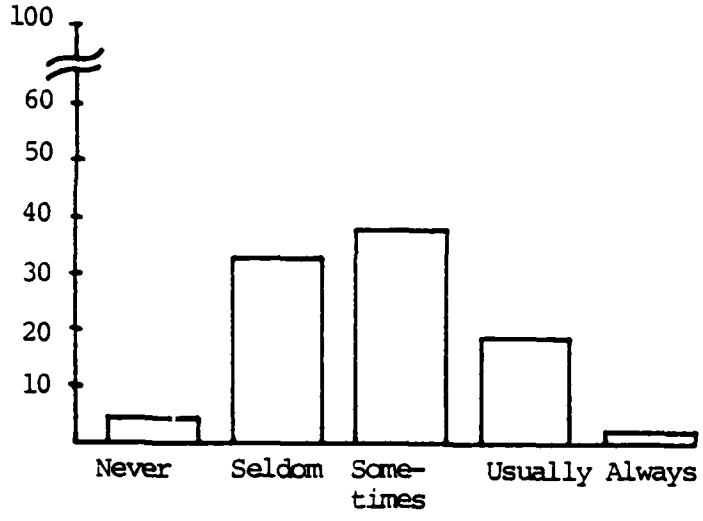

Figure A-IV-7. American Responses Distribution Histogram

Table A-IV-14

Israeli Responses Distribution

	Distribution (Amount)	Distribution (Percent)
Never	-	-
Sometimes	1	9.1
Usually	9	81.8
Always	1	9.1

answer. But here the tendency toward low frequency is even stronger than in Q2, since 33% of the answers are "seldom". At least two commentators devaluate the models actual utility not only because of the low frequency that they are used, but also because: "the model is always severely limited, for example, it might use acquisition cost as the only basis for comparison" [H-3], or, "the scope of the models that usually "support" the recommendations is limited" [H-4]. This is strengthened by an executive who is supposed to attend all DSARC sessions, who mentions that the only models he has seen used in these sessions were those of the Air Force briefings, "however the Air Force has only indicated relative comparisons (using red, green, yellow).... This technique has met with mixed success since sometimes it tends to hide significant issues" [L-3]. Another commentator views the low contribution of the quantitative models not only because of their limited scope, but because the forum is not open enough to exploit what they do offer. That because "the review sessions are never so emotionless as to deal with a dispassionate review of alternatives" [H-3].

A corresponding question to the Israeli AF officers, dealing with sessions equivalent to the (S)SARC, reveals a much greater extent of quantitative techniques usage. The responses are here "usually" (82%) or "always" (9%). Maybe this is the reason for the confidence in their ability to select between alternatives, not only to approve or disapprove the recommended one, as their American colleagues tend to do (see Q9--Exhibit 5).

E. CHAPTER SUMMARY

From the responses relating to the subject of this chapter, several observations can be drawn:

(1) In many of the cases difficulty exists in selecting an alternative, despite the refining process prior to top-level decision-making.

(2) At least in some of the cases the selection seems to be straightforward because of biased presentations made by the Services (or other program sponsors).

(3) American top-level decision-makers tend to approve or disapprove the recommended alternative rather than to decide and select between alternatives.

(4) The usage of quantitative models or techniques to assist top-level acquisition decision-making is done to a minor extent, and the models used are of limited scope.

(5) The Israeli decision-makers tend to use, to a greater extent, quantitative techniques, and that is expressed also in the self-perception of their decision-making capabilities.

A-V. Compatibility and Usefulness of Quantitative Decision-Making Techniques

A. PURPOSE

The purpose of this chapter is to examine the respondents perceptions about the compatibility and usefulness of quantitative techniques in assisting top-level acquisition decision-making. A special attention is paid to a MAUT (Multi-Attribute Utility Technique, or Theory).

B. COMPATIBILITY OF QUANTITATIVE TECHNIQUES--A GENERAL PERCEPTION

Q8 (see Exhibit 8) states that "in cases where the overall preference is unclear, a quantitative model might be helpful." One can interpret this question as relating to the model usage as a major tool for overall evaluation of weapon systems at any level, including the top-level, or as a mere presentation tool before top-level decision-makers. In fact, there is a great deal of similarity between the two. It is true, and it actually happens, that models are used in lower levels but are not fully presented to the top-levels, as mentioned by one commentator:

> The AFSARC does not use models for decision-making directly. We are, however, briefed on the use of decision aids and quantitative methods used by the staff in developing recommendations. [H-5]

On the other hand, it is hard to imagine a model used only as a top-level decision aid that has not been developed and used by levels below them. Thus, Q8 refers to a quantitative model as a decision-making aid at any level, including the top one. The distribution of Q8 answers is of the "middle" type.

Exhibit 8

Question No. 8 (Q8)--Numerical Summary

The Question's Phrasing:

In cases where the overall preference is unclear, a quantitative model might be helpful.

Table A-V-1

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	2	-	2	14.3	-	5.4
Moderately Agree	3	9	12	21.4	39.1	32.4
Perhaps Agree	7	11	18	50.0	47.8	48.6
Moderately Disagree	2	2	4	14.3	8.7	10.8
Decidedly Disagree	-	1	1	-	4.3	2.7

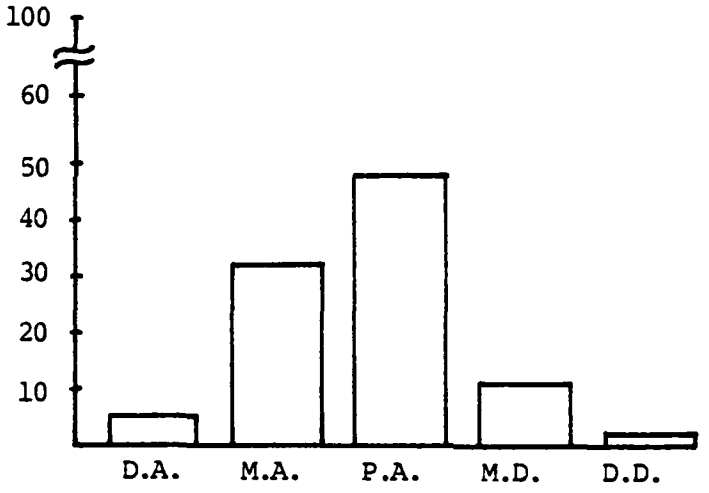

Figure A-V-1. American Responses Distribution Histogram

Table A-V-2

Israeli Responses Distribution

	Distribution (Amount)	Distribution (Percent)
Decidedly Agree	3	30.0
Moderately Agree	3	30.0
Moderately Disagree	4	40.0
Decidedly Disagree	-	-

Almost 50% are doubtful, or in other words, "perhaps agree" to the aid a quantitative technique might provide. But the tendency is, after all, in favor of the model's usefulness, since among those who are more determined, 38% agree with the statement and only 14% disagree. The Israeli respondents tend, in greater degree, toward usage of quantitative techniques as reflected by 60% that agree to the statement and 40% tend to disagree ("moderately disagree").

A corresponding question, Q10 (see Exhibit 9), concentrates more specifically on top-level decision-makers. The underlying rationale to the question is that one might think that quantitative decision-making techniques can be compatible mostly to low-level evaluations and decisions, since the latter are, perhaps, more technically oriented and based on measurable data. According to this line of thought, in top-level decision-making more unmeasurable value dimensions are involved, with decisions based mainly on subjective judgment or intuition, and therefore do not lend themselves to quantitative decision-making tools.

This idea appears in some of the written comments to the questionnaire. Several quotes are provided for illustration:

> At the program [office] level we tend to do little modeling outside the engineering domain, where we get good correlation factors. Objective modeling tends discipline but is not our normal tool in decision-making. [L-4]

> I am not favorably impressed with complex numerical modeling as a basis for important weapon systems decisions. A clear logic in our natural language is the most important and pre-eminent need. Next, a recognition that most decisions are <u>fundamentally subjective</u> since they are imbedded in a subjective set of reference values... . [H-6]

Exhibit 9

Question No. 10 (Q10)--Numerical Summary

The Question's Phrasing:

There is no use for a decision-making model to support top level decision-makers because they base their judgement mainly on a subjective experience, perception and intuition which cannot be rationally "managed".

Table A-V-3

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	-	1	1	-	4.3	2.7
Moderately Agree	5	10	15	35.7	43.5	40.6
Perhaps Agree	-	2	2	-	8.7	5.4
Moderately Disagree	5	6	11	35.7	26.1	29.7
Decidedly Disagree	4	4	8	28.6	17.4	21.6

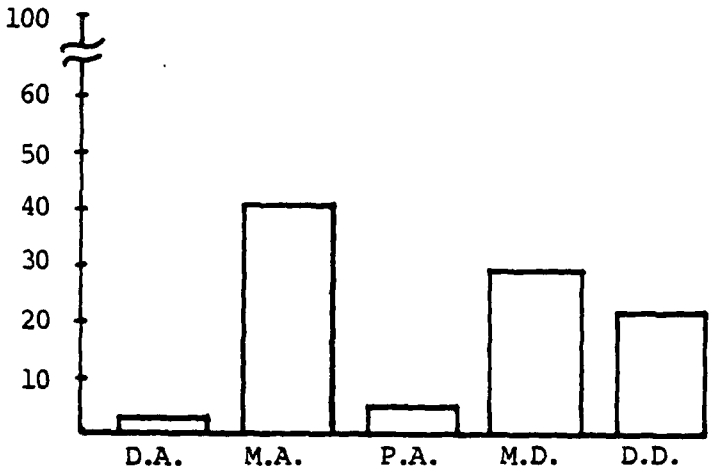

Figure A-V-2. American Responses Distribution Histogram

Table A-V-4

Israeli Responses Distribution

	Distribution (Amount)	Distribution (Percent)
Decidedly Agree	-	-
Moderately Agree	1	9.1
Moderately Disagree	1	9.1
Decidedly Disagree	9	81.8

The answers to Q10 are really split: 43% agree with the statement and 51% disagree. It is interesting to note that the person at the highest position responding to the questionnaire is on the "disagree" side, i.e., thinks that such models do suit top-level decision-makers.

In the Israeli community the picture is completely different, and consistent with trends observed before. 91%, including all four generals, disagree with the statement, i.e., think that quantitative models are compatible with top level decision-making.

In fact, Q10 is the key question of the whole questionnaire and the thesis itself. No wonder that many of the respondents added written comments with respect to this issue. Apparently, the comments reflect various insights, which emphasize the fact that the issue is much more complex than covered by the questions. Here are some citations from the verbal comments:

One respondent finds the models uncapable of handling judgment and intuition. Moreover, it can't handle some further factors that rule the decision-making process:

> The model would be totally perverted. It is not an issue of models--it's a matter of power and emotion! [H-3]

Other respondents who would like to see a cross-section model are backed down by the model's limitations to handle unlike alternatives (e.g., TOW missile vs. A-10 a/c to kill tanks or fighter a/c vs. SAM for air-defense [H-4,L-1]).

Another respondent emphasizes:

> The personnel experience and preference of senior officials in key positions plays heavily in the decision process...The skill of the program sponsor

to communicate the value of his program has great impact on the decision. [H-7]

Many warn that the model might be structured to support a "prior" selected alternative [for example H-8, L-5], or as put in more biting words:

> Use of such models is phony as a 3 dollar bill. It's a travesty on honest quantification. Anyone who would use such a model deserves what he gets! [H-3]

Many view models as a useful tool for decision-making [H-9,L-3,L-1,H-1,H-4 and more], but with an emphasis on the word "tool", i.e., the model is not the exclusive determinant in the decision process, and its outcomes do not dictate the decision. When used, its weakness should be recognized, and taken into account.

