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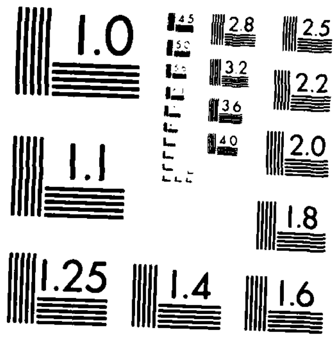

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A HEURISTIC APPROACH TO DECISION-MAKING FOR THE PURCHASE OF ACQUISITION DATA

THESIS

David B. Filippi
Captain, USAF

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AFIT/GLM/LSM/84S-22

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DEPARTMENT OF THE AIR FORCE
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Wright-Patterson Air Force Base, Ohio

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AFIT/GLM/LSM/84

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THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Logistics Management

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September 1984

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Acknowledgments

We wish to express our sincere thanks and appreciation to our families for allowing us the time to devote to this research effort. A special thank you is extended to our advisor, Lt Col Theodore J. Novak, Jr., and our reader, Mr. Jeff Daneman, for their patience and expert guidance. Finally, we would like to thank all those who took the time to suffer through those endless hours of interviews and interrogations.

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Abstract

Despite a variety of regulations and directives on the subject of acquisition data, there are currently no published criteria which will aid Program Managers in their decision to purchase acquisition data for a particular item. This research effort proposes a heuristic decision-making model which will aid Program Managers or Data Managers in their acquisition data purchasing decisions.

The researchers first identified, through a literature search and a series of personal interviews, eleven criteria relevant to the acquisition data purchasing decision. These criteria were then ranked and weighted by acquisition data experts using a second set of personal interviews.

By rating items for which acquisition data was purchased and later used in a competitive reprocurement, and items for which no acquisition data was purchased, the researchers developed two decision points for their model. These two points dictate whether or not the model's user should purchase acquisition data for the item being rated.

The researchers tested the model by randomly selecting items for which a decision has already been made to purchase or not purchase the acquisition data. Each item was rated using the decision-making model and the model's recommended

decisions were compared to the actual decisions made. This test procedure resulted in a 77.8% success rate where the model accurately predicted the actual decision made by the Program Manager.

The researchers recommended that further tests be performed to determine the ability of the model to predict various combinations of acquisition conditions, program types and purchase item types.

A HEURISTIC APPROACH TO DECISION-MAKING FOR THE PURCHASE OF ACQUISITION DATA

I. Introduction

Background

During the 1982-1983 time period the rapid increase in costs associated with the acquisition of spare parts for government weapon systems (an $837.5 million increase during Fiscal Year 1982) has been highlighted to the Congress, the general public, the Department of Defense (DOD), and Air Force Leadership (2:1-1).

In response, the Air Force Management Analysis Group (AFMAG) - Spare Parts Acquisition was formed at the direction of Secretary of the Air Force, Verne Orr, and Air Force Chief of Staff, General Gabriel, and formally chartered by the Air Force Vice Chief of Staff, General Skantz, on 20 May 1983. One of the primary purposes of AFMAG was to determine the reasons for the increase in the costs of spare parts for Air Force weapon systems (2:1-1).

The major factor behind the increased costs for spare parts cited by AFMAG was a lack of competition in the spare parts acquisition process. Since 1973 the percentage of spare parts competitively acquired by the Air Force has declined (See Figure 1) from a high of 37.5% to 20.7% in 1982 (2:2-12).

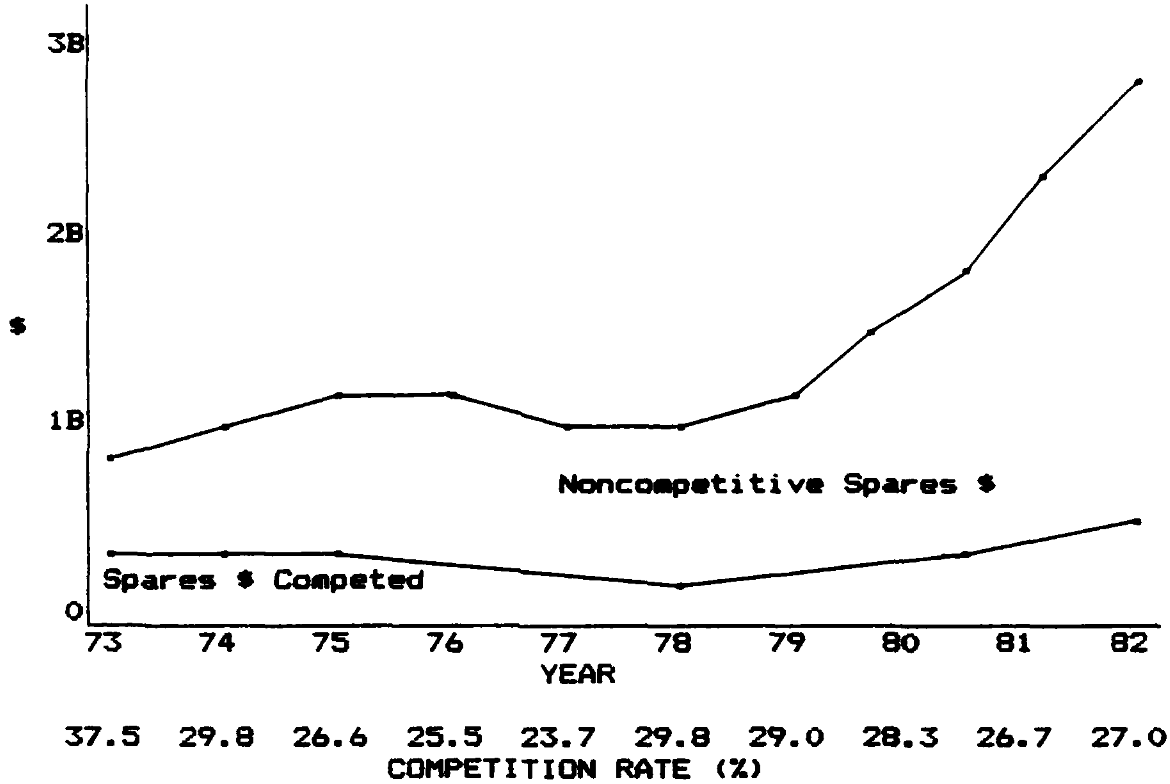


Figure 1. Air Force Spare Parts Competition

According to AFMAG, the four main reasons for this decreased competition rate were:

1. Fielding of New Weapon Systems: Between 1976 and 1982 new weapon systems (A-10, F-15, F-16) accounted for 32% of all Air Force spare part requirements. It is generally infeasible to compete for spare parts early in the production process due to numerous on-going engineering design changes (2:2-14).

2. Bureaucratic Processes: These are regulatory and legal constraints, such as Environmental Protection Agency requirements, that increase administrative burdens and lower

the profit margins of defense contractors. The net result has been a reduction of the defense industrial base from 6000 suppliers in 1964 to 3500 in 1980. As the base shrinks, the ability to achieve competition is reduced (2:2-19).

3. Proprietary Rights: When a contractor asserts that a part, component or process was developed at private expense, all engineering data describing that part or process is delivered to the Air Force with restrictions that preclude the use of that data for competitive spares purchasing (2:2-16).

4. Inadequate/Non-Existent Acquisition Data: The engineering data necessary to support the competitive acquisition of spares is created as part of the design and initial production of the weapon system, but Air Force efforts to obtain this data have not been effective. Approximately 16% of Air Force spare parts that are eligible for competitive procurement are instead purchased on a sole source basis because the requisite acquisition data is either missing or inadequate (2:2-15).

Of these four factors, AFMAG described the inadequacy and unavailability of acquisition data as being the greatest inhibitor towards increasing competition in the procurement of spare parts (2:3-3). Clearly the procurement of accurate, complete acquisition data is essential in reducing the high cost of Air Force spare parts.

Problem Statement

Although there are a variety of Directives, Regulations, Pamphlets, etc., that address the subject of acquisition data, there is no published methodology that helps Air Force Program Managers determine which parts under their responsibility will require acquisition data and which parts will not require acquisition data.

Definitions

The following terms used throughout this report are defined as follows:

Engineering Data. Engineering data is the master baseline documentation for a system. It describes parts, assemblies, and equipments and the way they go together to make up a system (3:54).

Acquisition Data. The acquisition data for a specific hardware item includes the engineering data for that item, but may also require and include additional data, such as item peculiar test data or packaging data, that is needed to acquire the part competitively (3:55).

Justification

The Department of Defense purchases approximately six million pieces of technical data each year at a cost of nearly $2 billion (22:1). In 1983 the Air Force alone acquired approximately 750,000 pieces of data which were ultimately stored at the Air Force Engineering Data Support Center (AFEDSC) located at Wright-Patterson AFB, Ohio (3-134).

The storage, handling, and administration of this data at the AFEDSC costs $2.2 million per year (3:136).

When considering the costs involved with purchasing and storing data, it is significant to note that some estimates have found that as little as 5 percent of the acquisition data bought by the Air Force has actually been used in the competitive acquisition of spare parts (24:2).

In their study, AFMAG found that the AFEDSC has a 10% error rate in processing data and that the facility was able to fill only 40% of user requests. The primary reason for this was that the Center's equipment and procedures (both in need of modernization) are unable to handle the large volume of data (3:134). The AFMAG also noted that problems associated with the cost estimation of data, proprietary data rights, the adequacy of data received, and the definition of data requirements can all be partially attributed to the ratio of trained manpower to the sheer volume of data to be reviewed (2).

The Air Force would greatly benefit from a reduction in the volume of unnecessary acquisition data. Data purchasing, handling and storing costs would be reduced. A reduced volume of acquisition data would ease manpower shortages in the management functions associated with data such as cost estimation and the determination of data adequacy. Finally, a reduction in data volume would reduce the administrative burden on AFEDSC, enabling that organization to reduce their error rate and provide better service to users.

Research Objectives

1. To identify and rank order the factors relevant in a decision to procure acquisition data for use in the competitive acquisition of spare parts.

2. To use the identified factors in building a model which will assist Air Force Program Managers in their decision concerning the procurement of acquisition data.

3. To test the validity of the constructed model.

Research Questions

1. What criteria should be considered in determining whether acquisition data will be procured for a particular part or component and how are they rank ordered in terms of relative importance?

2. How are the identified criteria combined to form a decision-making model?

3. Does the model accurately determine when acquisition data should be procured and when it should not be procured?

General Research Plan

This section presents a brief overview of the generalized approach to the research.

There are two basic approaches to answering the problem. One method would be to identify a large sample of procurement items for which acquisition data had been purchased but never used. Factors common to these items and to their data purchase decisions might then be identified and quantified. The difficulty in this approach is that the reasons for originally acquiring the data, a decision made perhaps as far back as ten years ago, would be difficult to ascertain solely from the available documentation. Also, determining the effects of the time factor, in the form of requirement changes, on the need for acquisition data for a particular item would require a detailed historical analysis of each particular item examined. It would also entail a detailed historical analysis of its parent weapon system, and the technology and manufacturing techniques applicable to both.

An alternative approach is to assume that the current decision-makers are attempting only to purchase acquisition data when they can identify the potential for its eventual use. The factors used by the decision-makers in making their decisions can then be identified and formed into a model. This was the method used in this research effort.

The general research plan will concentrate on collecting and organizing the knowledge of a selected sample of active duty Air Force Officers and DOD civilians concerning the procurement of acquisition data.

The research is divided into three main sections, or phases. Each phase will correspond to one of the three research questions. Each research question will in turn be used to satisfy one of the three research objectives. In addition, each succeeding research objective will build upon the results of the previous research objective (See Fig. 2).