C. PREFERRED QUANTITATIVE TECHNIQUE TO ASSIST ACQUISITION DECISION MAKING

Q4 (see Exhibit 10) was posed to explore what quantitative approach or technique was preferred by the respondents. The question is phrased in a general sense and does not address specific decision events, procedures or level of decision. The response is somewhat surprising, with an apparent "one sided" distribution of 50% favoring the MAUT approach (defined as "scores and weights assigned to factors"), while none of the other approaches exceeds 15% (!). Very similar situation is revealed in the Israeli community, were 55% favor the MAUT.

Another finding is that 23% of the high-level American respondents have never used any quantitative model in their decision-making. 4 respondents, 3 of the low-level and 1 of the high-level categories, chose to ignore this question.

Exhibit 10

Question No. 4 (Q4)--Numerical Summary

The Question's Phrasing:

If you ever used a model for overall evaluation of acquisition alternatives (not necessarily at milestones decisions), which one did you find the most useful?

Table A-V-5

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Scores & Weights	9	8	17	75.0	36.4	50.0
Decision Tree	-	4	4	-	18.2	11.8
Computerized	2	3	5	16.7	13.6	14.7
Another	-	2	2	-	9.1	5.9
Never Used	1	5	6	8.3	22.7	17.6

[Did not respond 3 + 1]
Never used + did not respond--10 out of 38--26.3%]

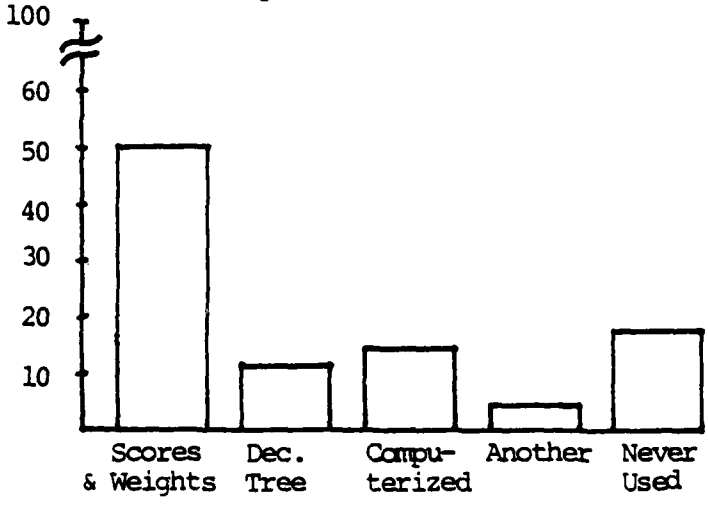

Figure A-V-3. American Responses Distribution Histogram

Table A-V-6

Israeli Responses Distribution

	Distribution (Amount)	Distribution (Percent)
Scores & Weights	6	54.5
Decision Tree	-	-
Computerized	1	9.1
Another	-	-
Depends on Case	4	36.4

Since the question offered an option to write down any sort of a model, one can think that the ignoring respondents, in fact, belong to the "never used" category. If so--percentages are obviously higher (26%).

D. THE COMPATIBILITY OF MAUT TO TOP-LEVEL ACQUISITION DECISION-MAKING

Q17 (see Exhibit 11), phrased in a negative way, states that "such a model [MAUT model, R.G.] is not useful for top-level decision-making." The answers are clearly "one-sided" distributed. 64% are on the "disagree" side while only 14% are on the opposite side. 22% are in the middle. This obvious favorable attitude towards the MAUT usage for top-level decision-making raises some wonders as compared to Q10's "split" distribution, in which 44% expressed their reservation towards such usage. To examine this phenomenon a test for *consistency* took place. The results are clear: of those who were in favor of model usage by top-levels per Q10, 70% remained consistent in their answer to Q17, 18% changed to a middle choice, and only 12% completely changed their minds. Of those who thought models are not compatible for top-levels in Q10, only 19% remained consistent in Q17, while 56% (!) completely changed their minds and 25% moved to the middle choice. What caused this inconsistency is hard to tell. Perhaps the corresponding question's wording caused different perceptions than those intended by the writer of the questions. But the well defined group that shifted, while all other respondents are stable, reduces the probability that this is the case. Those who thought

Exhibit 11

Question No. 17 (Q17)--Numerical Summary

The Question's Phrasing:

Such a model is not useful for top-level decision-making.

Table A-V-7

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	-	3	3	-	13.0	8.3
Moderately Agree	-	2	2	-	8.7	5.6
Perhaps Agree	4	4	8	30.8	17.4	22.2
Moderately Disagree	5	8	13	38.5	34.8	36.1
Decidedly Disagree	4	6	10	30.8	26.1	27.8

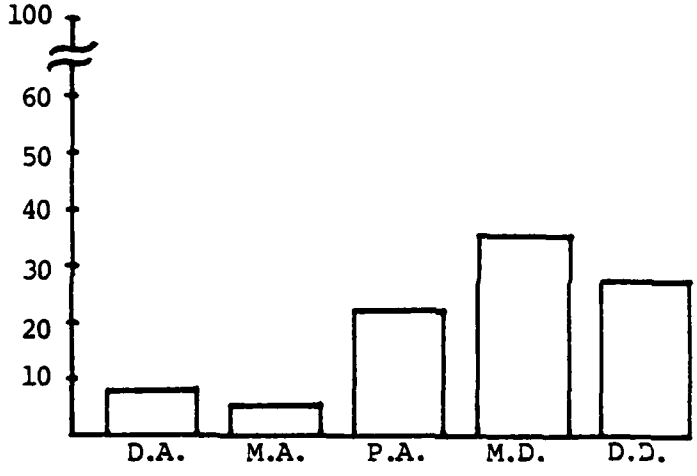

Figure A-V-4. American Responses Distribution Histogram

Comment: For the Israeli response see No. 1 in Table A-V-12 at the end of this chapter.

that quantitative models might be useful for top level in the first place, remained firm in their minds. Those who opposed that assumption--to a great extent changed their minds. It may be that the actual example presented in the questionnaire in Part IV (after Q10) caused the shift of attitudes, as hinted by one of the comments: "I think you are onto something in Part IV" [H-1]. On the Israeli side the consistency is much higher. As mentioned before, only one Israeli respondent agreed with the statement of Q10 while an overwhelming majority of 91% disagreed. The same person was the only one to agree with the statement of Q17.

Q18 (see Exhibit 12) corresponds to Q17, except that it narrows the scope to SecDef only. Though one could expect that people would be very doubtful about the usefulness of the model, at least at the SecDef level, this is not the case. The general distribution is pretty similar to that of Q17 with 68% disagree (i.e., do think that the model is useful also at the SecDef level, although he deals by and large with the political aspects of the decision), 23% "perhaps agree", and only 9% agree. The extent of disagreement with the statement is even greater than in Q17 since here 37% are at the extreme answer of "decidedly disagree" vs. 28% in Q17 and no one selected the opposite extreme vs. 8% in Q17. Q27 (see Exhibit 13) examines the value of the MAUT approach for any case of multicriteria decision. The responses are distributed according to the "middle" distribution type. The greatest portion of 39% prefer the "perhaps agree" answer. On the other hand, out of the rest, the number

Exhibit 12

Question No. 18 (Q18)--Numerical Summary

The Question's Phrasing:

Such a model is useful for all levels except SecDef, since political aspects can't be handled by the model.

Table A-V-8

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	-	-	-	-	-	-
Moderately Agree	-	3	3	-	13.6	8.6
Perhaps Agree	5	3	8	38.5	13.6	22.9
Moderately Disagree	3	8	11	23.0	36.4	31.4
Decidedly Disagree	5	8	13	38.5	36.4	37.1

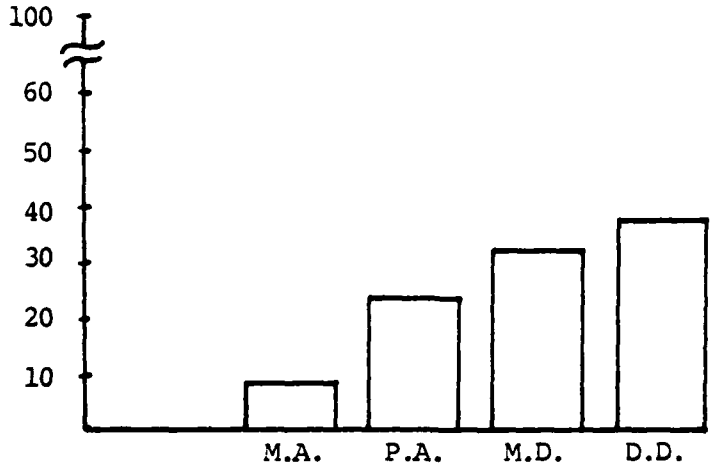

Figure A-V-5. American Responses Distribution Histogram

Comment: For the Israeli response see No. 2 in Table A-V-12 at the end of this chapter.

Exhibit 13

Question No. 27 (Q27)--Numerical Summary

The Question's Phrasing:

Such a model is a very good way to reach a decision in a multicriteria case.

Table A-V-9

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	1	2	3	7.8	8.7	8.3
Moderately Agree	6	7	13	46.1	30.4	36.1
Perhaps Agree	6	8	14	46.1	34.8	38.9
Moderately Disagree	-	4	4	-	17.4	11.1
Decidedly Disagree	-	2	2	-	8.7	5.6

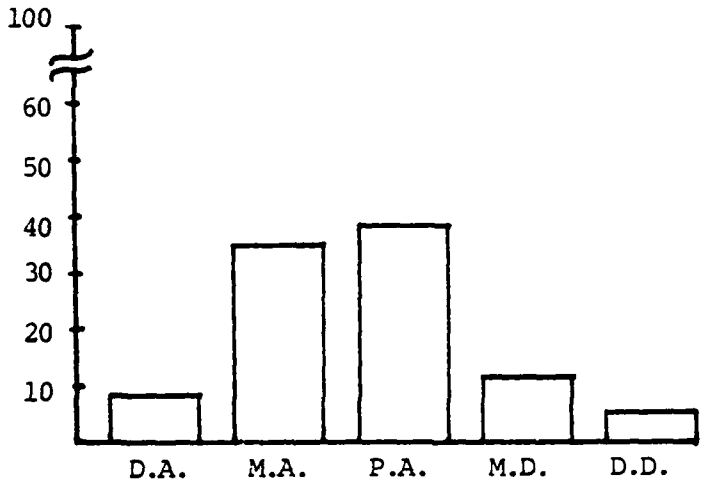

Figure A-V-6. American Responses Distribution Histogram

Comment: For the Israeli response see No. 3 in Table A-V-12 at the end of this chapter.

of those who agree with the statement that "such a model is a very good way to reach a decision in a multicriteria case", is much greater than that of those who disagree--44% vs. 17% respectively. Perhaps the large amount of reservation was caused by the phrase "very good" in the statement, since people usually tend not to commit themselves to superlative phrases. Several respondents commented that they would have selected a higher degree of agreement answer if the word "very" would have been eliminated [for example H-7,H-10].

Q15 and Q16 (see Exhibits 14 and 15 respectively) in fact state the same idea in opposite approaches, negative and positive. The responses are very consistent and for both questions the distribution is of the "one sided" type. In both questions the respondents express their belief that MAUT is useful for acquisition related decisions. The rejection of the negative statement of Q15 saying that "such a model is not for acquisition related decisions", is very clear--75% disagree and only 9% agree. 16% perhaps agree. The answers to the positive statement are a little less clear cut distribution: 50% agree and 25% disagree. 25% are in the middle. Again it may be that the usage of the superlative phrasing "useful in most cases" evoked the respondents reluctance to select clearly favorable answers. In any case, the favorable attitude toward MAUT in assisting acquisition decision-making is clearly spelled out by the responses to these two questions.

Exhibit 14

Question No. 15 (Q15)--Numerical Summary

The Question's Phrasing:

Such a model is not for acquisition related decisions.

Table A-V-10

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	-	1	1	-	4.3	2.8
Moderately Agree	1	1	2	7.7	4.3	5.6
Perhaps Agree	1	5	6	7.7	21.7	16.7
Moderately Disagree	6	9	15	46.1	39.1	41.7
Decidedly Disagree	5	7	12	38.5	30.4	33.3

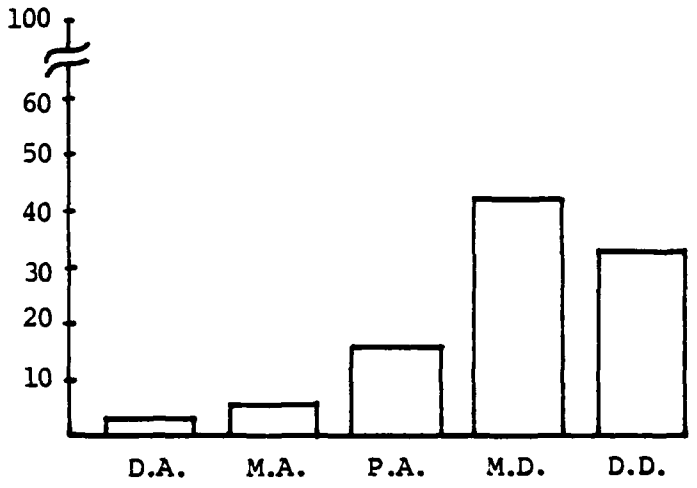

Figure A-V-7. American Responses Distribution Histogram

Comment: for the Israeli responses see No. 4 in Table A-V-12 at the end of this chapter.

Exhibit 15

Question No. 16 (Q16)--Numerical Summary

The Question's Phrasing:

Such a model may be useful in most cases of acquisition selection decisions.

Table A-V-11

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	2	4	6	15.4	17.4	16.7
Moderately Agree	5	7	12	38.5	30.4	33.3
Perhaps Agree	4	5	9	30.8	21.7	25.0
Moderately Disagree	2	5	7	15.4	21.7	19.4
Decidedly Disagree	-	2	2	-	8.7	5.6

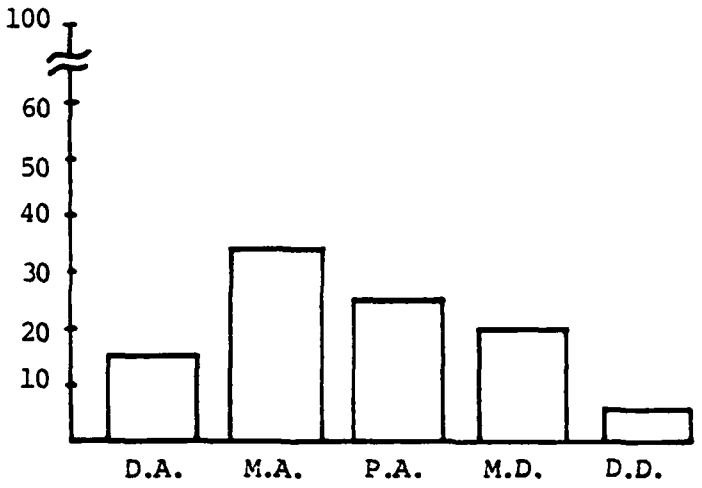

Figure A-V-8. American Responses Distribution Histogram

Comment: for the Israeli response see No. 5 in Table A-V-12 at the end of this chapter.

E. CHAPTER SUMMARY

From the exploration of the respondents attitudes toward quantitative technique use in assisting top-level decision-making in general, and acquisition related decisions, in particular, several dominant trends are identified. Naturally, these trends do not represent consensus, but in most cases in this chapter they are clearly deduced from the answers. These are:

(1) Quantitative techniques might help in cases of difficult selection between alternatives.

(2) The opinions are split with respect to the general use of quantitative techniques by high level decision-makers.

(3) The MAUT (Multi-Attribute Utility Theory) is highly preferred by the responding sample over any other quantitative technique, for acquisition decisions.

(4) Dealing with the specific technique of Multi-Attribute Utility, much of the reservation expressed towards general use of quantitative models disappears and the respondents are clearly favorable in their attitude:

(a) They think it does fit top-level decision-making, including at the chief level.

(b) They think it is useful for acquisition related decisions.

Thus, the respondents support the questionnaire's prior assumption that MAUT is the preferred approach among quantitative techniques that might assist top-level acquisition decision-making. [It is not to say that other approaches, some of them

computerized (as a complex MAUT can be as well), should not be used at the various phases and levels of evaluation of decision alternatives.] Thus, the prior emphasis put on exploration of the MAUT features and implementation techniques in the questionnaire may be considered posteriorily as an unbiased reflection of the respondents' preference.

Table A-V-12

Statements Selection By the Israeli Respondents (Selection is identical to agreement with the statement.)

No.	Corresponds to "American" Question #	The Statement	Selected by (amount)	Selected by (percent)
1	Q17	Such a model is not useful for top level decision-making	1	9
2	Q18	Such a model is useful for all levels except Min. of Defense since political aspects are not eligible for quantification	2	18
3	Q27	In spite of its weaknesses such a model is the best way to reach a decision in a multicriteria case	4	36
4	Q15	Such a model is not for acquisition related decisions	1	9
5	Q16	Such a model may be useful in most cases of acquisition selection decisions	6	55

A-VI. Advantages and Disadvantages of MAUT

A. PURPOSE

The purpose of this chapter is to explore the advantages and disadvantages of the MAUT, as they are conceived by the questionnaire respondents.

While the essential features of the MAUT capability in handling complex multicriteria decisions has been explored in the previous chapter, this chapter deals mostly with side-effects of this technique.

B. CHARACTERISTICS, ADVANTAGES AND DISADVANTAGES

Q19 (see Exhibit 16) addresses the MAUT's substantial approach to base the total evaluation on aggregated independent evaluations done through separate value-dimensions. An assumption is that people might consider such an approach as improper, preferring more sophisticated examination of interrelations between factors. The answers distribution to the question is pretty much "one-sided": 53% disagree with the statement and only 21% agree. 26% perhaps agree. Thus, the respondents do think that evaluation by separate factors is proper, although by that answer they do not express any rejection of further inter-factor evaluations, using other methods.

Q25 (see Exhibit 17) puts light on one of the prominent features assumed for MAUT, of creating a common denominator and common language of communication between the people involved in the decision. In cases where "the personal experience and preference of senior officials plays heavily in the

Exhibit 16

Question No. 19 (Q19)--Numerical Summary

The Question's Phrasing:

Evaluation by separate factors is not appropriate, since the appropriate evaluation is derived from the complex interrelations among factors.

Table A-VI-1

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	-	1	1	-	4.6	2.9
Moderately Agree	1	5	6	8.3	22.7	17.6
Perhaps Agree	3	6	9	25.0	27.3	26.5
Moderately Disagree	6	7	13	50.0	31.8	38.2
Decidedly Disagree	2	3	5	16.7	13.6	14.7

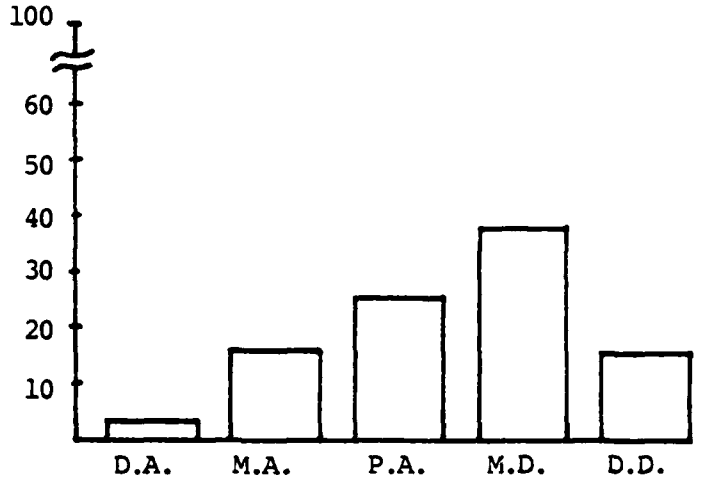

Figure A-VI-1. American Responses Distribution Histogram

Comment: for the Israeli response see No. 1 in Table A-VI-10 at the end of this chapter.

Exhibit 17

Question No. 25 (Q25)--Numerical Summary

The Question's Phrasing:

Such a model enables better communication among people involved in the decision-making.

Table A-VI-2

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	4	3	7	30.8	13.0	19.4
Moderately Agree	5	11	16	38.5	47.8	44.4
Perhaps Agree	4	6	10	30.8	26.1	27.8
Moderately Disagree	-	1	1	-	4.3	2.8
Decidedly Disagree	-	2	2	-	8.7	5.6

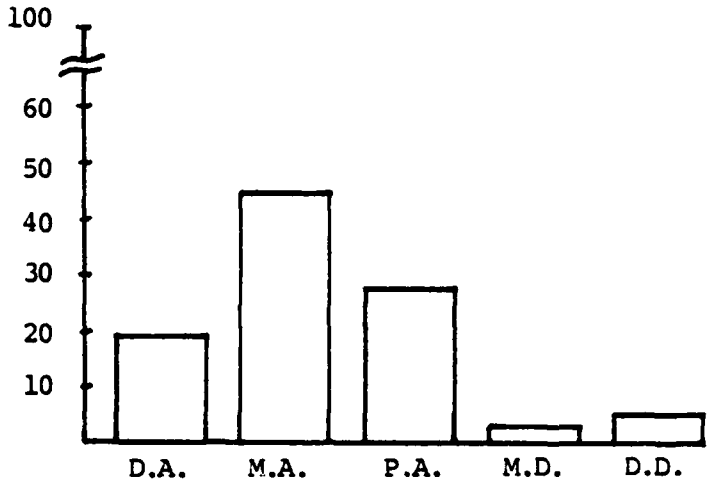

Figure A-VI-2. American Responses Distribution Histogram

Comment: for the Israeli response see No. 2 in Table A-VI-10 at the end of this chapter.

decision process, and the skill of the program sponsors to communicate the value of the program has a great impact" [H-7], MAUT can compensate the differences in experience and reduce the impact of personal communication skills, by "offering an easily comprehended standard of comparison" [H-11]. What is deduced from the above citations is clearly spelled out in the answer distribution, where 64% think the MAUT model enables better communication, and only 8% object.

Still "one-sided", although less definit, is the attitude toward the assumption stated in Q21 (see Exhibit 18) saying that "such a model leads people to refer to the really important issues in the decision." 50% agree with the statement, 19% disagree and a relatively high percentage are inbetween, accounting for 31%.

The respondents' written comments in this respect reveal the controversy about this issue. On the one hand there are comments such as:

> Those who have used such a model often find that it helps them come to grips with the critical factors in selection. [L-6]

Or,

> Basically, a model is useful to force the decision-maker to consider and weigh all the factors" [H-11],

and

> ...including all relevant decision factors is the tough part. [H-1]

Or,

> Models similar to the one you described are helpful in focusing attention on critical issues in a disciplined way. [H-12]

Exhibit 18

Question No. 21 (Q21)--Numerical Summary

The Question Phrasing:

Such a model leads people to refer to the really important issues in the decision.