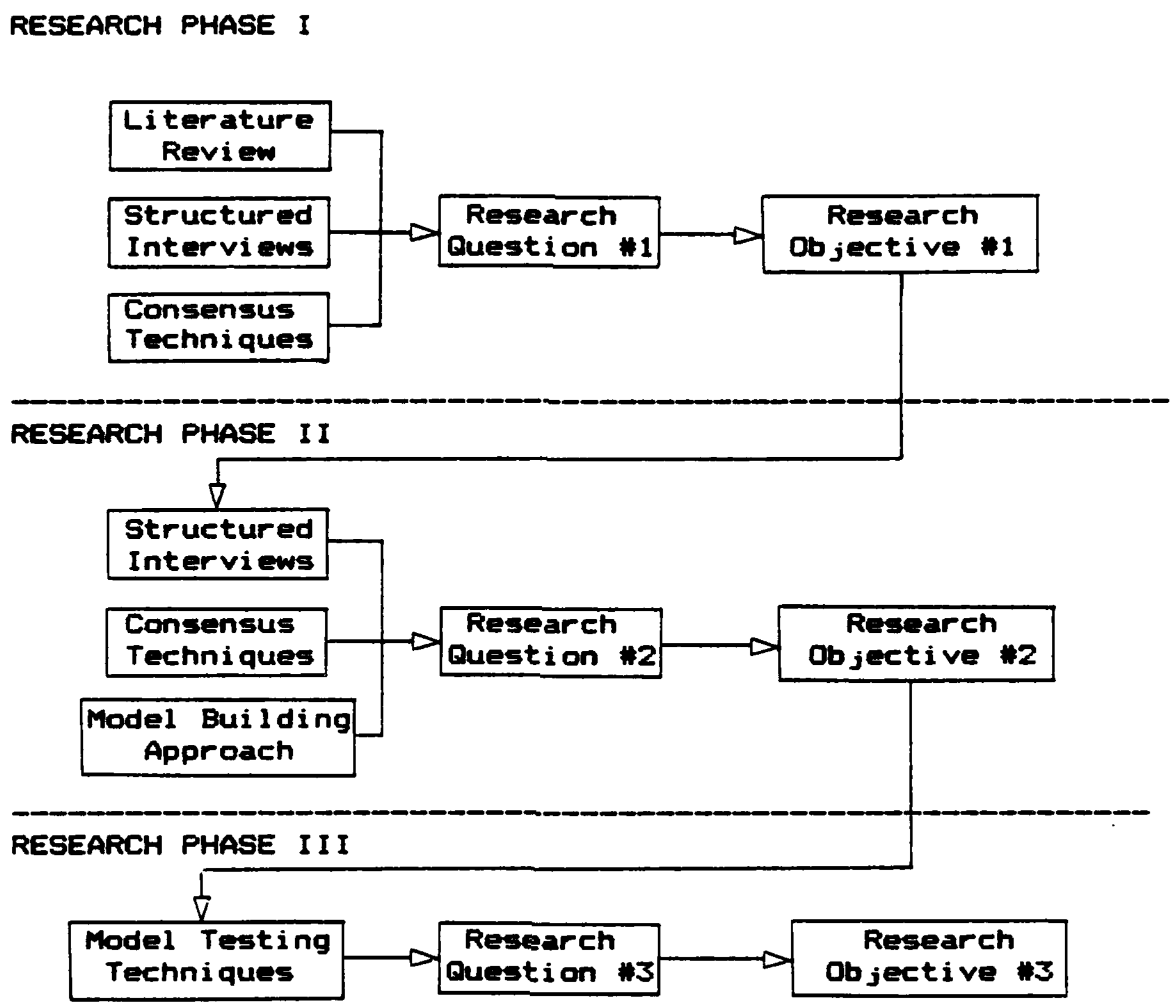


Figure 2. Research Plan

The first phase of the research will attempt to identify the relevant decision-making factors involved in the procurement of acquisition data (Research Objective #1). The research vehicle used in this phase will be a structured interview (See Appendix F). The results of this interview, which is based in part on findings from the literature, will be processed using statistical techniques (See Appendix C) to ensure that a consensus exists among all individuals interviewed as to the relative importance of the decision-making criteria. If all the individuals do not agree after the initial interviews, the Delphi Technique (See Appendix A) will be used to reach a consensus.

The decision-making criteria concerning the procurement of acquisition data identified in the first research phase will be used in the second research phase to form a decision making model (Research Objective #2). The model will be based on the Kepner-Tregoe approach to decision-making (See Appendix B). The Kepner-Tregoe Model requires that weight factors be assigned to certain decision-making criteria. These weights will be identified using the same structured interview and consensus achieving techniques that were applied in the first research phase.

The third research phase involves testing the decision-making model (Research Objective #3) formed during the second research phase. Testing will be conducted by applying the model to a random sample of parts/components where the decision to procure/not procure acquisition data is already known. A comparison of the known decisions to the results of the model applications will result in a success/failure rate for the model's ability to make the "correct" decision concerning the procurement of acquisition data.

Research Report Overview

As an overview of this research report, the content of the remaining chapters is briefly discussed.

Chapter II is a review of the literature that is applicable to the procurement of acquisition data. The first area discussed is the spare parts provisioning process, which ultimately generates the requirements for acquisition data. Acquisition data is defined in greater depth than previously, along with a detailed description of the process by which acquisition data is procured. The difficulty with the early definition of acquisition data requirements is also discussed. Finally, the results of previous research that has been done in this subject area are outlined.

Chapter III describes the methodology used to accomplish the research objectives and answer the research questions discussed in Chapter I. This chapter describes the population from which the research data was collected, the structured interview instruments that were used to gather the data, the procedures used to process and analyze the data, and the techniques used to form and validate the decision-making model. Finally, scope, limitations, and assumptions of the research are described.

Chapter IV contains an analysis of the data collected from the survey instruments and a description of the model-building and model validation processes. The procedures described in Chapter III will be used to process the data and to build and validate the model.

Chapter V discusses the characteristics of the acquisition data decision-making model developed by the researchers, and provides a greater explanation of the criteria and decision points contained in the model. In addition, this chapter explains how the model is to be used in the day-to-day work environment.

Finally, Chapter VI summarizes the results drawn from the research objectives. The utility of the decision-making model is discussed along with recommendations for its use. Recommendations for further research in this area are also discussed.

II. Literature Review

Spare Parts Provisioning Process

The provisioning process enables the Air Force to identify the type and quantity of spare parts needed to support the initial fielding of an operational weapon system. The process also establishes the manner in which spare parts will be procured (2:2-21). Available procurement alternatives include open competitive bidding or sole-source procurement from the prime contractor (17:2-5).

Generally, the prime contractor is asked (required by the contract) to recommend the method of procurement for a spare part. This is accomplished through the use of numeric Contractor Recommended Codes (CRC) and suffix codes which indicate the basis for the assignment of a particular numeric code (5:2-6). A description of the CRCs and suffix codes (See Appendix G) is contained in MIL-STD-789B, "Procurement Methods Coding of Replenishment Spare Parts [17:4]."

Following their submittal, the Contractor Recommended Codes are reviewed by a team of representatives from the Air Force Air Logistic Center (ALC) which will have responsibility for the logistical support of the weapon system under consideration (24:7). The review team considers the CRCs, negotiations with the prime contractor, and various other factors such as design stability in assigning a Procurement Method Code (PMC) and PMC suffix to the spare part under consideration. The particular PMC and suffix assigned determine the method by which the spare part will be procured throughout the life of the part's weapon systems. The Procurement Method Codes and Procurement Method Code suffixes are also described in MIL-STD-789B (See Appendix G) (17:2-11). Those items PMC coded for competitive procurement are the items which will require acquisition data (6:5-32).

The Nature of Acquisition Data

Acquisition and engineering data, defined in chapter I, are actually specific forms of technical data. Technical data is defined in DOD Instruction 5010.12, "Management of Technical Data" as:

> ...recorded information used to define a design and to produce, support, maintain or operate items of defense material. These data may be recorded as graphic or pictorial delineations in media such as drawings or photographs; text in specifications or related performance or design type documents; in machine forms such as punched cards, magnetic tape, computer memory printouts; or may be retained in computer memory. Examples of recorded information include engineering drawings and associated lists, specifications, standards, process sheets, manuals, technical reports, catalogue item identifications, and related information [15].

Acquisition data is further defined in MIL-STD-885B, "Procurement Data Packages." According to this document acquisition data is:

> ...a generic term applicable to types of technical data when used for procurement purposes. It is a composite of specifications, plans, drawings, standards and other data as may be necessary to describe existing materials so they may be procured by the method contemplated [16:2].

Additional clarification as to what constitutes acquisition data is contained in MIL-STD-490, "Specification

Practices" which establishes the format and content of system specifications, which together with drawings, form a basis for a Technical Data Package (TDP) which can be used for competitive procurement. Type 'C' Product Specifications are defined as specifications used in the production of a prime item of equipment and are essentially sufficient to serve as a TDP. Specifically, a Type C1b, Prime Item Product Fabrication Specification contains all the information needed for competitive procurement when combined with engineering drawings and associated lists (18).

DOD-1000B, "Drawings, Engineering and Associated Lists" is the specification which defines different levels of drawings progressing from system inception to production. Level 3 drawings provide engineering data for quantity production of an end item of equipment and for the competitive procurement of spare parts which are substantially identical to the original items. If level 3 drawings are specified in a contract and delivered with acceptable quality and unrestricted rights, the Air Force should have sufficient information to procure competitively (5:2-5).

Acquisition Data Procurement Process

The process of obtaining technical data (including acquisition data) begins within the System Program Office at the beginning of the weapon system acquisition cycle. The typical System Program Office is a matrix-type organization, with a Program Manager being appointed during the conceptual phase of the weapon system acquisition process. The Program Manager is responsible for all aspects of the weapon system acquisition (29:10). The Program Manager will appoint a Data Management Officer (or serve in that capacity himself), who serves as the focal point for the management of data actions during the life of the program (4:4-5).

Prior to contract award, the Data Management Officer issues a data call to all agencies which have a potential need for data (4:4-5). A data call is defined as:

> ...a request by the System/Project Manager, Commander or other authority to all Government participants to submit their requirements for contractor-prepared data on a given procurement action [15].

Agencies that believe they have a need for data will respond to the data call by identifying the type of data and the delivery schedule that they require. Requests for data must be justified by the requestors (24:5).

After data requests have been received by the Data Management Officer, they are reviewed in accordance with Air Force Regulation 310-1, "Management of Contractor Data." This review is accomplished by the Data Requirements Review Board, which is chaired by either the Program Manager or the Data Management Officer. This board screens all requests for data in an attempt to eliminate those that are unnecessary. The screened list of data requirements is included in the procurement contract as a contractor specification through the use of DOD Form 1423, "Contract Data Requirements List" (CDRL). The contractor is then contractually required to provide the appropriate data according to the specified schedule (4:1-14). A pictorial description of the technical data procurement process is shown in Figure 3.

The Acquisition Data "Time" Problem

The quandary in the procurement of acquisition data is that it is desirable to define data requirements early in order to communicate those requirements to the contractor and hence, reduce total costs related to engineering data acquisitions. Yet, the Air Force must avoid specifying what data is to be acquired until requirements are actually known and design stability is achieved (6:5-31).

A recent study by the Analytics Corporation, based on interviews with personnel from USAF Aeronautical Systems Division (ASD), Air Force Logistics Command (AFLC), and the ALCs, determined that the earliest point in the weapon system acquisition process where a feasible decision concerning acquisition data requirements could be made was immediately after the Physical Configuration Audit (6:5-33). The Physical Configuration Audit (PCA) is the formal examination of the "as built" configuration of an item against its technical documentation or product baseline. PCA typically occurs when the first production item is produced (11). The Analytics study indicated that while the PCA is the earliest feasible time for a definition of acquisition data requirements, it is "too late" in terms of reducing total costs related to engineering data (6:531-32).