Table A-VI-3

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	3	4	7	23.1	17.4	19.4
Moderately Agree	3	8	11	23.1	34.8	30.6
Perhaps Agree	6	5	11	46.2	21.7	30.6
Moderately Disagree	1	4	5	7.7	17.4	13.9
Decidedly Disagree	-	2	2	-	3.7	5.6

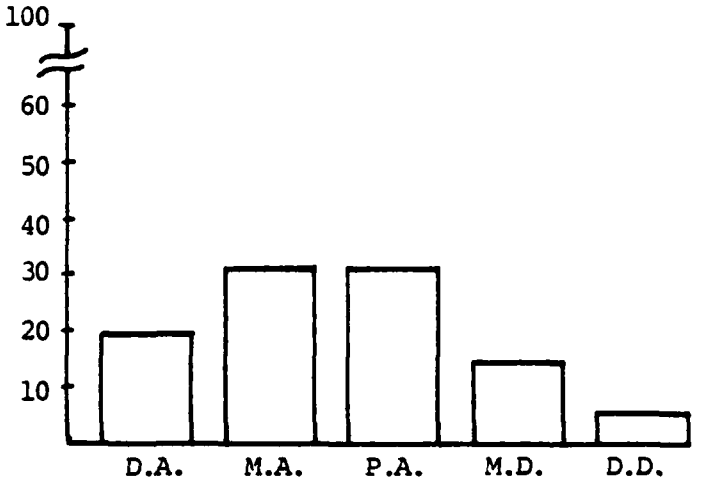

Figure A-VI-3. American Responses Distribution Histogram

Comment: for the Israeli response see No. 3 in Table A-VI-10 at the end of this chapter.

But on the other hand, there are those who think differently as reflected from the following comments:

> Models tend to amplify irrelevant data with respect to relevant data. [H-6]

Or,

> Model can serve to focus debate, but it could mask items not addressed.

There are commentators who recognize MAUT's capability to throw light on the important issues, but warn against a tendency to rely totally on the models results in making the decision. Here are some examples:

> Such a model would give useful insight into the choice being made, but would never be the circumference of insight. [H-13]

Or,

> Model is simply a tool to summarize results of evaluation. [H-14]

The conclusion drawn from this variety of responses might be that MAUT has the potential to focus attention on the important issue and to provide insight into alternatives <u>if</u> properly used. Being aware of potential pitfalls like including irrelevant data or excluding significant items, one can exploit the technique's advantages. All this is true unless the model is biased or deliberately structured to support priorly selected alternatives. As put by one of the respondents:

> Model would be very useful unless the decision is proformula. [H-2]

The question to what extent MAUT can reduce the effect of a biased presentation of alternatives is addressed in the body of the thesis.

Another tentative feature of MAUT is in helping people to manage their thinking and judgment in a logically organized manner, which naturally helps the decision-making. This feature is addressed by Q20 (see Exhibit 19). Again, the favorable attitude is clearly spelled out from the answers distribution: 67% agree, only 8% disagree, 25% perhaps agree. Here the notion of judgment is emphasized. The question is to what extent a technique which is designed to handle judgment ("what appears to be 'quantitative' is in reality subjective as both the weights and the rating are based on judgment" [L-7]), appeals to the decision-makers who based their decisions by and large on judgment ("In my experience--most, if not all acquisition decisions are a matter of judgment" [H-1]). It seems that the respondents had no doubts about the answer to that question.

Q29 (see Exhibit 20) addresses a controversial issue as observed from the answers' distribution. The question indicates the possibility that the discussion would concentrate on figures of weights and scores (also called "utility measures", or "location measures"), which one may consider as diversion from the essential issues under the decision. The respondents split on this issue very sharply: 46% agree, 40% disagree and only 14% are in the middle.

The written comments express the respondents' reservation:

> While the use of a model may help to more fully evaluate the differences between alternatives, I feel that your observation that a model may shift emphasis from significant issues to a mere discussion of weights and scores is the <u>critical</u> flaw. [L-8]

Exhibit 19

Question No. 20 (Q20)--Numerical Summary

The Question's Phrasing:

The model leads people to manage their judgment in a logical manner, which helps the decision-making.

Table A-VI-4

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	3	6	9	23.1	26.1	25.0
Moderately Agree	4	11	15	30.1	47.8	41.7
Perhaps Agree	5	4	9	38.5	17.4	25.0
Moderately Disagree	1	-	1	7.7	-	2.8
Decidedly Disagree	-	2	2	-	8.7	5.6

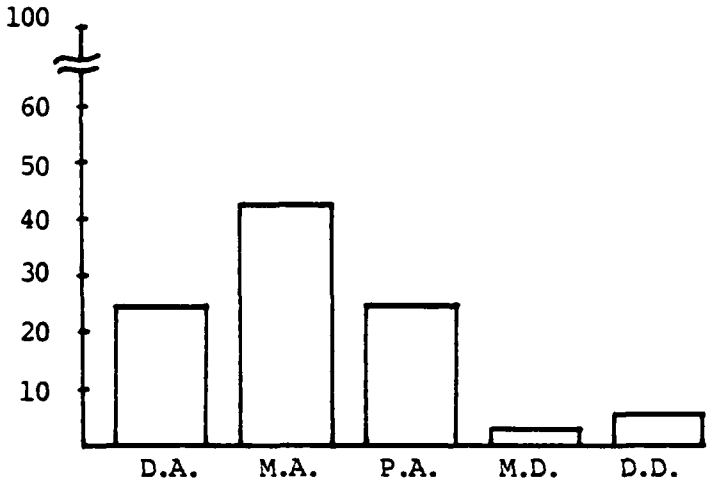

Figure A-VI-4. American Responses Distribution Histogram

Comment: For the Israeli response see No. 4 in Table A-VI-10 at the end of this chapter.

Exhibit 20

Question No. 29 (Q29)--Numerical Summary

The Question's Phrasing:

Such a model may shift the discussion from the significant issues to unnecessary arguments on scores and weights.

Table A-VI-5

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	2	2	4	15.4	9.1	11.4
Moderately Agree	5	7	12	38.5	31.8	34.3
Perhaps Agree	1	4	5	7.7	18.2	14.3
Moderately Disagree	5	8	13	38.5	36.4	37.1
Decidedly Disagree	-	1	1	-	4.6	2.9

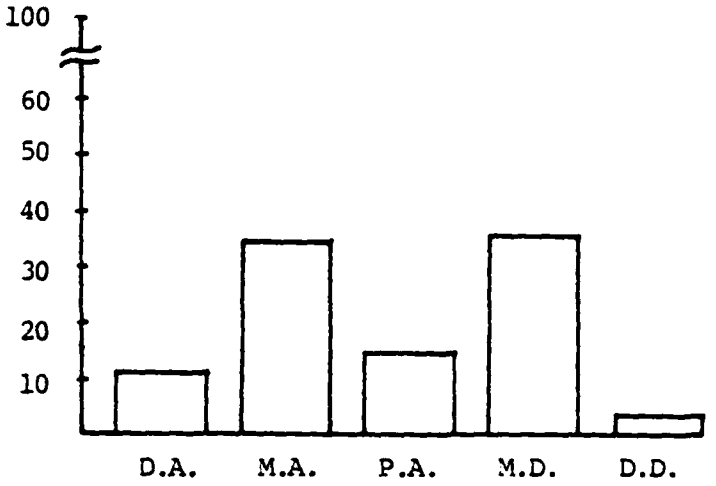

Figure A-VI-5. American Responses Distribution Histogram

Comment: for the Israeli responses see No. 5 in Table A-VI-10 at the end of this chapter.

It seems that the controversy is mostly on the word "unnecessary", since arguments on scores and weights and the rationale behind them can be arguments on the very essence of the decision. So the question is about the possibility that they would become "unnecessary". Just awareness can probably reduce such occurrence.

Q22, A23 and Q24 (see Exhibits 21, 22, 23, respectively) focus on the notion that structuring the evaluation into a model (or a procedure) framework, and presenting it as such to the decision-maker, may suppress his natural intuition, bias his judgment, and bind his decision-making freedom. The respondents explicitly reject these three potential deficiencies. The question statements are all positively stated, thus disagreement means rejection. The respective distributions for the three questions are: 72% disagree, 20% agree, 8% perhaps agree; 80% disagree, 12% agree, 8% perhaps agree; 63% disagree, 23% agree, 14% perhaps agree. One can notice that the third distribution is a little less "one-sided" relative to the other two. This is caused, perhaps, by the implications of the use of decision tools and not because of the specific nature of the MAUT procedure. As mentioned by one of the respondents:

> If a decision-maker embraces a model--but then disagrees with the model outcome, he may be baring his belly to his foes. [L-5]

This feature is addressed in Q26 (see Exhibit 24) where the emphasis is put on the decision criticism, using the model

Exhibit 21

Question No. 22 (Q22)--Numerical Summary

The Question's Phrasing:

Such a model suppresses the natural intuitive judgment.

Table A-VI-6

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	-	1	1	-	4.3	2.8
Moderately Agree	2	4	6	15.4	17.4	16.7
Perhaps Agree	1	2	3	7.7	8.7	8.3
Moderately Disagree	6	11	17	46.2	47.8	47.2
Decidedly Disagree	4	5	9	30.8	21.7	25.0

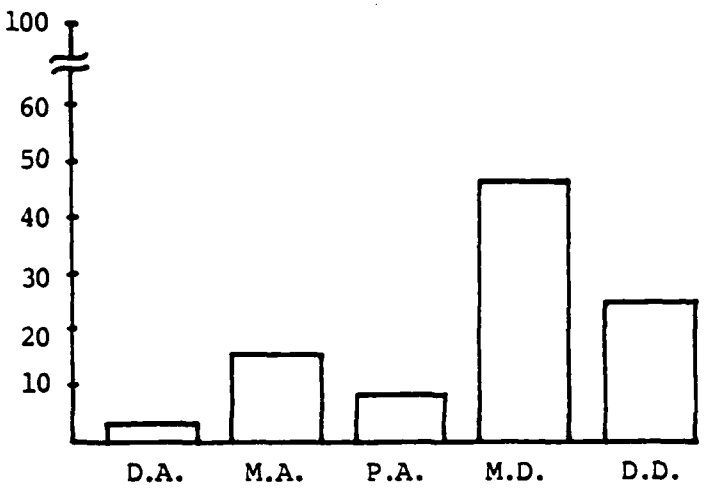

Figure A-VI-6. American Responses Distribution Histogram

Comment: for the Israeli response see No. 6 in Table A-VI-10 at the end of this chapter.

Exhibit 22

Question No. 23 (Q23)--Numerical Summary

The Question's Phrasing:

Such a model may bias the decision-maker's good judgment.