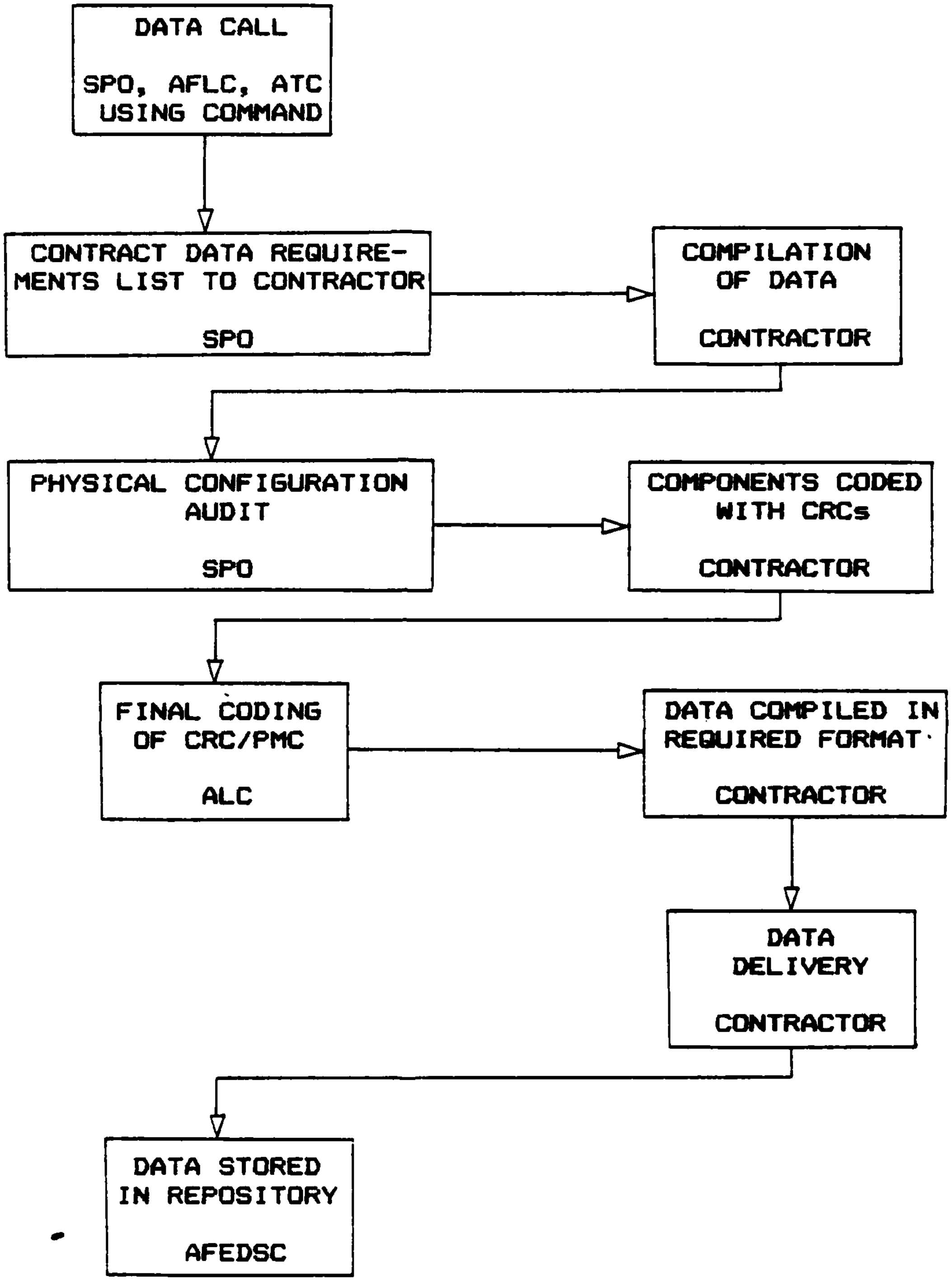


Figure 3. Technical Data Procurement Process

The Analytics study concluded that no clear criteria exist for an early definition of acquisition data requirements concerning the procurement of spare parts (6:5-33).

In order to define acquisition data requirements sooner in the weapons system acquisition process, the Analytics study recommended that AFLC examine the feasibility and cost of developing profiles of typical spares requirements for various types of systems and equipments. The requirements for acquisition data could then be based upon these profiles (6:6-6). This recommendaton is roughly analogous to the proposals of two other research studies in this subject area.

Previous Research Studies

The two main works on the subject of decision-making criteria used for the procurement of acquisition data are studies prepared by graduate students at the Air Force Institute of Technology (AFIT) located at Wright-Patterson AFB.

The first, "An Assessment of Relevant Decision-Making Factors in the Purchase of Reprocurement Data," was completed in 1979 by Captain Robert L. Johnson, USAF, and Captain Mark A. Southwick, USAF.

The objectives of Johnson and Southwick's thesis were:

1. To identify the factors considered in determining whether reprocurement data are purchased.

2. To provide general guidelines which will assist Air

Force Managers in deciding whether to purchase reprocurement data (24:21).

The research methods used by Johnson and Southwick were a research questionnaire and a case analysis (24:23). The questionnaire was used to poll ALC Engineering Data Section Personnel concerning the factors they considered when deciding to procure acquisition data (24:23-24). The case analysis statistically analyzed the characteristics of spare parts that exhibit a high annual usage rate (AUR). This analysis was based on the assumption that parts with a high AUR will need to be procured on a continuing basis, and hence, should be reprocured competitively, i.e., would need acquisition data. The weapon system used for the case analysis was the C-130 aircraft (24:23,28).

Johnson and Southwick's research questionnaire identified seven factors used by Air Force Managers when determining the need for acquisition data:

1. The cost of the replenishment item.

2. The design stability of the item.

3. Expected life of the item in the inventory.

4. The cost of the reprocurement data.

5. ASPR (now FAR) requirement to purchase competitively whenever possible.

6. The possibility that the original supplier may go out of business.

7. The lack of alternatives to promote competitive buying (24:85).

In addition to identifying these factors, Johnson and Southwick used a form of factor analysis to determine that the three most important of the above factors in order were:

1. The design stability of the item.

2. The cost of the replenishment item.

3. Length of expected life of the item in the inventory (24:86).

Johnson and Southwick's case analysis of C-130 spare parts identified a statistical correlation between the actual method of procurement (AMOP) of a spare part (competitive or not competitive) and that part's annual usage rate (AUR) (24:48). In addition, a statistical correlation was identified between the AUR of a spare part and that part's Item Classification (as defined by the first two digits of the Federal Stock number) (24:87).

Based on these statistical correlations Johnson and Southwick recommended that the Item Classification of spare parts be used as the primary criterion in the decision to procure acquisition data (24:88).

Johnson and Southwick qualified their findings as being limited to the C-130 aircraft. They recommended that similar studies be performed on other weapon systems to determine if their decision-making criterion had universal application (24:90).

This recommendation was followed by Falconer and Murphy in their thesis, "An Analysis of Factors which should be Considered in Developing Repocurement Data Requirements."

Falconer and Murphy applied the research techniques used by Johnson and Southwick to other weapon systems. Specifically, case analyses were performed on the KC-135 cargo-type aircraft, and the F-4 and A-7 fighter-type aircraft (21:2).

Falconer and Murphy's research produced the following findings:

1. For each aircraft studied, a statistical correlation existed between the actual method of procurement and the annual usage rate of a spare part.

2. For each aircraft studied, a statistical correlation existed between the annual usage rate and Item Classification of a spare part.

3. The same Item Classifications on each weapon system do not exhibit the same annual usage rate. This means that there is a particular Item Classification/annual usage rate relationship peculiar to every weapon system. This is a key point, it means that the Item Classification/annual usage rate relationships of preceeding weapon systems cannot be used to predict similar relationships of new systems (21:58).

To utilize the findings of these two research studies in the decision-making process, an analysis of every Air Force weapon system would have to be performed to determine the system peculiar relationship between annual usage rate and Item Classification. This method ignores the need for some decision-making criteria in the early stages of the weapon system acquisition process. In order to economically contract for acquisition data, accurate decisions concerning the need for acquisition data have to be made before the first production item is manufactured. It is not feasible to wait until spare parts are procured to determine the need for acquisition data for those parts. The methodology in Chapter III describes an attempt to provide decision-making criteria that can be used in the early stages of the weapon system acquisition process.

III. Methodology

This chapter describes the methodology by which the research questions in Chapter I were answered.

Included in this chapter are descriptions of the research site (including a discussion of why it was chosen), the survey population, and the sample of individuals interviewed. Next, the researchers discuss decision-making models and techniques in general, and why the techniques used in this thesis were selected. This is followed by a description of the step-by-step process the researchers used to answer all research questions and objectives. This process is broken down into three main Research Phases, with each phase corresponding to one Research Objective. A flowchart accompanies each phase to allow for easier understanding of the methodology used by the researchers. The researchers conclude by listing all assumptions and limitations pertaining to the methodology, and provide the reader with a brief summary of the methodology, including a flowchart of the entire research methodology.

Related to, but not included in, the methodology are descriptions of the Delphi Technique (Appendix A), the Kepner-Tregoe decision-making analysis (Appendix B), Kendall's Coefficient of Concordance, W (Appendix C), and the test for Differences Between Two Population Means (Appendix D). Appendix E contains abbreviated Chi-Square and t-test tables used under the "Kendall Coefficient" and

"Difference Between Two Means" tests. Finally, Appendix F contains a copy of the two structured interview questionnaires used to collect the data for this thesis.

Research Site

This thesis effort surveyed Program Managers and Configuration Management Personnel within AFSC's Aeronautical Systems Division (ASD) located at Wright-Patterson AFB, Ohio. ASD was chosen because it is located at the same site as the researchers and this organization purchases 78% of all acquisition data within the U.S. Air Force (26). Having the research site located on the same base allowed the research team to collect data within the time constraints of the thesis completion date.

Population

The survey population consisted of all civilian or military personnel who participate in the Procurement Method Coding process at AFSC/ASD. The total population consists of approximately 256 people. To determine the survey population size, the researchers relied on information supplied by the Directors of each program office at ASD.

Sample

The survey sample was drawn from the list of individuals supplied by the program office directors. To make the assumption that the selected sample accurately represents each program office within ASD, a sample size of thirty individuals was chosen. In order to invoke the Central Limit Theorem, a sample size of at least twenty individuals should have been selected. The greater the sample size, the better the approximation of the population. The researchers felt, however, that a sample greater than thirty would be too unwieldy, given the time constraints placed on thesis completion.

Using the Central Limit Theorem requires that an assumption be made that no respondents discuss interview responses with other respondents. This assumption may be supported because the researchers warned each respondent that discussing their responses with others will invalidate any results obtained from t structured interviews.

The exact number of persons from each program office was chosen using a stratified random sampling technique in conjunction with the following method:

TABLE I

Calculation of the Number of Representatives Interviewed *

ORG'N	(POP	X	11.72%	=	AMT)	SAMPLE
AE	31	X	11.72%	=	3.63	4
AF	16	X	11.72%	=	1.88	2
B-1	12	X	11.72%	=	1.41	1
RW	77	X	11.72%	=	9.02	9
YP	12	X	11.72%	=	1.41	1
YY	4	X	11.72%	=	0.47	1
YZ	25	X	11.72%	=	2.93	3
TA	79	X	11.72%	=	9.26	9
	256					30

* At least one person was required from each SPO (except for those SPOs with no data personnel)

1. A percentage of sample size to population size was calculated -- 30/256 = 11.72%.

2. This percentage was applied to the total number of data personnel available within each program office. Table I shows the exact number of individuals selected from each program office.

Those individuals selected by their supervisors were deemed "experts" in the area of data acquisition. Because it relied on the respondents being "experts" in their field, this methodology precluded random selection (23:11).

Problem Solving Approach

Decision-Making Models and Techniques. There are a number of decision theory approaches available to today's manager. Most techniques, such as the zero-sum and the mixed strategy games, use the concepts of competitors' actions and states of nature. These concepts did not apply to the present situation of determining when to purchase acquisition data; there are no different outcomes possible in the states of nature -- you either choose to purchase acquisition data or you do not. Neither is there a known penalty for not choosing one alternative over another.

According to Schoderbek, Schoderbek and Kefalas, "probably the most fundamental element in [Operations Research] is the need to quantify the business problem under study [31:133]".

> However, decisions that are more of a judgmental nature, less prone to recur with regularity, and more affected by environmental factors are not readily subject to quantification [31:133].

Because the researchers were working with subjective decision criteria, Bayesian Decision Criteria, Statistical Decision Theory, and other Operations Research techniques did not apply. Instead, the researchers attempted to find a technique which would lead to "Go" and "No Go" decision points based on established criteria. Since no criteria were presently set forth under any regulation, publication, or guide, the researchers first needed to determine criteria which would aid in the acquisition data purchase decision. The criteria presently used are "wisdom, luck, and a good measure of experience [26]."

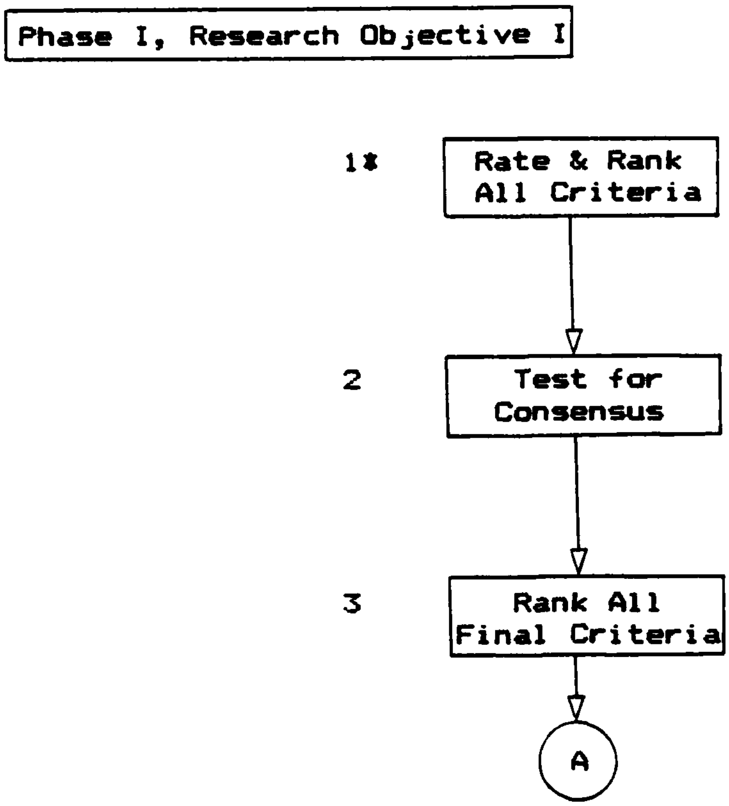
One desirable way to determine objectives or criteria (when none are already set forth) is to organize members into panels or committees (8:191). The intent is to tap the knowledge available from within a group and arrive at a consensus. However, there are several problems inherent in gathering data through group meetings, such as the influence of dominant members or the pressure to conform. The Delphi technique was chosen as the means to extract the expertise and experience from those individuals who have been working in the area of purchasing acquisition data, because it overcomes the inherent weaknesses of group sessions. For a complete explanation of the Delphi Technique, refer to Appendix A.

Because many of the criteria found in the literature review were quite subjective in nature, quantitative decision theory models were of no use (20). The only suitable decision-making technique which utilizes both subjective criteria and subjective ratings of those criteria is the Kepner-Tregoe approach (25). Appendix B contains a thorough description of this decision-making tool.

The Process. Figure 4 takes the reader through Steps #1, #2 and #3 of the methodology to accomplish Research Objective I. Figure 5 depicts the problem-solving approach to achieve Research Objective II, and includes Steps #4 through #9. Finally, Figure 7 shows the approach taken to attain Research Objective III, and it includes Steps #10 and #11 of the research methodology.

Step #1. The researchers used a "structured" interview to obtain acquisition data decision criteria from the sample. A structured interview is very similar to a survey technique in that all questions are prepared prior to the interview; there is no spontaneous exchange of ideas between the interviewer and the respondent.

The survey instrument (See Appendix F) contained a list of all criteria found by the researchers through their literature review, along with a brief explanation of the criteria. The respondents were asked to rate each criterion on a scale from zero to five based on its importance in deciding whether or not to purchase acquisition data. If



* All Numbers Refer To Steps In Methodology

Figure 4. Methodology Flowchart -- Phase I

the criterion was very important, it should have been given a rating of five; if it was not at all significant, it should have been given a rating of zero. Any time a respondent rated a criterion as a zero or a five, rationale for the decision was requested. If the researchers could not have shown consensus on the ranking of the criteria (see the end of this subsection for a discussion on ranking the criteria), these rates would have been used to calculate interquartile ranges and mean ratings. This data would then have been provided as "feedback" under a second set of interviews to determine the decision-making criteria.

In addition, the respondent was asked to determine whether the criterion is a "MUST" or a "WANT." A "MUST" criterion is one which absolutely must be present before acquisition data will be purchased. If this criterion does not exist, the Government will not purchase the acquisition data. A "WANT" criterion is one which is desirable when deciding whether or not to purchase acquisition data, but is not absolutely necessary.

Because many of the potential criteria listed on the questionnaire were rather ambiguous (design stability, item complexity, etc.), respondents were also asked to provide their opinions of how these criteria are defined. In addition, respondents were allowed to add any criteria not already listed on the questionnaire. Finally, the respondents were asked to rank order all criteria (including criteria thay have added), from most important to least important. Kendall's Coefficient of Concordance requires that the "experts" rank order all criterion before concensus can be determined (See Step #2).

<u>Step #2</u>. In this step the researchers tested for consensus among respondents as to the ranking of criteria obtained from Step #1. The researchers used Kendall's Coefficient of Concordance, W, to test for overall agreement among the respondents. A complete description of this test is provided in Appendix C.

Step #3. This step simply entailed ranking all the criteria found under Step #1 in order of importance from most important to least important. The overall rankings were based on the sums of the ranks for each criterion. The criterion with the lowest sum was ranked number one in importance. The criterion with the next lowest sum was ranked number two in importance, and so on, until the criterion with the highest sum remained. This criterion was ranked lowest among all the decision-making criteria provided by the acquisition data experts.

This concludes Phase I of the research effort and provides the reader with the answer to Research Objective I, "To identify and rank all criteria . . . ." Figure 5 depicts the methodology for solving Phase II, Research Objective II of this research effort.

Step #4. Because the researchers found that no "MUST" criteria existed, all eleven criteria had to be weighed using a second "structured interview" technique. The survey instrument for determining the criteria's weights can be found in Appendix F.

The researchers asked the respondents to weight each criterion from one to ten based on that criterion's importance in the decision to purchase acquisition data. The respondents were told that no criterion could be weighted higher than the previous criterion, but it could be weighted the same as the previous one. This was to avoid the possi-

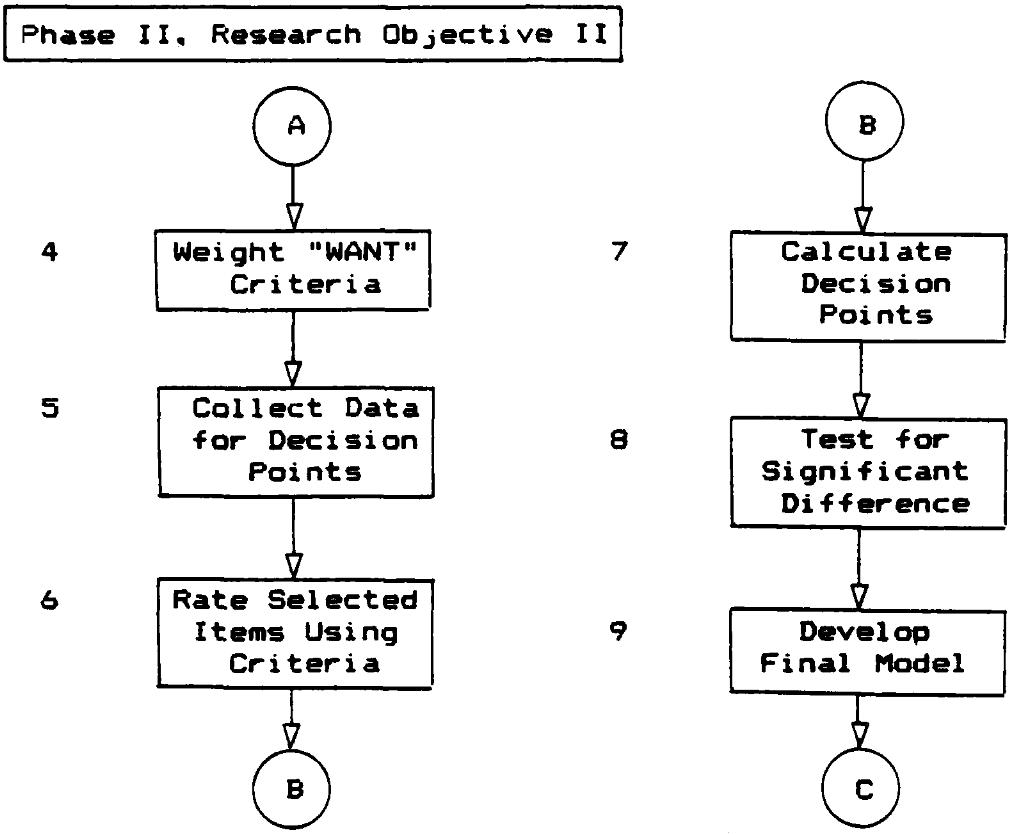


Figure 5. Methodology Flowchart -- Phase II

bility of one criterion being ranked lower than another after Steps #1 through #3, and yet being weighted higher after Step #4.

The first criterion in rank did not necessarily have to be given a weight of ten (the highest possible weight), nor did the last criterion have to be given a weight of one (unless, of course, the previous criterion was given the weight of one).

For example, say that the following criteria are ranked from most significant to least significant:

1. Design stability
2. Expected inventory life of the item
3. Complexity of design
4. Cost of the acquisition data
5. Amount of critical materials
6. Cost of the replenishment item
7. Amount of fixed tooling

Each respondent was then asked to weight each criterion from one to ten, with ten being the highest. This is how the weightings might look for one respondent:

1.	Design stability	(9)
2.	Expected inventory life	(9)
3.	Complexity of design	(7)
4.	Cost of the acquisition data	(4)
5.	Amount of critical materials	(2)
6.	Cost of the replenishment item	(2)
7.	Amount of fixed tooling	(2)

A second respondent may have weighted the criteria differently:

1.	Design stability	(10)
2.	Expected inventory life	(8)
3.	Complexity of design	(7)
4.	Cost of the acquisition data	(7)
5.	Amount of critical materials	(2)
6.	Cost of the replenishment item	(1)
7.	Amount of fixed tooling	(1)

The researchers then derived an average weight for each of the criteria using the following equation for calculating the arithmetic mean of a sample (7:55-59):

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad (1)$$

where: n = total number of respondents
x_i = the weight given the criterion by respondent i

In the example above, had only two respondents been interviewed, the weights for the above criteria would be:

1. Design stability (9.5)
2. Expected inventory life (8.5)
3. Complexity of design (7.0)
4. Cost of the acquisition data (5.5)
5. Amount of critical materials (2.0)
6. Cost of the replenishment item (1.5)
7. Amount of fixed tooling (1.5)

Step #5. The researchers then had item managers select one item each for which acquisition data was purchased and later used under a competitive bid. The item managers were also asked to select one item each for which no acquisition data was purchased.

Step #6. The item managers were to rate the item they had selected using the criteria developed in Steps #1 through #4. The respondent rated the item from one to ten against every criterion, and the rating was multiplied by the weight for that criterion. The products for each criterion were then summed, and an "item value" was obtained for that particular item. If the item being rated was an item for which the acquisition data was purchased and used, the item value should have been relatively high. If the item being rated was one for which no acquisition data was purchased, the item value should have been relatively low.

In the example presented above, one selected item may have a very high design stability, so the respondent might give it a rating of 8. It may also be anticipated that this item will have a long inventory life, so the respondent gave it a rating of 7. The respondent may know that the item is somewhat non-complex, so he gave it a rating of 8 for "complexity of design," and so on, until the final rating looks like this:

	CRITERION	WT	X	RT	= AMT
1.	Design stability	(9.5)	X	9	= 85.5
2.	Expected inventory life	(8.5)		7	59.5
3.	Complexity of design	(7.0)		8	56.0
4.	Cost of the acquisition data	(5.5)		4	22.0
5.	Amount of critical materials	(2.0)		8	16.0
6.	Cost of the replenishment item	(1.5)		10	15.0
7.	Amount of fixed tooling	(1.5)		7	10.5
	ITEM VALUE				264.5

<u>Step #7</u>. The researchers then calculated an average item value of those items for which acquisition data was purchased and used, and of those items for which acquisition data was not purchased. Equation (1) used in Step #4 to calculate the average weight was also used here to calculate the average item value.

The average item value of items for which acquisition data was purchased and later used (we call this the "high item value") became the "Go" decision point in the final model. The average item value of items for which no acquisition data was purchased (we call this the "low item value") became the "No Go" decision point.

During operational use of this decision-making technique, if a data manager derives an item value equal to or greater than the "high item value," he should decide to purchase acquisition data. If the calculated item value is equal to or less than the "low item value," he should decide to not purchase acquisition data for that item. If the item value falls between the two decision points, it is the manager's decision whether or not to purchase acquisition data.

<u>Step #8</u>. In order to infer that there exists a true difference between the two decision points, the researchers performed a test for the difference between two means. The necessary assumptions that 1) both sampled populations have relative frequency distributions that are approximately normal, 2) the population variances are equal, and 3) the samples are randomly and independently selected from the populations, appeared to be reasonable.