Table A-VI-7

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	-	2	2	-	9.1	5.7
Moderately Agree	1	1	2	7.7	4.6	5.7
Perhaps Agree	2	1	3	15.4	4.6	8.6
Moderately Disagree	9	14	23	69.2	63.6	65.7
Decidedly Disagree	1	4	5	7.7	18.2	14.3

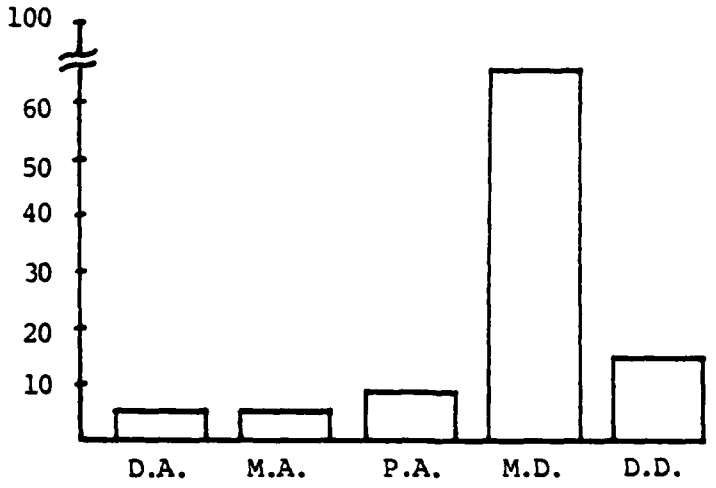

Figure A-VI-7. American Responses Distribution Histogram

Comment: for the Israeli response see No. 6 in Table A-VI-10 at the end of this chapter.

Exhibit 23

Question No. 24 (Q24)--Numerical Summary

The Question's Phrasing:

Such a model may somehow bind the decision-maker's freedom.

Table A-VI-8

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	-	1	1	-	4.6	2.9
Moderately Agree	3	4	7	23.0	18.2	20.0
Perhaps Agree	-	5	5	-	22.8	14.3
Moderately Disagree	8	8	16	61.6	36.4	45.7
Decidedly Disagree	2	4	6	15.4	18.2	17.1

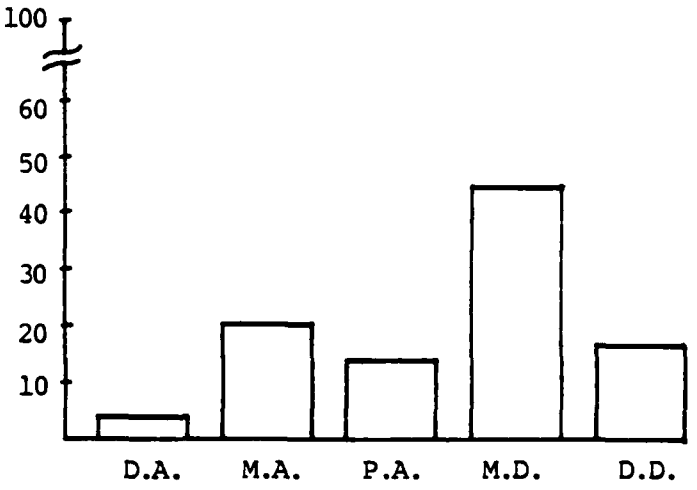

Figure A-VI-8. American Responses Distribution Histogram

Comment: for the Israeli response see No. 7 in Table A-VI-10 at the end of this chapter.

Exhibit 24

Question No. 26 (Q26)--Numerical Summary

The Question's Phrasing:

Such a model may be used as a tool to criticize the decision (e.g., by Congress), and therefore undesirable.

Table A-VI-9

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	-	1	1	-	4.6	2.9
Moderately Agree	3	7	10	25.0	31.8	29.4
Perhaps Agree	2	2	4	16.7	9.1	11.8
Moderately Disagree	5	7	12	41.7	31.8	35.3
Decidedly Disagree	2	5	7	16.7	22.7	20.6

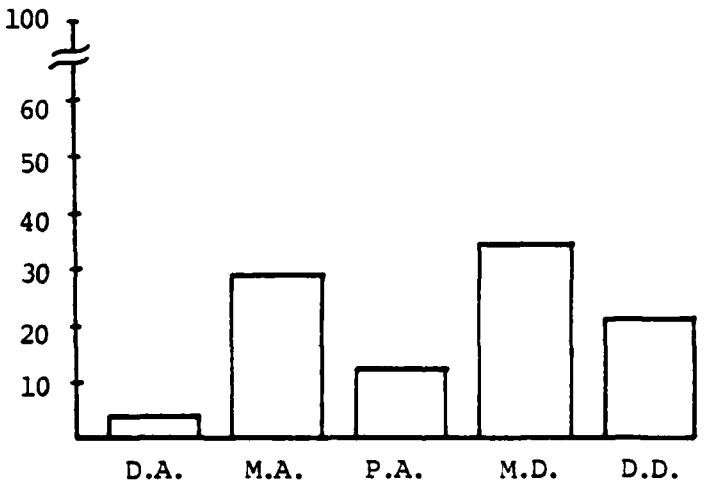

Figure A-VI-9. American Responses Distribution Histogram

Comment: for the Israeli response see No. 8 in Table A-VI-10 at the end of this chapter.

outcomes, by bodies external to the decision-making community. In fact, it can be used by "in-house" rivals, as well.

The answers to Q26 are split. Although the majority of 56% do not think that such a "danger" makes the model undesirable, a significant portion of 32% do think so. One of the respondents suggests,

> ...that model results--if publically available--could compromise the choice when the debate starts...the quantitative results should be privately held. [H-11]

But there is also the one who thinks that the "external" control on decisions acts as an incentive for models use:

> ...With the Congressional oversight of the decision-making process, backup of decision [by a quantitative model, R.G.] is virtually mandatory. [L-9]

C. CHAPTER SUMMARY

The analysis of this chapter's responses reveals several favorable side-effects of the MAUT procedure:

(1) It allows better communication and understanding among the people involved in the decision-making.

(2) It has the potential to focus discussion on the important issues.

(3) It assists decision-makers in putting order into their line of thinking.

Some important cautions are raised by the commentators:

(1) Not to include irrelevant data.

(2) Not to overlook significant attributes.

(3) Not to consider the model as the whole circumference of the decision, rather as a mere tool.

The respondents expressed their confidence that a quantitative technique used as a decision tool does not suppress the decision-maker's intuition, bias his judgment, or bind his freedom. That is because either the model does not incline to do so, or because decision-makers are immune to such tendencies, or both.

Finally, the respondents are aware of the case in which the model results may be used as a tool to criticize the decision, but the majority do not think that this should necessarily cause model undesirability.

Table A-VI-10

Statements Selection By the Israeli Respondents (Selection is identical to agreement with the statement)

No.	Corresponds to "American" Question #	The Statement	Selected by (Amount)	Selected by (Percent)
1	Q19	Evaluation based on separate independent factor evaluations is improper	0	0
2	Q25	Such a model enables better communication among people involved in the decision-making	5	45
3	Q21	The model makes clear what is really important to the decision-making	3	27
4	Q20	The model forces the people involved to orderly arrange their judgment and preferences	6	55
5	Q29	Such a model may shift the discussion from the significant issues to arguments on weights and scores	4	36
6	Q22	Such a model suppresses the natural-intuitive judgment	0	0
7	Q24	Such a model may somehow bind the decision-maker's freedom	4	36
8	Q26	Such a model may be used as a tool to criticize the decision by external bodies	9	82

A-VII. Implementation of MAUT Procedure

A. PURPOSE

The purpose of this chapter is to examine how the questionnaire respondents perceive MAUT procedure implementation, in its use as top-level acquisition decision-making tool.

B. ANALYSIS

The first question in this chapter, Q28 (see Exhibit 25), refers to the nature of the model. Having in mind methods like "Goeller Scorecard" or the "colors method" (using red, green and yellow to denote relative values), the question states that a score for each factor is sufficient and the aggregation of utility for the overall preference should be left for a pure judgment. The response to this statement is clear cut. 83% disagree and only 6% agree. 11% are in the middle. Only 1 Israeli agreed with the statement. Thus, the preference is clear: if, at all, to use such a procedure, it should go all the way through, including the aggregate utility derived from the summation of the products of weight times the associated scores, by each of the attributes.

The next two questions deal with the eligibility to change the model's components and by that to affect its outcomes. Q13 (see Exhibit 26) puts this idea in the negative way saying that the model must <u>not</u> be changed. The answer's distribution is almost completely "uniform" with equal percentages in all five degrees of agreement. Q14, (see Exhibit 27), whose statement "allows" the decision-maker to change weights and score

Exhibit 25

Question No. 28 (Q28)--Numerical Summary

The Question's Phrasing:

There is no need for weights and total score. A score for each factor separately is sufficient. The rest should be left for pure judgment.

Table A-VII-1

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	1	1	2	7.7	4.6	5.7
Moderately Agree	-	-	-	-	-	-
Perhaps Agree	2	2	4	15.4	9.1	11.4
Moderately Disagree	8	13	21	61.6	59.1	60.0
Decidedly Disagree	2	6	8	15.4	27.3	22.9

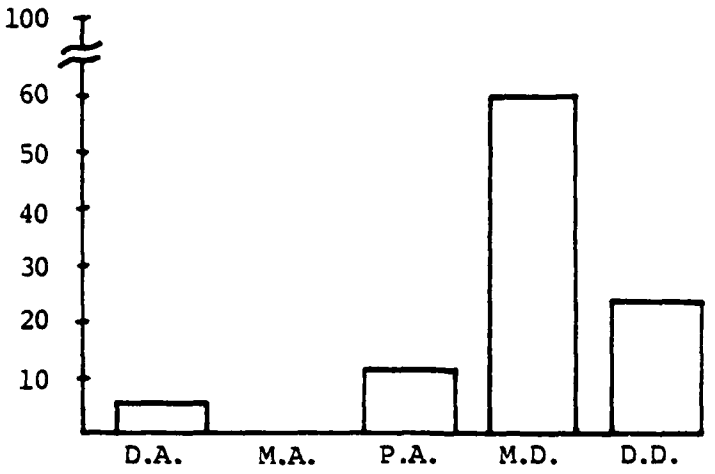

Figure A-VII-1. American Responses Distribution Histogram

Comment: for the Israeli response see No. 1 in Table A-VII-10 at the end of this chapter.

Exhibit 26

Question No. 13 (Q13)--Numerical Summary

The Question's Phrasing:

The model is supposed to be objective therefore may not be changed. (The decision-maker is not bound, of course, by the model outcomes.)

Table A-VII-2

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	1	5	6	7.7	23.8	17.6
Moderately Agree	3	3	6	23.1	14.3	17.6
Perhaps Agree	2	4	6	15.4	19.0	17.6
Moderately Disagree	4	5	9	30.8	23.8	26.5
Decidedly Disagree	3	4	7	23.1	19.0	20.1

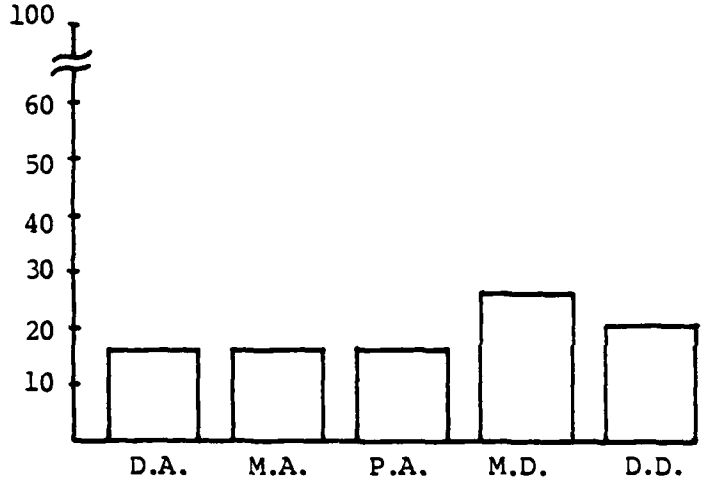

Figure A-VII-2. American Responses Distribution Histogram

Comment: for the Israeli response see No. 2 in Table A-VII-10 at the end of this chapter.