The Null Hypothesis was that the mean for population 1 equals the mean for population 2, while the Alternative Hypothesis was that the means of the two populations are not equal. To determine if the two means are the same, the following values must be calculated (7:337-342):

1. $\bar{x}_1$ = high item value
2. $\bar{x}_2$ = low item value
3. s_1 = standard deviation of high item value
4. s_2 = standard deviation of low item value
5. s_p^2 = pooled sample estimator of δ^2
6. t = Student's t-statistic

The equations used to determine s_p^2 and t are given on the following page:

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \tag{2}$$

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - 0}{\sqrt{s_p^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \tag{3}$$

Referring to TABLE XII in Appendix E, the researchers used a significance level of = .05 at [(3 + 3 - 2) = 4] degrees freedom. If the calculated t-value exceeds the t-value in Appendix E, the researchers would reject the Null Hypothesis that the high item value is no different than the low item value. In other words, there is a significant difference between the "Go" and "No Go" decision points.

Since a significant difference was found between the high and low item values, the researchers then proceeded to Step #9, development of the final model. For a complete explanation of the Small-Sample Test for the Difference Between Two Population Means, see Appendix D.

Step #9. In effect, the final model has already been developed for the researchers. Final development merely entailed putting the model into a format which was both functional and aesthetic. Figure 6 is the final model format chosen by the researchers. The final model lists each criterion, followed by its calculated weight. It would be the user's role to fill in a rate for each criterion and find the product of the weight and the rate. The user would then sum the products for each criterion to arrive at a "Total Item Value" for the item being purchased. This "Total Item Value" would then be compared against the Go/No Go points listed in Section II of the model to determine if acquisition data should be purchased for that item.

SECTION I			
CRITERIA	WT X	RT =	AMT
1)			
2)			
3)			
4)			
5)			
6)			
7)			
8)			
9)			
10)			
11)			
TOTAL ITEM VALUE (TIV)			

SECTION II
If TIV > "high" -- Purchase Acquisition Data
If TIV < "low" -- DO NOT Purchase Acquisition Data
If "low" < TIV < "high" -- YOUR CHOICE !!!

Figure 6. Potential Final Model Format

Now that the researchers have completed Phase II of the thesis effort, Research Objective II, "To use the identified factors in building a model . . . ," is accomplished. The researchers now move on to Phase III of this project in order to achieve Research Objective III. Phase III incorporates Steps #10 and #11, as depicted in Figure 7.

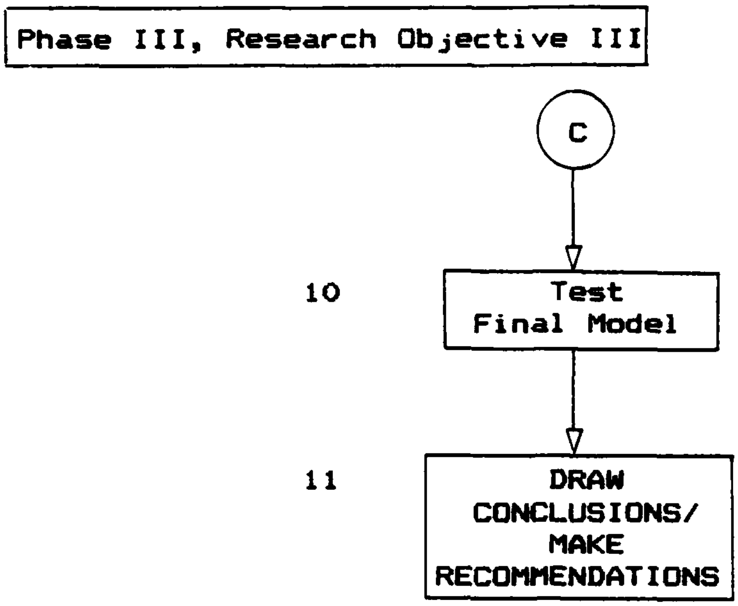


Figure 7. Methodology Flowchart -- Phase III

Step #10. To test the final model, the researchers randomly selected items from various program offices and had Program Managers perform the decision-making analysis (In reality, the decision had already been made to purchase or not purchase acquisition data for these items). The Program Manager calculated a Total Item Value for the item, and, based on the "Go"/"No Go" decision points, decided whether or not to purchase acquisition data. His decision was then compared with the actual, documented decision, and a total percentage of "correct" decisions was calculated.

Step #11. Conclusions/recommendations will be set forth under Chapter VI of this research effort.

Assumptions

This research effort was performed under the following assumptions:

1. The best Data Managers were indeed chosen for their abilities as data managers.

2. Because the researchers insisted that no information be discussed outside the interview, anonymity was maintained by all respondents during the successive iterations of the interviews.

3. The "experts" will tend to rate each item somewhat uniformly.

4. Under those contracts for which the Government purchased and later used acquisition data, valid reasons or criteria existed for purchasing the data.

5. Under those contracts for which acquisition data was not purchased, valid reasons or criteria existed for not purchasing the data.

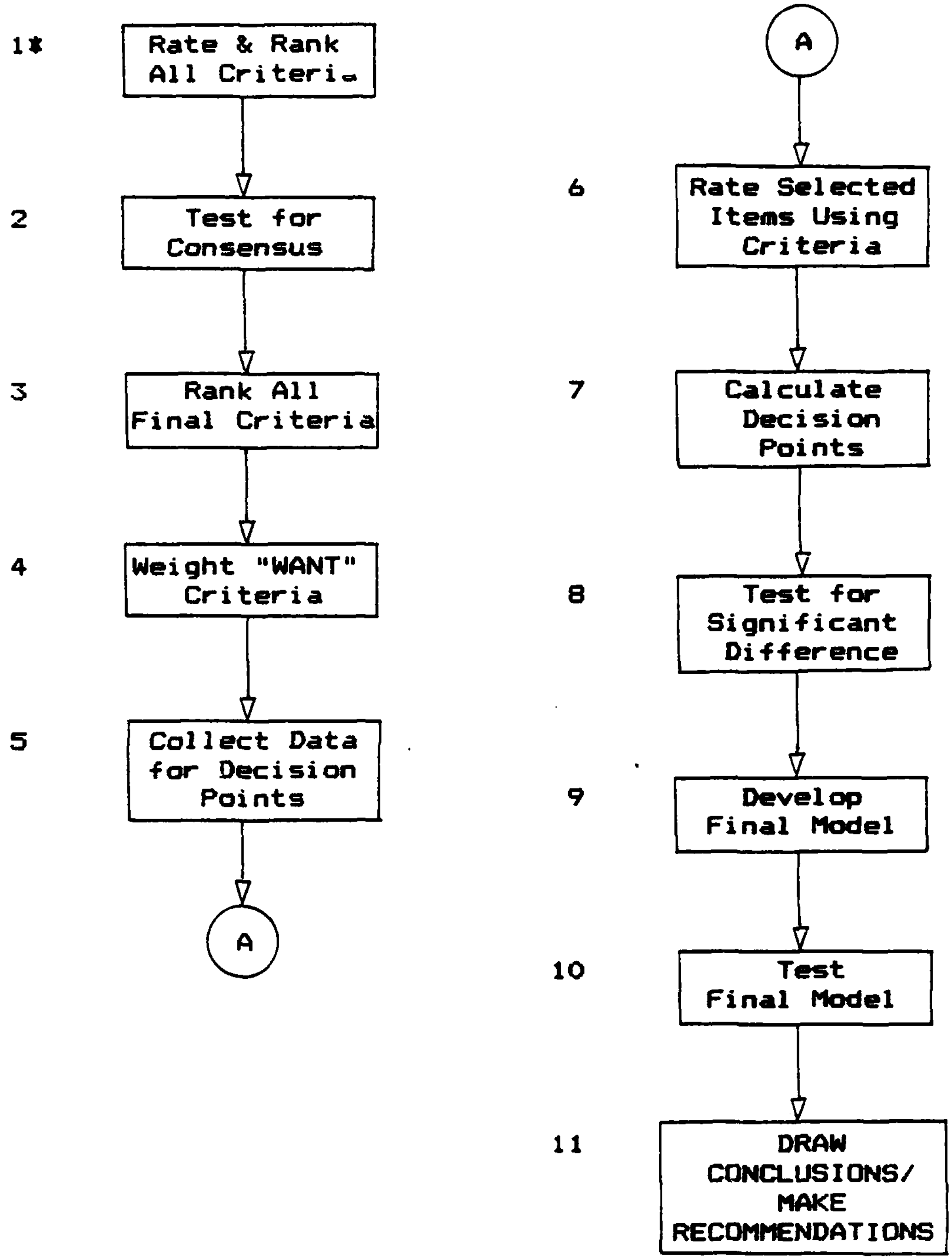
Limitations

1. This research effort was limited to a fifteen month schedule for completion as dictated by the Air Force Institute of Technology (AFIT), School of Systems and Logistics.

2. Personal interviews were limited in time due to the heavy workloads of the respondents.

Summary of Methodology

Figure 8 depicts the entire methodology used to develop an acquisition data decision-making model:



* All Numbers Refer to Steps in Methodology

Figure 8. Overall Methodology Flowchart

IV. Data Analysis

The purpose of this chapter is to collate, analyze, and present the interview data using the research methodology that was developed in Chapter III.

This chapter has three main sections, with each section corresponding to one of the three research phases as outlined in Chapter I. In turn, each Research Phase is designed to answer one of the three thesis Research Questions. Each Research Phase is further subdivided into a series of steps as outlined in Chapter III.

Research Phase I

Research Phase I was designed to answer Research Question #1 which stated: What criteria should be considered in determining whether acquisition data will be procured for a particular part or component, and how are the criteria rank ordered in terms of relative importance?

Step #1. The results of the first structured interview (See Appendix F for a copy of the first survey tool) are contained in Tables IV and V. Table III lists each decision criteria beside its "criteria designator." Table IV depicts the experts' subjective ratings of each decision criterion on a scale of 1 to 5. Criteria that were identified by each expert as "MUSTS" are indicated by the letter "M" following each rating.

In order to be considered a "MUST" for the purpose of the decision-making model, a particular criterion had to have been identified as a "MUST" by 90% (27 of 30) of the experts interviewed. The researchers chose the level of 90% based on the opinions of ASD contracting personnel. Table II shows the results of each contracting individual's opinion as to how many respondents should identify a particular criterion as a "MUST" before it should be considered as such in the final model.

The researchers used the median and the mode as the methods to obtain a final level of agreement among the contracting personnel's opinions. The median is often a better measure of central tendency because it is less sensitive than the mean to a few extremely large or extremely small measurements (7:61). The mode is useful as a measure of central tendency because it emphasizes data concentration (7:54). The researchers also include the mean of the sample for comparison purposes.

TABLE II

Contracting Personnel's Opinions as to the Level Required Before a Criterion may be Considered a "MUST"

Person #	Percentage	Person #	Percentage
1	95	7	90
2	90	8	60
3	85	9	85
4	95	10	90
5	75	11	95
6	90	12	90

Mean = 1040/12 = 86.67%   Median = (90 + 90)/2 = 90%

Mode = 90%

Analysis of the data indicated that no decision criterion qualified as a "MUST". Table IV depicts the total number of times that each criterion was identified as a "MUST" by the experts and it includes the computed percentages. Since the highest rating of "MUSTS" for any criterion was only 40%, no criteria were designated as "MUSTS" in the final decision-making model.

The letters under the "Criteria Designator" column of Table III are used in the "Criteria" row of Table IV to represent each associated criterion.

TABLE III

List of Acquisition Data Decision-Making Criteria

CRITERIA DESIGNATOR	CRITERIA
A	Cost of the Replenishment Item
B	Design Stability
C	Expected Inventory Life
D	Cost of the Acquisition Data
E	Organizational/Regulatory Requirements
F	Original Supplier's Business Solvency
G	Amount of Fixed Tooling
H	Anticipated Quantity of the Buy
I	Amount of Critical Materials
J	Time/Personnel Requirements (Cost Effectiveness)
K	Complexity of Design

TABLE IV

Experts' Subjective Rating of Decision Criteria

CRITERIA

EXPERTS	A	B	C	D	E	F	G	H	I	J	K
1	0	4	4	4	4	4	4	4	3	2	2
2	1	4	4	2	4	2	3	5M	3	4	3
3	0	4	3	5M	4	3	3	4	2	3	4
4	0	5M	4	5	3	2	3	4	2	2	3
5	2	4	4	4	3	4	3	5M	1	3	4
6	1	4	5	4	4	4	4	5M	2	2	4
7	0	5M	4	5	4	2	3	5M	3	4	4
8	1	4	3	4	5M	3	4	4	1	1	2
9	0	4	2	3	4	3	3	4	0	2	3
10	0	4	4	4	4	3	3	5M	3	3	4
11	1	4	4	4	3	3	3	4	2	4	4
12	2	5	4	4	4	4	3	5M	3	2	4
13	1	5M	4	4	4	3	4	5	2	3	3
14	0	4	3	4	3	3	3	4	3	3	4
15	1	4	4	3	3	3	4	4	2	3	4
16	3	3	3	3	3	2	2	1	3	2	3
17	4	4M	4M	4M	3M	4	0	0	1	4	4
18	3	4M	2	4M	4M	3M	0	1	0	4M	3
19	0M	3M	3M	0	2M	3M	0	2M	1M	0	1M
20	1	1	3M	3M	0	1	1	3M	1	4M	2
21	3	1	1	4M	4M	3M	0	2	1	0	4M
22	2	1	2	4M	4M	4M	0	3	0	0	4M
23	4	5M	4	5M	4	3	1	3	4	5M	4
24	4M	1	3M	3M	3M	4M	2M	3	3M	1	3M
25	4	5	4M	4M	5M	3	3	5M	4	4	5M
26	3	4M	5M	4	0	4M	1	4M	4	4	4
27	1	4	3	3M	1	4	0	4M	4	2M	3
28	3M	4M	2	0	4M	4	0	4M	3M	2	4M
29	2	3	4	3	5M	3	0	3	0	1	3
30	3	5M	3	4M	4	3	3	0	4	4M	5M
TOTAL "MUSTS"	3	10	6	11	10	6	1	12	3	5	8
% OF TOTAL	10	33	20	37	33	20	3	40	10	17	27

Selected comments by the experts concerning the definition of each decision criterion, and the experts' reasons for assigning either the highest or lowest rating to a criterion are contained in Appendix H.

In responding to the first structured interview the experts failed to identify any new decision criteria that would affect the model. This was attributed to the fact that the eleven previously identified decision criteria were largely the results of two recent research efforts that utilized a similar research population. In addition, other relevant criteria were found through preliminary interviews with personnel knowledgeable in the acquisition data environment.

Table V depicts the individual experts' rank ordering of the decision criteria. This rank ordering by the experts was required in order to test for a consensus as to the ranking of the decision criteria in terms of relative importance. The actual test for consensus is performed in Step #2.

Step #2. In this step Kendall's Coefficient of Concordance was used to test for consensus among the experts as to the ranking of the decision criteria in terms of their relative importance. The actual computations involved in the analysis are presented following Table V. For a more detailed explanation of Kendall's Coefficient of Concordance see Appendix C.

TABLE V

Experts' Rank Ordering of Decision Criteria

CRITERIA

EXPERTS	A	B	C	D	E	F	G	H	I	J	K
1	4	1	2	7	11	9	6	3	8	10	5
2	5	1	3	6	11	10	7	4	9	8	2
3	2	1	3	5	9	10	7	4	8	11	6
4	5	1	2	4	10	9	6	3	8	11	7
5	4	1	3	6	11	8	7	2	10	9	5
6	3	2	1	4	8	9	10	5	6	11	7
7	4	2	3	1	9	11	8	5	7	10	6
8	3	1	2	6	8	10	7	4	9	11	5
9	4	2	1	7	11	8	9	5	10	6	3
10	5	1	3	7	10	8	11	2	9	6	4
11	3	2	4	1	7	10	11	5	8	9	6
12	4	1	2	5	9	11	8	6	10	7	3
13	3	1	4	5	10	11	8	7	9	6	2
14	5	2	3	1	9	10	11	6	8	7	4
15	2	1	4	3	8	9	10	5	7	11	6
16	4	1	5	6	8	7	10	9	2	11	3
17	1	1	5	3	11	9	10	3	6	7	8
18	3	5	6	3	1	11	8	8	8	2	7
19	3	5	1	8	11	6	10	1	7	8	4
20	1	5	1	1	5	8	8	1	5	8	8
21	8	7	6	2	1	4	11	5	9	10	3
22	7	8	6	2	1	4	10	5	10	9	2
23	8	2	7	9	1	11	10	6	5	3	4
24	3	10	11	7	8	1	2	6	4	5	9
25	7	2	4	3	6	11	10	5	9	8	1
26	9	3	1	7	11	4	10	1	8	6	5
27	9	1	8	6	10	6	11	5	2	4	2
28	4	1	4	10	1	10	8	4	4	8	1
29	5	3	2	7	6	8	11	4	10	9	1
30	5	3	8	4	9	6	7	11	10	1	2
SUMS	133	77	115	146	231	249	262	140	225	232	131
RANK	4	1	2	6	8	10	11	5	7	9	3

MEAN SUM: 176.46

H_0: The rankings are unrelated.

H_1: A consensus on the rankings has been achieved

W = Kendall's Coefficient of Concordance (0 < W < 1)

k = the number of experts [30]

N = the number of criteria [11]

s = the sum of the observed deviations from the mean of the SUMS (SUMS obtained from TABLE IV)

$$s = \sum \left(R_i - \frac{\sum R_i}{N} \right)^2 \qquad (4)$$

$$s = (132-176.46)^2 + (77-176.46)^2 + (115-176.46)^2 + (146-176.46)^2 + (231-176.46)^2 + (249-176.46)^2 + (262-176.46)^2 + (140-176.46)^2 + (225-176.46)^2 + (232-176.46)^2 + (131-176.46)^2 = 40876.70$$

$$W = \frac{s}{(1/12)\ (k \times k)\ (N^3 - N)} = \frac{40876.70}{99000} = .41290 \qquad (5)$$

$$\text{Chi-Square Value} = (k)(N-1)(W) = 30(10).41290 = 123.869 \qquad (6)$$

The test chi-square value at α = .05 level of significance based on 10 (N-1) degrees of freedom = 18.3070.

Since the actual Chi-Square value of 124.134 exceeded the test value of 18.3070, the null hypothesis could easily be rejected. Thus, the surveyed experts achieved consensus in their ranking of the decision criteria in terms of relative importance.

Step #3. As a result of the rankings provided by the experts, Table VI displays the final ranking of the criteria obtained from the first set of interviews. The final rankings are based on the sums in Table V, with the criterion having the lowest sum ranked first, the criterion with the next lowest sum ranked second, and so on.

TABLE VI

Final Rank Ordering of Decision Criteria

RANK	CRITERIA	PREVIOUS DESIGNATOR
1	Design Stability	B
2	Expected Inventory Life	C
3	Complexity of Design	K
4	Cost of the Replenishment Item	A
5	Anticipated Quantity of Buy	H
6	Cost of the Acquisition Data	D
7	Amount of Critical Materials	I
8	Organizational/Regulatory Requirements	E
9	Time/Personnel Requirements	J
10	Original Supplier's Business Solvency	F
11	Amount of Fixed Tooling	G

NOTE: From this point forward, all criteria will be shown using their ranks as criteria designators.

Research Question #1 Answered

With the completion of step #3, the researchers have now provided the answer to Research Question #1. Table VI reflects the researchers' analysis of the data gathered from the survey of the experts. This data indicates which criteria should be considered in determining whether acquisition data should be purchased for a particular part or component, ranked in relative order of importance. For a more detailed understanding of each of the criteria, see Chapter V and Appendix H.

TABLE VII

Experts' Subjective Weighting of Decision Criteria

EXPERTS	CRITERIA 1	2	3	4	5	6	7	8	9	10	11
1	10	10	9	7	7	5	4	3	1	1	1
2	10	9	9	8	8	7	4	4	4	3	3
3	9	9	9	8	7	6	5	3	2	1	1
4	10	8	7	5	5	5	4	4	3	3	3
5	10	10	10	9	7	7	4	4	3	2	1
6	9	8	7	6	6	5	5	5	4	3	1
7	8	8	7	6	6	6	6	5	4	4	3
8	9	6	6	6	6	6	4	4	3	1	1
9	9	8	7	6	5	5	5	4	4	2	2
10	10	10	9	9	8	8	6	4	4	2	1
11	10	10	9	8	7	6	5	4	3	2	1
12	9	9	9	8	8	7	7	3	3	2	2
13	10	9	8	8	6	5	5	4	3	2	1
14	10	10	10	8	5	5	4	4	3	3	3
15	8	8	8	8	8	7	5	4	2	1	1
16	9	9	8	8	5	5	4	3	3	2	1
17	10	9	8	8	7	7	6	5	5	2	1
18	10	9	8	7	7	7	6	6	6	5	4
19	10	10	10	9	9	9	9	9	9	7	7
20	9	9	9	9	7	7	6	6	2	2	2
21	10	9	8	7	6	5	3	2	2	2	1
22	10	9	8	7	6	5	4	4	3	2	1
23	10	9	7	6	5	4	4	4	4	1	1
24	8	8	7	6	6	6	5	4	4	2	1
25	9	9	9	7	7	7	5	5	3	2	2
26	10	9	8	7	7	6	5	4	4	2	1
27	10	8	8	8	7	7	7	6	6	4	1
28	10	9	9	8	8	6	6	6	4	4	2
29	10	10	9	8	8	4	3	3	3	2	1
30	9	9	9	8	7	7	7	6	6	4	4
TOTALS	285	267	249	223	201	182	153	132	110	75	55
AVG WT	9.5	8.9	8.3	7.4	6.7	6.1	5.1	4.4	3.7	2.5	1.8

Research Phase II

Research Phase II was designed to answer Research Question #2, which stated: How are the identified criteria combined to form a decision-making model?

Step #4. With no identified decision criteria being qualified as a "MUST", all eleven criteria were included in the next structured interview as "WANTS". This interview involved the subjective weighting of each criterion by the same group of experts. Weighting was done on a scale of 1 to 10 in accordance with the rules as described in Chapter III, Step #4. The average weight of each criterion was then computed using the simple arithmetic mean of the responses. The results of this process can be seen under Table VII in the "AVG WT" row.

Step #5. Three ALC item managers selected one item each for which acquisition data had been purchased and later used under a competitive bid. These items will be referred to as "High Item Value" items. They consisted of:

Item A1: A twelve-beam cathode Ray Tube used in an imaging system for tactical reconnaissance.

Item A2: An airtight McDonnell-Douglas F-4 Phantom II viewfinder lens.

Item A3: A tailpipe clamp for the Lockheed T-33.

Three ALC item managers also selected one item each for which no acquisition data had been purchased. These items will be referred to as "Low Item Value" items and they consisted of:

Item B1: Production carbon wheels and brakes for the General Dynamics F-16.

Item B2: The ACES II ejection seat.

Item B3: The Aim-9P Sidewinder Missile.

Step #6. The six ALC item managers proceeded to evaluate each of the selected purchase items using the decision criteria that were identified in Research Phase I. Each purchase item was assigned a rating (on a scale of 1 to 10) for each decision criterion based on the rater's judgment of how much the item exhibited the traits of that decision criterion. The rate assigned to each decision criterion was then multiplied by the previously computed subjective weight (See Table VII, "AVG WT") for that criterion. The resulting products were then summed to obtain a "Total Item Value" for each purchase item. The ratings and Total Item Values for each purchase item are shown in Table VIII.

Step #7. The decision points for the model were then calculated by computing the arithmetic mean of each set of Total Item Values. The Mean Item Value associated with the set of "High Item Value" items became the "Go" decision point and the Mean Item Value associated with the set of "Low Item Value" items became the "No Go" decision point. Both decision point values are depicted in Table VIII.

TABLE VIII

Purchase Item Ratings and Total/Mean Item Values

CRITERIA	WT.	ITEM RATINGS A1	A2	A3	B1	B2	B3
Design Stability	9.5	10	10	10	10	9	10
Expected Inv. Life	8.9	10	10	9	9	8	10
Design Complexity	8.3	3	7	9	2	2	2
Cost of Repl.Item	7.4	5	3	8	5	2	4
Antic. Qty of Buy	6.7	9	5	4	8	5	9
Cost of Acq. Data	6.1	7	6	8	1	1	1
Amt of Crit. Matls.	5.1	10	7	8	3	7	6
Orgn/Reg. Reqts	4.4	5	5	8	3	3	2
Time/Pers. Reqts	3.7	4	9	10	10	4	2
Sup. Bus. Solv.	2.5	1	3	10	1	1	1
Amt. Fixed Tooling	1.8	10	8	5	8	7	4
TOTAL ITEM VALUES		457.2	447.3	531.6	370.8	306.5	353.1
MEAN ITEM VALUES		478.7			343.5		

Step #8. In order to infer that there existed a true difference between the decision points, a statistical test for the difference between two means was performed. The test performed was the "Small-Sample Inferences about the Difference Between Two Population Means: Independent Sampling" (See Appendix D). The following computations are the results of the test for a difference between two population means:

H_0: The mean of the "High Item Value" items equals the mean of the "Low Item Value" Items.