Exhibit 27

Question No. 14 (Q14)--Numerical Summary

The Question's Phrasing:

The model is prepared by an analytical process through the different levels, but the decision-maker may change weights and scores (interact with the model) according to his judgment.

Table A-VII-3

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	7	10	17	53.8	47.6	50.0
Moderately Agree	3	6	9	23.1	28.6	26.5
Perhaps Agree	-	2	2	-	9.5	5.9
Moderately Disagree	3	1	4	23.1	4.8	11.8
Decidedly Disagree	-	2	2	-	9.5	5.9

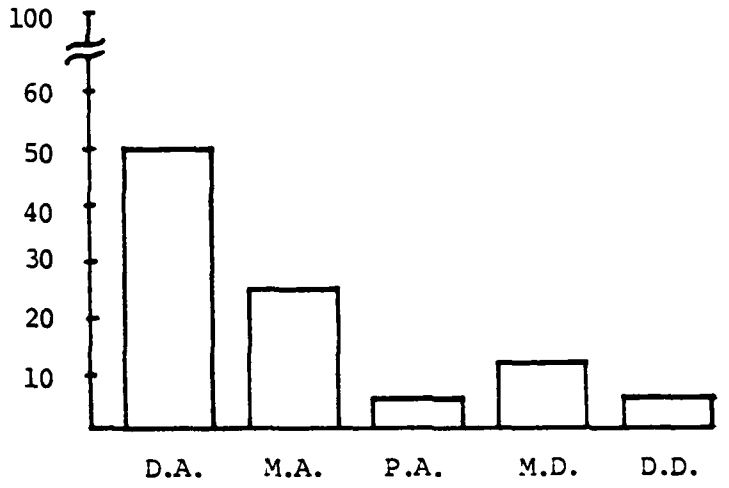

Figure A-VII-3. American Responses Distribution Histogram

Comment: for the Israeli response see No. 3 in Table A-VII-10 at the end of this chapter.

according to his judgment when he is presented a structured model breaks this tie. Here the distribution is extremely "one-sided": 76% agree with the decision-maker's freedom to change the model. Furthermore, of these 76%, 50% decidedly agree, an unusual amount for the extreme choice. Another issue is how the decision-maker should actually make such changes. No doubt, there is firm basis for one of the commentators observation:

> Usually, I do not think the decision-maker will openly or overtly change weights and scores. To do so at the 'end' only invites allegations of improper rigging of selection.

Thus, the decision-maker's interaction with the model requires delicate and wise manipulation of the decision process and the decision group.

The following set of questions deal with techniques of determining weights and scores or rather--who should determine them. Four alternatives are presented by the questions:

(1) The decision-maker himself should determine both weights and scores.

(2) The decision-maker should determine only weights (while scores are determined otherwise, presumably at lower levels).

(3) People involved (i.e., staff members, decision group members and the like) should determine weights and scores.

(4) Group of experts should determine weights and scores.

In fact, these alternatives are not mutually exclusive and some or all of them can be used at the same procedure through its various phases and iterations. Moreover, there are many

more combinations of "by whom" and "how" scores and weights are determined than these four alternatives. The respondents had to cope with these limitations, which resulted in a partial picture. In any case, the respondents were aware that the four alternatives might not suffice. 58% pointed at Q12 (see Exhibit 28) to the decision-maker as the one who should determine weights and scores. Only 25% disagree, and 17% did not have a definite opinion. About the same distribution occurred in Q31 (see Exhibit 29), suggesting that only weights should be determined by the decision-maker: 56% agreed, 32% disagreed and 12% were undecided ("perhaps agree"). Compared to the high agreement about the decision-maker as being the weights and scores determinator, it is interesting to observe the respondents rejection of the other alternatives, namely: the determination done through an aggregation of individual evaluation of people involved in the decision (Q33, see Exhibit 30), or by a group of experts (Q32, see Exhibit 31). In the latter case, there is a "middle" distribution with the largest group of 32% of the answers at the "perhaps agree" row. Different is the Israeli attitude toward the experts alternative. 64% of the Israeli's favor this alternative. It may be that the apprehension of a biased model underlies the American reservation towards any kind of aggregate opinions in structuring the model. But perhaps the rejection is caused just by unawareness of the techniques usually implemented in MAUT. And it may be that this is a mere result of poor questioning (caused by

Exhibit 28

Question No. 12 (Q12)--Numerical Summary

The Question's Phrasing:

The decision-maker himself has to determine weights and scores.

Table A-VII-4

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	3	6	9	23.1	26.1	25.0
Moderately Agree	4	8	12	30.1	34.8	33.3
Perhaps Agree	3	3	6	23.1	13.0	16.7
Moderately Disagree	2	2	4	15.4	8.7	11.1
Decidedly Disagree	1	4	5	7.7	17.4	13.9

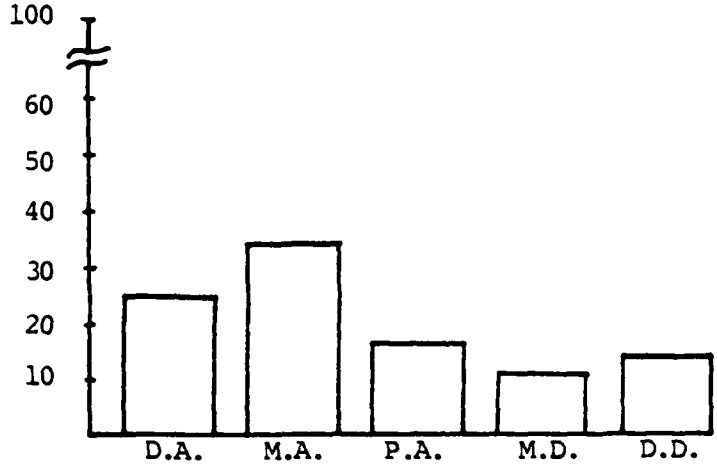

Figure A-VII-4. American Responses Distribution Histogram

Comment: for the Israeli response see No. 4 in Table A-VII-10 at the end of this chapter.

Exhibit 29

Question No. 31 (Q31)--Numerical Summary

The Question's Phrasing:

> The weights are the main ingredient in the model outcome, therefore they should be determined by the decision-maker himself.

Table A-VII-5

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	1	6	7	8.3	27.3	20.6
Moderately Agree	5	7	12	41.7	31.8	35.3
Perhaps Agree	2	2	4	16.7	9.1	11.8
Moderately Disagree	4	4	8	33.3	18.2	23.5
Decidedly Disagree	-	3	3	-	13.6	8.8

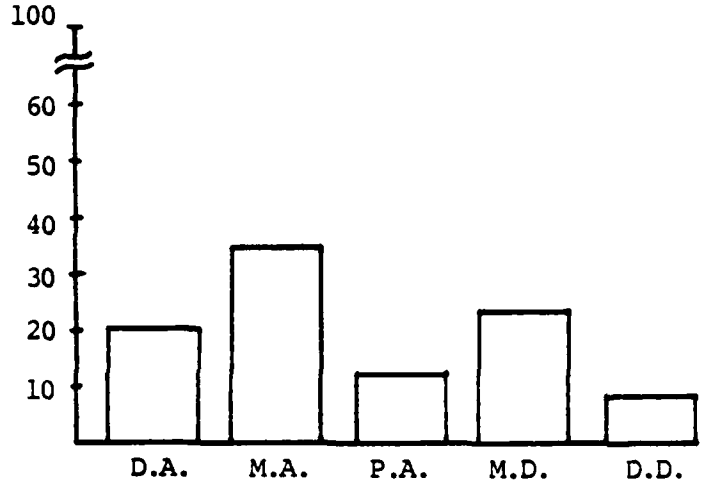

Figure A-VII-5. American Responses Distribution Histogram

Exhibit 30

Question No. 33 (Q33)--Numerical Summary

The Question's Phrasing:

Weights and scores should be determined by summing up assignments made individually by people involved in the decision.

Table A-VII-7

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	-	3	3	-	14.3	9.1
Moderately Agree	3	3	6	25.0	14.3	18.2
Perhaps Agree	2	5	7	16.7	23.8	21.2
Moderately Disagree	6	6	12	50.0	28.6	36.4
Decidedly Disagree	1	4	5	8.3	19.0	15.2

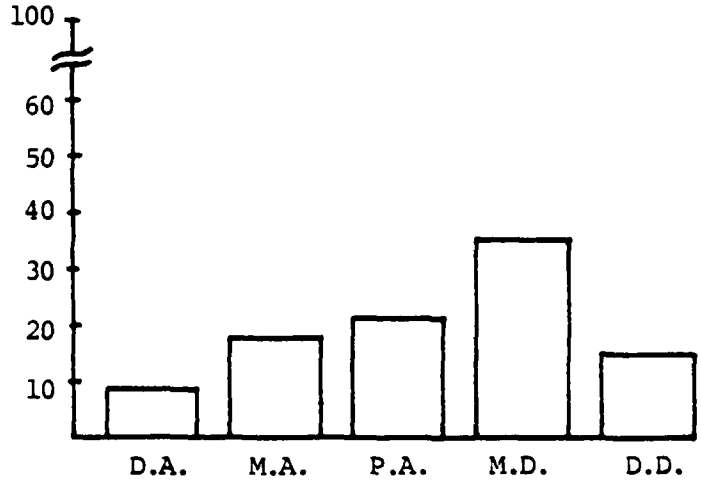

Figure A-VII-7. American Responses Distribution Histogram

Comment: for the Israeli response see No. 5 in Table A-VII-10 at the end of this chapter.

Exhibit 31

Question No. 32 (Q32)--Numerical Summary

The Question's Phrasing:

Weights and scores should be determined by a common work of a group of experts.

Table A-VII-6

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	1	2	3	8.3	9.1	8.8
Moderately Agree	4	1	5	33.3	4.6	14.7
Perhaps Agree	3	8	11	25.0	36.4	32.4
Moderately Disagree	2	6	8	16.7	27.3	23.5
Decidedly Disagree	2	5	7	16.7	22.3	20.6

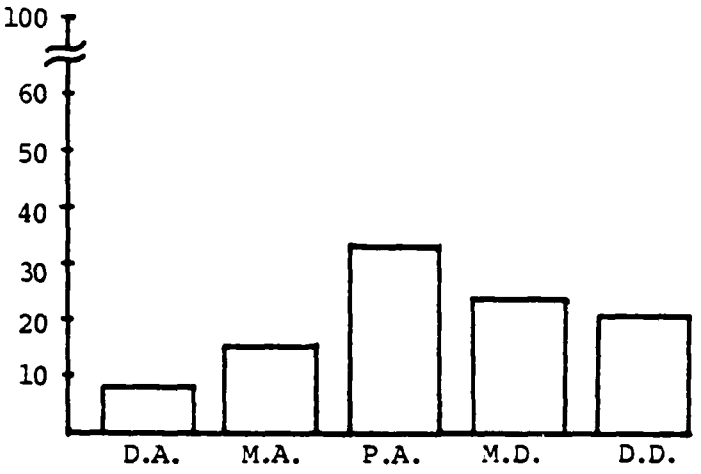

Figure A-VII-6. American Responses Distribution Histogram

the author's unawareness of the MAUT techniques at the time of the composition of the questionnaire...).

A "uniform" distribution is observed in Q30 (see Exhibit 32), dealing with whether or not weights and scores should be assigned on different occasions by different people. The distribution reflects, perhaps, the variety of ways to maintain the MAUT procedure. But perhaps it is again the lack of experience in MAUT implementation that causes people to arbitrarily select their answer all-over the spectrum.