H_1: The two means are significantly different.

n = The number of items in each population [3].

x_1 = The "High Item Value" mean [478.7].

x_2 = The "Low Item Value" mean [343.5].

s_1 = Std deviation of the "High Item Values" [46.079].

s_2 = Std deviation of the "Low Item Values" [33.215].

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} = 1613.2552 \qquad (2)$$

$$\text{'t' value} = \frac{(\bar{x}_1 - \bar{x}_2) - 0}{\sqrt{s_p^2 \ (1/n_1 + 1/n_2)}} = 4.1226 \qquad (3)$$

Test 't' value (based on α = .05 significance level = 2.920 and (n-1) degrees of freedom)

Since the calculated 't' value exceeded the test value, the null hypothesis could be rejected. This indicated that there was a significant difference between the "Go" and the "No Go" decision points. This roughly means that the model allows for a meaningful distinction between a decision to purchase acquisition data and a decision to not purchase acquisition data.

Research Question #2 Answered

The identified decision criteria were combined to form a decision-making model that is depicted in Figure 9. See Chapter V for a detailed description of the model's use.

SECTION I			
CRITERIA	WT	X RT	= AMT
1) Design Stability	9.5		
2) Expected Inventory Life	8.9		
3) Complexity of Design	8.3		
4) Cost of the Replenishment Item	7.4		
5) Anticipated Quantity of Buy	6.7		
6) Cost of the Acquisition Data	6.1		
7) Amount of Critical Materials	5.1		
8) Organizational/Regulatory Requirements	4.4		
9) Time/Personnel Requirements	3.7		
10) Original Supplier's Business Solvency	2.5		
11) Amount of Fixed Tooling	1.8		
TOTAL ITEM VALUE (TIV)			

SECTION II
If TIV >= 478.7 . . . . Purchase Acquisition Data
If TIV <= 343.5 . . . . DO NOT Purchase Acquisition Data
If 343.5 <= TIV <= 478.7 . . . . YOUR CHOICE !!!

Figure 9. Decision-Making Model

Research Phase III

Research Phase III was designed to answer Research Question #3 which stated: Does the model accurately determine when acquisition data should be procured and when it should not be procured?

Step #10. To test the model, nine purchase items were randomly selected by the ASD Directorate of Contract Policy and Review. The decision to purchase acquisition data had already been made for the items. Using the developed model, each purchase item was analyzed by one item manager who was familiar with neither the model nor the purchase item. The results of the Item Manager's analysis of the purchase items are shown in Table IX. In Table IX, the symbol "#" represents the final ranking of each criterion as shown in Table VI. In addition, "TIV" stands for "Total Item Value."

The nine purchase items that were selected for analysis and a comparison of the actual purchase decisions with the model's recommended decisions are shown in Table X.

TABLE IX

Ratings and Total Item Values of Purchase Items

#	WT.	ITEM RATINGS								
		A1	A2	A3	A4	A5	A6	A7	A8	A9
1	9.5	8	9	10	9	2	8	1	7	9
2	8.9	9	7	5	9	3	6	4	3	4
3	8.3	7	9	7	7	1	4	4	1	5
4	7.4	8	8	7	7	4	6	5	1	2
5	6.7	7	10	8	9	7	7	5	5	4
6	6.1	8	6	2	5	3	2	2	7	5
7	5.1	10	9	7	10	8	5	7	2	6
8	4.4	10	10	5	10	9	8	8	9	8
9	3.7	7	7	8	6	5	8	7	9	6
10	2.5	3	4	3	8	4	7	2	3	2
11	1.8	7	10	7	6	5	6	5	5	5
TIVs		510.1	529.1	422.6	514.3	266.7	384.7	271.8	284.7	336.7

TABLE X

Purchase Items and Test Results

PURCHASE ITEMS	ACTUAL DECISION	MODEL DECISION
A1. CW 65 Anti-Exposure Suit	BUY	BUY
A2. CW 64 Cold Weather Flight Cover	BUY	BUY
A3. HBU-12/A Aircraft Lap Belt	BUY	CHOICE
A4. HU-55 Aircrew Flight Helmet	BUY	BUY
A5. EW Jamming Assignment Computer	DON'T BUY	DON'T BUY
A6. Information-Digitizing Encoder	BUY	CHOICE
A7. Transmitter-Directing Exciter	DON'T BUY	DON'T BUY
A8. Digital Radio Frequency Memory	DON'T BUY	DON'T BUY
A9. EF-111 Interface Adapters (ATE)	DON'T BUY	DON'T BUY

Step #11. Conclusions about the decision-making model and recommendations for further testing will be outlined in Chapter VI.

Research Question #3 Answered

In testing, the model successfully predicted a decision to purchase acquisition data for seven of nine (77.8%) purchase items. For the other two purchase items, the model's results were not conclusive. For this randomly selected sample of purchase items, automatic use of the model would have duplicated the actual decision in the seven cases where results were conclusive.

Conclusion

This chapter has taken the reader through a step-by-step problem solving and data analysis approach to answer the three Research Questions posed by the researchers. In the end, the researchers developed and tested a heuristic acquisition data decision-making model. The criteria and decision points contained in the model will be discussed in greater detail in the following chapter.

V. The Decision-Making Model

Introduction

This chapter introduces the acquisition data decision-making model developed and tested by the researchers (See Figure 10 for a copy of the final decision-making model). A brief explanation of each of the eleven decision criteria will be presented along with a description of the rating scale for each criterion and how the model is intended to be used.

The Criteria

The acquisition data decision-making model is comprised of eleven general criteria in descending order of importance. Each criteria has an associated weight which reflects the relative importance of that criterion in the decision to purchase or not purchase aquisition data.

Design Stability. There are numerous descriptions of what constitutes design stability. Perhaps the most widely used definition for a stable item is: an item which is baselined for production. In other words, an item which has a design ready to move into production is a stable item. Another definition would be: an item which has had few engineering changes to its configuration.

Expected Inventory Life. Expected Inventory Life is the length of time the item is expected to be used by the military service, not the expected wear life of the item.

ITEM DESCRIPTION ______________________ ORG'N __________

____

____

SECTION I			
CRITERIA	WT	X RT	= AMT
1) Design Stability (Low = 1; High = 10)	9.5		
2) Expected Inventory Life (Low = 1; High = 10)	8.9		
3) Complexity of Design (High = 1; Low = 10)	8.3		
4) Cost of the Replenishment Item (Low = 1; High = 10)	7.4		
5) Anticipated Quantity of Buy (Low = 1; High = 10)	6.7		
6) Cost of the Acquisition Data (High = 1; Low = 10)	6.1		
7) Amount of Critical Materials (High = 1; Low = 10)	5.1		
8) Organizational/Regulatory Requirements (No Push = 1; Strong Push = 10)	4.4		
9) Time/Personnel Requirements (Many = 1; Few = 10)	3.7		
10) Original Supplier's Business Solvency (Good = 1; Poor = 10)	2.5		
11) Amount of Fixed Tooling (Great = 1; Little = 10)	1.8		
TOTAL ITEM VALUE (TIV)			

SECTION II	
If TIV >= 478.7	Purchase Acquisition Data
If TIV <= 343.5	DO NOT Purchase Acquisition Data
If 343.5 <= TIV <= 478.7	YOUR CHOICE !!!

Figure 10. Final Acquisition Data Decision-Making Model

Complexity of Design. Complexity of design can best be defined as the combined outcome of the interaction of the following main determinants:

(1) The number of elements comprising the item,

(2) The attributes of the specified elements of the item,

(3) The number of interactions among the specified elements of the item, and

(4) The degree of organization inherent in the item design (31:79).

Cost of the Replenishment Item. The cost of the replenishment item is the total cost of the item being purchased, including all Life Cycle Costs.

Anticipated Quantity of Buy. Anticipated quantity of buy does not simply reflect the quantity of buy for the immediate contract or initial spares. It reflects the total estimated quantity of buy for this particular item over the entire expected inventory life.

Cost of the Acquisition Data. The cost of the acquisition data is the cost to the Government for purchasing all the necessary data required to build an exact copy of the item or component. In other words, this cost would include not only the cost of the acquisition data package, but those additional costs known as "offsetting costs." These offsetting costs might be purchasing personnel costs, administrative costs, the costs of acquiring proprietary or unlimited rights, or the costs associated with ensuring that the data package is complete and accurate.

Amount of Critical Materials. The amount of critical materials includes critical materials used in the item or component itself, and those used in the manufacturing process.

Organizational/Regulatory Requirements. Organizational/regulatory requirements are a measure of the degree to which higher headquarters, or local Government or base organizations press for the purchasing of acquisition data.

Time/Personnel Requirements. Time/personnel requirements are a reflection of the amount of personnel dedicated to the acquisition data procurement process. This criteria is really a cost effectiveness issue. Are there enough personnel available within the SPO to adequately ensure that the acquisition data to be purchased will be complete and accurate? Do the personnel assigned to the purchasing and evaluation of acquisition data packages have enough time to adequately review those packages?

Original Supplier's Business Solvency. The "Original Supplier's Business Solvency" criteria is an assessment as to the financial and business strength of the firm who originally developed the item or component to be purchased. Does it appear that this firm will be in business with the

Department of Defense for a long time to come, or will he no longer maintain the facilities to produce the item soon after contract performance is complete?

Amount of Fixed Tooling. This criterion requires an assessment as to the amount of fixed tooling needed to produce the item for which we are purchasing acquisition data.

Using the Acquisition Data Decision-Making Model

Rating the Criteria. The first step in using the acquisition data decision-making model is rating each criterion. The user must rate the item for which the Government intends to buy acquisition data against each of the eleven criteria. The rating scale for each criterion is a continuous scale from one to ten based on the degree to which the acquisition item satisfies each criterion. Provided below are characteristics associated with the two extremes of the rating scale for each criterion. Remember, each criterion can be rated as any number along the continuum of one to ten.

Design Stability. If the item has a very low design stability, rate it as a one. If the item has a very high degree of design stability, rate it as a ten.

Expected Inventory Life. If the item being purchased has a low expected inventory life, rate it as a one;

if it has a very high expected inventory life, rate it as a ten. Use other similar items as a basis of comparison for determining high or low expected inventory life.

Complexity of Design. If the item being purchased has a very high design complexity, rate it as a one; if it is very non-complex, rate it as a ten.

Cost of the Replenishment Item. Relative to other items of a similar nature, if this item has a very low life cycle cost, it should be rated as a one. If the item has a relatively high life cycle cost, rate it as a ten.

Amount of Critical Materials. If the item being purchased has a very high content of critical materials, or if many of the materials are very difficult to obtain, rate it as a one; if it has a very low amount of critical materials, rate it as a ten.

Organizational/Regulatory Requirements. If there is very little pressure from higher levels of management to purchase acquisition data from the prime contractor, rate this criterion as a one. If higher management very strongly recommends purchasing acquisition data, rate this criterion as a ten. NOTE: It is often left to the discretion of the Program Manager to make the final determination as to whether or not the data is necessary. If this is the case, rate this criterion as a one if the Program Manager has full authority to make the acquisition data procurement decision.

Time/Personnel Requirements. If in the user's opinion purchasing and evaluating the acquisition data requires a large amount of personnel and time to thoroughly review the data packages, rate this criterion as a one. Moreover, if the time and personnel costs of purchasing the data greatly exceed the cost of the data itself, rate this criterion as a one. In other words, if time/personnel requirements are great, rate this criterion as a one. If the acquisition and evaluation process is minimal and requires only a few personnel to do the job, rate this criterion as a ten.

Original Supplier's Business Solvency. If it appears that the original supplier of the item for which the Government wishes to purchase acquisition data will most likely still have the facilities to build the item, rate this criterion as a one. If it appears that the original supplier's business solvency is not strong, rate this item as a ten.

Amount of Fixed Tooling. If the item for which the Government intends to purchase acquisition data requires a very large amount of fixed tooling in its manufacturing process, rate this criterion as a one. If the item uses very little fixed tooling in its manufacturing process, rate this criterion as a ten.