In contrast to the balanced distribution in Q30, the preference is very clear in Q11 (see Exhibit 33)--the last one in the implementation section. 72% of the respondents express their view that the numerical framework of the MAUT procedure is not sufficient for decision-making. The model presentation before the decision-maker should be supplemented by the underlying data, rationale and methodology that brought about the model's weighting, rating and overall preference. Only 17% disagree with the above idea, and 11% are in the middle.

C. ADDITIONAL PRACTICAL COMMENTS

The written comments made by the questionnaire respondents raise some additional desirable features in the MAUT procedure which are not covered by the questions. The following quotes introduce these features:

> ...A range of subjective values and numerical estimates need to be presented to top decision-makers, with uncertainties clearly spelled out. [H-13]

Exhibit 32

Question No. 30 (Q30)--Numerical Summary

The Question's Phrasing:

> Weights and scores should be assigned independently from each other at a different time, and perhaps, by different people.

Table A-VII-8

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	3	4	7	25.0	18.2	20.6
Moderately Agree	4	4	8	33.3	18.2	23.5
Perhaps Agree	-	5	5	-	22.7	14.7
Moderately Disagree	4	3	7	33.3	13.6	20.6
Decidedly Disagree	1	6	7	8.3	27.3	20.6

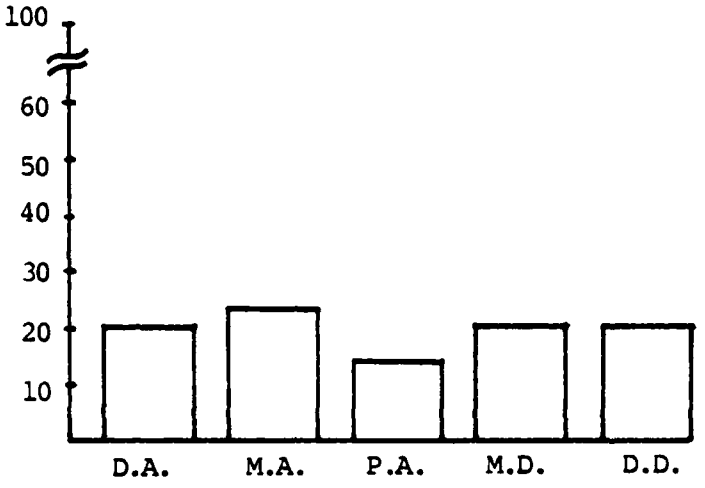

Figure A-VII-8. American Responses Distribution Histogram

Comment: for the Israeli response see No. 6 in Table A-VII-10 at the end of this chapter.

Exhibit 33

Question No. 11 (Q11)--Numerical Summary

The Question's Phrasing:

Such a model may be used only if supplemented by representation of the detailed data for each topic.

Table A-VII-9

American Responses Distribution

	Distribution (Amount)			Distribution (Percent)		
	Low	High	Total	Low	High	Total
Decidedly Agree	7	12	19	53.8	52.2	52.8
Moderately Agree	4	3	7	30.8	13.0	19.4
Perhaps Agree	2	2	4	15.4	8.7	11.1
Moderately Disagree	-	4	4	-	17.4	11.1
Decidedly Disagree	-	2	2	-	8.7	5.6

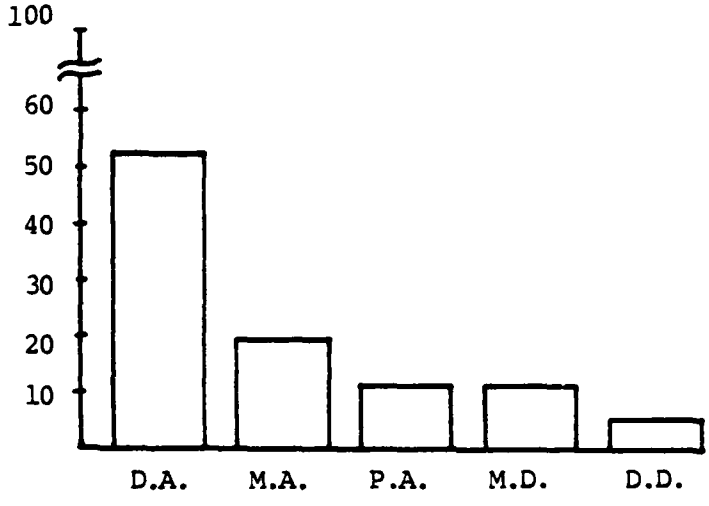

Figure A-VII-9. American Responses Distribution Histogram

Comment: for the Israeli response see No. 7 in Table A-VII-10 at the end of this chapter.

> The model can be improved by specifying at the outset that the scores must exceed some threshold value for selected 'critical' factor. [H-4]
>
> Go-No-Go factors should be identified at early stages, especially those perceived by the decision-maker, which usually tend to be revealed only at the end. [L-10]
>
> The model should be expanded to include probabilities since most of the decisions deal with the future where evaluations are mere estimates...Also constraints should be included in the model. [L-11]

Two main requirements are raised by the above comments:

(1) Uncertainties and risks should be treated by the model, and clearly presented to the decision-maker.

(2) The model should maintain thresholds (or constraints) for the critical factors. Another set of comments relates to the "relationship" between the model and the decision-maker. The following quotes might illustrate:

> The model, i.e., the structured decision process is a useful tool, but it must be acceptable to final decision-makers, and emphatically not plugged into a computer or be defined by 'experts'--specifically weights and scores. [H-1]
>
> I have found that judgement of experienced members of the decision-group ("intuition") is a dominant factor. Analysis and models are steered by comments of these participants. "Good" decision-making is enhanced by bringing them in early, so that data base etc., is organized to their "taste". [H-15]

The conclusion is that the decision-maker should be consulted at an early stage of the evaluation procedure structuring to ensure his acceptance of this procedure. Furthermore, he should affect the important details of the procedure according to his experience, intuition and preferences.

Another requirement is the model simplicity. It should be easy to present in a decision session, easy to grasp by

decision-makers whose expertise is not necessarily in the very details of the alternatives presented or in sophisticated modeling procedures. Models that "hide" their procedures within a computer or can be understood only by the experts who built them have little value for top-level decision-makers, if any.

D. CHAPTER SUMMARY

After a reasonable rounding of some vague answering trends, the following conclusions reflect the general preferences of the respondents:

(1) The model is subject to change by the decision-maker. The latter should implement such changes in a way that would be acceptable as a proper procedure.

(2) The decision-maker is preferred as the authority to determine weights and scores. There are reservations to parameters determination being done by people involved in the decision, or by a group of experts.

(3) A presentation of the MAUT procedure should be supplemented by the data, rationale and methodology which underly the numerical results.

Some additional requirements are raised through the verbal comments to the questions:

(1) The model should handle uncertainties, and risks should be clearly demonstrated to the decision-maker.

(2) The model should maintain threshold for critical factors.

(3) The procedure (model) should be accepted by the decision-maker and the acceptance cleared at an early stage.

(4) Decision-makers should be consulted on the procedure structuring at its initial phases.

(5) Simplicity is a paramount feature of such procedure or model.

In general it must be said that the MAUT actual implementation in the acquisition decision-making warrants a more thorough discussion than allowed by the questionnaire, or suggested by the answers and the written comments. This is done in detail in the body of this thesis.

Table A-VII-10

Statements Selection by the Israeli Respondents
(Selection is identical to agreement with the statement)

No.	Corresponds to "American" Question #	The Statement	Selected by (Amount)	Selected by (Percent)
1	Q28	The model is too elaborate. Scores only are sufficient. The rest should be left to pure judgment.	1	9
2	Q13	The model is supposed to be objective therefore may not be changed. (The decision-maker is not bound by the model outcomes.)	4	36
3	Q14	Scores and weight would be determined in the process prior to the decision. The decision-maker may change them according to his own judgment.	7	64
4	Q12	The decision-maker himself should determine weights and scores.	2	18
5	Q33	Weights and scores should be determined by independent evaluations of people involved in the decision.	4	36
6	Q32	Weights and scores should be determined by a group of experts.	7	64
7	Q11	Such a model should be supplemented by the detailed data and underlying rationale.	6	55

A-VIII. Relative Importance of Value-Dimension Categories

A. PURPOSE

The purpose of this section is to examine whether or not some systematic characteristics are observed in the relative importance weight assigned to three value-dimension categories (Direct, Socio-economic, Political) by the questionnaire's respondents.

This examination should assist in defining initial steps in MAUT procedure structuring for top-level acquisition decision-making, as introduced in the body of this thesis.

B. METHODOLOGY

The analysis of the above mentioned subject is based on the data collected in Part II of the questionnaire. In Part II the respondents were asked to evaluate the relative importance of three main value dimension categories--Direct, i.e., factors that affect directly the military forces, Socio-economic, i.e., factors that have an impact on the national social and economic areas, and political, i.e., the external and internal political aspects of the decision. This evaluation is done for several decision levels[1] separately. Each respondent was asked to refer to two cases. In fact, some respondents did not fill in this part at all. Some referred to one case only, and some

---

[1]With this respect, DSARC and (S)SARC have been considered as decision bodies although formally they have recommending authority only. The underlying assumption was that in consolidating their recommendations these bodies should reach, in a sense, some sort of decision.

referred only to those levels in which they felt sufficiently knowledgeable to make the evaluation. Probably in quite a few cases the respondent referred to the same system (they were not asked to note the specific system's name). To examine what bias this might cause, two cases, in which system identification has been noted by some of the respondents, were checked--one American case and one Israeli case. In both cases, individuals that referred to the same weapon system, evaluated the relative importance of the categories completely differently from each other.

For each column, i.e., for each category at each level a simple average of weights through all cases (systems) is calculated. The absolute numerical value of these averages, which is exhibited in Tables A-VIII-1 and A-VIII-2 has no practical meaning since it can't be used "as is" in a MAUT procedure evaluation for any specific system. This is obvious because any specific decision has its 'specific' weighting and no "general (average) weighting" can replace it (unless they are coincidentally identical). But the relative dimensions of the averages do reveal some interesting relations between categories and between levels.

C. CATEGORIES WEIGHTING CHARACTERISTICS

Although the absolute values of the weights in a corresponding category and level are to a great extent divergent (e.g., the weight of "direct" category at SecDef level for one system might be 25% and for another--90%), there are some

Table A-VIII-1

Average Importance Weights (Expressed in Percentage) Assigned to Three Categories (Direct, Socio-Economic, Political) at Five Decision Levels, as Observed in 57 Cases by the American Respondents

	SecDef			DSARC			(S)Sec			(S)SARC			Below		
	Dir	SE	Pol	Dir	SE	Pol	Dir	SE	Pol	Dir	Se	Pol	Dir	SE	Pol
Aver-age	55.6	11.7	32.7	71.6	9.3	19.1	66.9	10.6	22.5	74.5	8.5	17	85.3	6.2	8.5
Std. Dev.	28.8	10.3	24.0	24.3	8.1	19.6	22.9	9.2	20.1	21.2	10.2	18.6	14.9	7.5	10.6

Table A-VIII-2

Average Importance Weights (Expressed in percentage), Assigned to Three Categories (Direct, Socio-Economic, Political) In Three Decision Levels, as Observed in 16 Cases by the Israeli Respondents

	Min. of Def.			General HQs			IAF HQs		
	Dir	SE	Pol	Dir	SE	Pol	Dir	SE	Pol
Average	33.7	36	29.7	53.6	38.2	8.2	66.5	22	11.5
Standard Deviation	23.2	16.4	29.9	31.4	33.4	12.5	29.3	27.6	17.1

"rules" (or characteristics) within the weighting of each single system, which are common to almost 100% of the cases in the sample. Thus the average weights also relate to each other according to these same rules, which are surprisingly corresponding to what was expected by pure common sense. The categories weighting characteristics of the American community can be summarized as follows:

(1) In general, the higher the decision level is, the greater is the combined weight of the political and socio-economic categories, relative to the direct category.

(2) The recommending bodies, i.e., the DSARC and (S)SARC tend to be more "direct" category-oriented than their decision-making superiors, i.e., SecDef and (S)Sec, respectively. (In some cases they are equally "direct" category-oriented but almost never less than their superiors.

(3) For the American decision-makers the socio-economic category weights less than the political category, and its relative weight values are very low (10% and less) for almost all cases considered, as well as on the average.

The categories weighting characteristics for the Israeli community can be summarized as follows:

(1) Like in the American community, the higher the decision level is, the greater is the combined weight of socio-economic and political categories relative to the direct category.

(2) Different from the American community, the socio-economic category tends to weigh more than the political one.

(3) Through all levels the relative weight of the "direct" category is smaller, and that of the combined socio-economic and political categories is bigger, than for the corresponding levels in the American community.

A general rule is that emphasis on specific category is kept through all levels. For example, if a system has unusually high political weight of 75% at SecDef level, it has also an unusually high weight of 60% at the DSARC, 70% at (S)Sec, and 60% at (S)SARC levels.

D. CHAPTER SUMMARY

The categories weighting analysis reveals several rules of behavior, as discussed in this chapter. This may have an impact on the MAUT value tree structuring and on reducing the amount of sensitivity analysis required. This is discussed in greater detail in the body of this thesis.

A-IX. Identifying Value-Dimensions

A. PURPOSE

The purpose of this chapter is to attempt the structuring of an initial "value tree", compatible for some acquisition "general cases", by identifying its value dimensions (or in other words--attributes, or factors).

B. METHODOLOGY

Part VI of the questionnaire suggested a list of 19 value dimensions. The respondents were asked to rate each dimension by a score on a 0-4 scale, according to its impact on a specific system decision. The purpose for the rating was to identify such dimensions that have repeating 0 or 1 scores, in order to consider their elimination from the list. The possibility of finding relative weights according to the attributes rating was abandoned since the rating dealt with different systems and different life cycle phases, and any aggregate rating weight would have been meaningless.

Another purpose of the attributes list question was to stimulate comments about the various attributes. Finally, the respondents were asked to suggest additional attributes which they thought warranted inclusion in the list.

C. CONCLUSIONS

The value dimensions rating did not identify any dimension that should be eliminated. Except for several question marks, there were no written comments on the listed attributes. This

does not mean that the list can be structured as is into a MAUT value tree. It requires quite a few changes and adjustments, as discussed in the body of this thesis.

Finally, Part VI of the questionnaire provided a list of additional value dimensions, as suggested by the respondents. The "raw" list is as follows:[1]

(1) FMS potential

(2) Operating flexibility (e.g., V/STOL, carrier suitability)

(3) Testing results

(4) Affordability

(5) Producibility (production base, production readiness)

(6) Competition (Second Source)

(7) Mobilization capability

(8) Complexity, required skill levels

(9) Force multiplier

(10) Growth potential

(11) Contract financing

(12) Contractual terms/conditions

(13) Operational suitability

(14) Cost uncertainty

(15) Innovation degree (a new system, an improved system, new features)

(16) Meeting threat over long run

(17) Contribution to general technological advance

---

[1]The list includes the additional value dimension only, as defined by the respondents.

Processing these value dimensions together with the pre-listed ones into a value tree is done in the body of the thesis.

LIST OF REFERENCES

Archibald, R.D., Managing High-Technology Programs and Projects, John Wiley & Sons, New York, 1976.

Bauer, V., Wegener, M., "A Community Information Feedback System with Multiattribute Utilities," in D.E. Bell, R.L. Keeney, and H. Raiffa, eds., Conflicting Objectives in Decisions, John Wiley & Sons, New York, 1977.

C&C Associate Consultants, Life Cylce of Major System Acquisitions, Springfield, Va., 1980.

Cohen, E., Principles of Decision-Making Process in the Headquarters, Unpublished paper, presented to the IDF's Multiservice School for Command and Headquarters, August 1977.

Comptroller General, Report to the Congress, PSAD-80-6, Impediments to Reducing the Costs of Weapon Systems, 8 November 1979.

Connolly, J.H., Personal Communication. Washington, D.C., 20 August 1981.

Daws, R.M., and Corrigan, B., "Linear Models in Decision-Making," Psychological Bulletin, Vol. 81, pp. 97-106.

Decisions and Designs, Inc., Technical Report PR 80-1-307, Decision Analysis of Advanced Scout Helicopter Candidates, by M.L. Donnell and J.W. Ulvila, February 1980.

Department of Defense Directive No. 5000.1, Subject: Major System Acquisition 19 March 1980.

Department of Defense Instruction No. 5000.2, Subject: Major System Acquisition Procedures, 19 March 1980.

Department of the Air Force, AF Regulation 57-1, Statement of Operational Need (SON), 12 June 1979.

Donnell, M.L., Personal Communication (via telephone), Monterey, Ca., McLean, Va., 2 Nov. 1981.

Dunn, W.N., Public Policy Analysis: An Introduction, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1981.

Edelman, F., "Art and Science of Competitive Bidding," Harvard Business Review, Vol. 43, No. 4, pp. 53-66, July-August 1965.

Edwards, W., Personal Communication, Los Angeles, 2 October, 1981.

Edwards, W., "Social Utilities," The Engineering Economist, Summer Symposium Series, Vol. 6, 1971.

Edwards, W., "Use of Multiattribute Utility Measurement For Social Decision Making," in D.E. Bell, R.L. Keeney, H. Raiffa, eds., Conflicting Objectives in Decisions, John Wiley & Sons, New York, 1977.

Edwards, W., and Newman, R.J., The Evaluation of Criminal Justice Programs: An Approach To The Use of Multiattribute Utility Technology, Unpublished manual developed under grant from the National Institute of Law Enforcement and Criminal Justice, November 1980.

Einhorn, H.J., and Hogarth, R.M., "Unit Weighting Schemes of Decision-Making," Organizational Behavior and Human Performance, Vol. 13, pp. 171-192, 1975.

Ellis, H.M., The Application of Decision Analysis to the Problem of Choosing an Air Pollution Control Program for New York City. Unpublished Ph.D. dissertation, Graduate School of Business Administration, Harvard University, Cambridge, Mass., 1970.

England, W.B., and Leeders, M.R., Purchasing and Materials Management, Richard D. Irwin, Inc., Homewood, Ill., 1975.

Executive Office of the President, Office of Management and Budget (OMB), Circular No. A-109, Subject: Major System Acquisition, 5 April 1976.

Fellowes, F.G., Personal Communication. Washington, D.C., 20 August 1981.

Fisher, G.H., Cost Considerations in Systems Analysis, American Elsevier, New York, 1975.

Giangue, W.C., Prevention and Treatment of Streptococcal Sore Throat and Rheumatic Fever--A Decision Theoretic Approach, Ph.D. Thesis, Harvard University, 1972.

Hermann, R.J., Personal Communication, Washington, D.C., 20 August 1981.

Huber, G.P., Sahney, V., and Ford, D., "A Study of Subjective Evaluation Models," Behavioral Science, Vol. 14, 1969.

Keen, P.G.W., and Morton, M.S.S., Decision Support Systems: An Organizational Perspective, Addison-Wesley Publishing Company, Reading, Ma., 1978.

Keeney, R.L., "Multiplicative Utility Functions," Operations Research, Vol. 22, pp. 22-34, 1974.

Keeney, R.L., "Utility Functions for Multi-Attribute Consequences," Management Science, Vol. 18, pp. 276-287, 1972.

Keeney, R.L., and Nair, K., "Selecting Nuclear Plant Sites in the Pacific Northwest Using Decision Analysis," in D.E. Bell, R.L. Keeney and H. Raiffa, eds., Conflicting Objectives in Decisions, John Wiley & Sons, New York, 1977.

Keeney, R.L., and Raiffa, H., Decisions With Multiple Objectives: Preferences and Value Tradeoffs, John Wiley & Sons, New York, 1976.

Krajewski, L.J., and Thompson, H.E., Management Science--Quantitative Methods In Context, John Wiley & Sons, New York, 1981.

LaBerge, W.B., Personal Communication. Monterey, Ca., 4 May 1981.

Larichev, O.I., "A Practical Methodology of Solving Multicriterion Problems with Subjective Criteria," in D.E. Bell, R.L. Keeney, and H. Raiffa, Conflicting Objectives in Decisions, John Wiley & Sons, New York, 1977.

LeGrow, A.W., Measuring Aircraft Capability For Military and Political Analysis, Thesis, Department of National Security Affairs, Naval Postgraduate School, Monterey, Ca., 1976.

Little, J.D.C., "Brandaid," Operations Research, Vol. 23, No. 4, pp. 628-673, May 1975.

Little, J.D.C., "Models and Managers: The Concept of Decision Calculus," Management Science, Vol. 16, No. 8, pp. B466-485, Apri- 1970.

Mckenney, J.L., and Keen, G.W., "How Managers' Minds Work," Harvard Business Review, Vol. 52, No. 3, May-June 1974.

MIT, Technical Report No. 43, Multidimensional Utility Functions: Theory, Assessment and Applications, by Keeney, R.L., October 1969.

Naval Material Command, Navy Program Manager Guide, December 1980.

Pacific Missile Test Center, Technical Publication TP-79-31, Mission Operability Assessment Technique: A System Evaluation Methodology, by W.R. Helm and M.L. Donnell, 10 October 1979.

Peck, M.J., and Scherer, F.M., The Weapon Acquisition Process: An Economic Analysis, Harvard University, Boston, Ma., 1962.

Prest, A.R., and Turvey, R., "Cost Benefit Analysis: A Survey," The Economic Journal 15, (300), pp. 683-735, 1965.

Procurement Associates Inc., Contracting With The Federal Government, Covina, Ca., 1972.

Quade, E.S., Analysis for Public Decisions, Elsevier, New York, 1979.

Raiffa, H., Decision Analysis: Introductory Lectures on Choices Under Uncertainty, Addison-Wesley, Reading, Ma., 1968.

Raiffa, H., Preferences for Multi-attribute Alternatives, RM-4968-DOT/RC, The Rand Corporation, Santa Monica, Ca., 1969.

Rice, D.B., Defense Resource Management Study--Final Report, Office of the Secretary of Defense, 1977.

Sherwin, R.G., and Laurance, E.J., "Arms Transfers and Military Capability," International Studies Quarterly, Vol. 23, No. 3, pp. 360-387, September 1979.

Simon, H.A., "A Behavioral Model of Rational Choice," in H.A. Simon, Models of Man, Wiley, New York, 1957.

Social Science Research Institute, USC, Technical Report SSRI 81-2, Value Tree Analysis of Energy Supply Alternatives, by Stillwell, W.G., Winterfeldt, D.V., and John, R.S., June 1981.

Trimble, R.F., Personal Communication. Washington, D.C., 20 August 1981.

University of Michigan, A Technical Report, Multi-attribute Utility Theory: Models and Assessment Procedures, by Winterfeldt, D., and Fischer, G.W., 5 November 1973.

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