Calculating the Total Item Value (TIV). Once each criterion is rated from one to ten, the user should multiply the weight for each criterion by the rate just assigned. The product is then placed in the column marked "AMT." The user must then sum all the products to arrive at a TIV.

Determining the Outcome. The final step in using the acquisition data decision-making model is to compare the calculated TIV with the high and low decision points listed under Part II of the model. If the TIV is equal to or greater than 478.7, it is recommended that the decision-maker (user) purchase acquisition data for that item. If the TIV is equal to or less than 343.5, it is recommended that the decision-maker not purchase acquisition data for that item. If the TIV falls between 343.5 and 478.7, it is left to the decision-maker's discretion to purchase or not purchase acquisition data for the item being acquired.

VI. Findings and Recommendations for Future Research

Research Summary

This research effort was undertaken to provide a model which will help determine when it is appropriate to purchase or not purchase acquisition data for a particular item. To accomplish this task, the researchers looked at several popular decision-making techniques and chose the one most appropriate for solving the problem set forth in Chapter I. The researchers chose the technique known as the Kepner-Tregoe approach for problem solving and decision-making.

Because the Kepner-Tregoe approach is mostly used to help select one alternative among many, the researchers had to modify the technique so that it would be useful in situations where alternate courses of action are not always available. This meant that the researchers had to calculate two decision points -- a "Go" (Buy acquisition data) and a "No Go" (Do not buy acquisition data) decision point.

The researchers' plan of attack consisted of breaking the effort down into three major phases. The first phase corresponded with the researchers' first objective, to identify and rank order the factors relevant to the acquisition data purchasing decision. The second phase corresponded with the second research objective, to use the factors from objective 1 to develop a decision-making model. Finally, phase three corresponded with the third research objective, to test the model which was developed.

Research Objective #1

Findings for Objective #1. The researchers used a three step process (See Chapter III, Steps #1 through #3) to achieve their first objective. Through personal interviews and a thorough literature review, the researchers obtained eleven criteria most often used in the acquisition data decision-making process. These criteria were used in the final model (See Chapter V, Figure 10) to determine when it is appropriate to purchase acquisition data for a particular item.

Recommendations for Objective #1. The Phase 1 effort (identifying and ranking criteria) of the final decision-making model was quite strong. The random sampling interview techniques used by the researchers, as well as the efforts of several previous theses, in attempting to identify the criteria relevant to the decision-making process were very fruitful. It is always possible to find "just one more" specific criterion if you interview several data managers, but the criteria identified in this research effort are generic enough to encompass them.

The results of the experts' rankings of the criteria were somewhat surprising. The researchers did not anticipate such a strong agreement among the experts' rankings because both Air Force Systems Command and Air Force Logistics Command personnel were used to rank the items. During their preliminary research under this topic, the researchers found a distinct difference in opinion about what was considered important in the decision to purchase acquisition data. This in itself was not so startling due to the differences in roles played by each command. Air Force Systems Command is concerned with an item before it moves into the operational Air Force, while Air Force Logistics Command is mainly concerned with supporting the item after it is placed in operation.

Nonetheless, most of the experts (80%) ranked "design stability" either first, second or third in importance. The next five criteria -- expected inventory life, complexity of design, cost of the replenishment item, anticipated quantity of buy, and cost of the acquisition data -- were all ranked fairly close in importance. The last five criteria -- amount of critical materials, organizational/regulatory requirements, time/personnel requirements, business solvency, and amount of fixed tooling -- were ranked well below the first six criteria.

It might be worthwhile for an analysis to be performed to determine if there is a significant difference between the opinions of Air Force Systems Command and Air Force Logistics Command personnel. When funding for a program is cut back, the area which most often bears the brunt of the funding reduction is logistics support (spares, initial provisioning, training support, etc.). If we can identify those criteria most pressing to each command, perhaps program managers can be more equitable in their cutbacks.

Research Objective #2

Findings for Objective #2. The researchers' second objective entailed developing a model to assist Program Managers in their decisions concerning the procurement of acquisition data. Chapter V describes in detail each of the criteria found under Phase 1 of this research effort, and it explains how to use the model. The researchers used a six step process (See Chapter III, Steps #4 through #9) to arrive at a working acquisition data decision-making model.

The Kepner-Tregoe approach dictates that each of the criteria found under Phase 1 be weighted on a scale from one to ten. Even though there was a fairly distinct break between the first six and the last five criteria under the experts' rankings of those items, there was a gradual reduction in the weighting of all the criteria. In other words, there was no tremendous difference between the weight of one criterion and the next lower criterion. This gives credence to the criteria as a whole in their importance or usefulness in determining if acquisition data is required.

In addition to weighting the criteria, the researchers had to develop a "Go" and "No Go" decision point for the model. To derive the "Go" decision point, item managers rated items for which acquisition data was purchased and used under a competitive reprocurement. The "No Go" point was derived by item managers rating items for which no data was purchased. The researchers found that it was mostly on sub-assemblies or larger components that the government chose not to purchase acquisition data, while it was smaller, less complex items that the government purchased the acquisition data.

Using the test for the difference between two means described in Appendix D, the researchers found that there indeed existed a significant difference between the "Go" and "No Go" decision points. Had this test proved inconclusive, it would have been meaningless for a Program Manager to use the model for deciding whether or not to purchase acquisition data. By showing that there exists a true difference between the two decision points, the second objective is fulfilled -- the researchers have now arrived at a potentially useful model.

Recommendations for Objective #2. There are several areas of the acquisition data decision-making model which would benefit from further testing. First of all, due to time constraints, the researchers were only able to select three items to develop the "Go" decision point, and three items to develop the "No Go" decision point. Since the two decision points are crucial to the model's success, it would be very beneficial to select a larger sample size of items for which acquisition data was and was not purchased.

In addition, it might be interesting to study the effects on the decision points if similar types of items are selected for both the "Go" and "No Go" points. There may also be a correlation between the type of item selected for evaluation and the value of the decision point. In other words, are there different decision points for different Program Offices?

Another area for further study might be the concept of having only one decision point. If the Total Item Value falls above this point, buy acquisition data. If the Total Item Value falls below this point, do not buy the data. The researcher should investigate the potential lack of flexibility that this approach might present to the decision-maker.

Research Objective #3

Findings for Objective #3. The third objective of the researchers was to test the validity of the model. The researchers' approach was to randomly select purchase items for which a decision has already been made regarding the purchase of acquisition data. The researchers then compared the model's recommended decision with the actual decision made by Program Managers. This objective encompassed Steps #10 and #11 of the research methodology presented in Chapter III.

The researchers selected nine items, and the model accurately predicted seven of the nine items. The remaining two decisions proved inconclusive, for the model recommended the choice be left to the decision-maker.

Recommendations for Objective #3. Before any new model can be used in field operations, it is essential that the model be thoroughly tested. Consequently, this is the area of the researchers' study that requires support. The random sample of purchase items used to test the model was somewhat limited, again due to time constraints. Therefore, the researchers recommend that the bulk of any follow-on work be spent on testing the acquisition data decision-making model.

It needs to be determined if the model holds up under the test of purchase items of various sizes, complexities, design and compositions. It also needs to be determined if the model gives similar recommendations to various types of item, or if the model's accuracy diminishes. Finally, it would be interesting to determine if the model is consistent in its recommendations for items within the same program, or even within the same Program Office.

In order for the model to be useful as a decision-making tool, it must stand the test of all possible combinations of acquisition conditions, program types, and purchase item types. Although the researchers accomplished their final objective of testing the validity of the decision-making model, the strength of the model depends upon the outcome of future tests.

General Observations About the Model

In many respects, the acquisition data decision-making model developed by the researchers is rather unique. Unlike many other Operations Research modeling or decision-making techniques, the Kepner-Tregoe approach does not require quantification of the variables under study. Just glancing at the criteria gives the user an idea that there are many subjective aspects to this model. For example, how does one accurately define "design stability," or "item complexity," or the "original supplier's business solvency?" Ask ten individuals about the same item and you are likely to get ten different opinions.

But that is the advantage of this Kepner-Tregoe approach. Because each of the criteria are weighted, they absorb the subjectivity associated with an opinionated rating system. The weight associated with each criterion is composed of other experts' opinions . . . the weight is simply an average of opinions from experts with twenty years service to experts with four years service.

Therefore, it does not matter if the decision-maker has a limited familiarity with the acquisition data environment. If the decision-maker knows enough about the particular item he is purchasing (we would assume so, or else he should not be in the position to make the decision whether or not acquisition data should be purchased) to have a feel for its design stability, item complexity, and so on, a well-tested model should give strong guidance for a good decision.

In Chapter II, the researchers discussed the acquisition data "time" problem. Briefly stated, this time problem is a situation where defining acquisition data requirements at the onset of a program represents the lowest cost of data to the Government. However, data experts state that the earliest feasible time to define acquisition data requirements is not until after the Physical Configuration Audit.

By eliminating some of the uncertainty surrounding the need for acquisition data, the decision-making tool proposed in this thesis has the potential to significantly reduce the cost of that data. Using the hypothesized model can help reduce costs, for it (1) allows the decision-maker to purchase the data early in the contracting process, and thereby negotiate reasonable data costs when the Government has a stronger bargaining position, and (2) allows the decision-maker to decide not to purchase acquisition data when it is inappropriate to do so.

As mentioned above, the researchers feel that further testing would be beneficial before one attempts to operationalize this model. However, if the model fails this testing, the results of this research effort are still significant, for we now have a complete listing of criteria important to the acquisition data decision-making process. That in itself is a major stride forward to making a better decision. Having eleven criteria instead of just the two or three presently used, brings program and data managers closer to making a decision under certainty rather than making a decision under uncertain conditions.

One final observation which comes from the researchers' contacts with the various "experts" on acquisition data.

The decision-maker will be able to justify purchasing acquisition data, if he so chooses, regardless of the outcome of the acquisition data decision-making model. Although more difficult to do so with the current emphasis on competitive acquisition, the decision-maker will also be able to justify not purchasing acquisition data, if he so chooses.

As with any other decision-making model, this model is simply a tool to be used when the decision-making process becomes too complex. It is not a panacea; nor is it supposed to be a panacea. In the final analysis, the decision-maker must make the decision, not the decision-making model.

Appendix A: The Delphi Technique

Background

The Delphi is an "organized brainstorming and consensus technique which can be used for many problems which defy quantification or preciseness [8:191]."

> Essentially, the delphi is a series of intensive interrogations of each individual expert (by a series of questionnaires) concerning some primary question interspersed with controlled feedback. The procedures are designed to avoid direct confrontation of the experts with one another [27:381-388].

The developers of the Delphi technique (RAND Corp) argue that the procedures are more conducive to independent thought and "allow more gradual formulation to a considered opinion [27:381-382]."

Trying to establish a consensus from within a group can lead to some very significant problems. First of all, the group consensus is "highly influenced, if not determined, by the views of the member of the group who does the most talking . . . [9:3]." A second problem is "noise -- irrelevant or redundant material that obscures the directly relevant material offered by participants [9:3]." A final significant problem is the group pressure placed on individuals to follow the group's consensus, whether it be active or subconscious pressure (9:3).

The Delphi technique was developed to counter these three problem areas. The Delphi method gathers information from and deals "separately with experts who have generally the same specialized capabilities [8:191]." All opinions are recorded separately from one another and then a summary of the results is passed to the group, thereby diminishing the first problem (9:3). It also reduces noise by using controlled feedback which "summarizes relevant opinions given on specific items within the survey [28:27]." And finally, the Delphi method reduces "group pressure" because results are expressed in "terms of a statistical score." Thus, there is no pressure to arrive at a consensus (10:4).

Procedure

The first task under the Delphi Technique is selecting the "experts." The technique "strives to get the [experts] to feel free to give their best inputs by submitting them anonymously, frankly and unfettered by face-to-face meetings [8:191-192]." After they are chosen, the first of what may be several questionnaires is issued. The individuals are to record on the survey instrument their responses regarding a particular set of questions. These responses are then summarized and sent back to the respondees along with a mean response to the item and the interquartile range of responses.

The respondent is then asked to reevaluate his original response now that he has seen the feedback from all respondents. If the second answer lies outside the interquartile range, he is asked to explain his reason for selecting that response. Again, all answers are tabulated and returned to the respondees with a summary of the reasons why the answers outside the interquartile range were chosen. A third round of interviews is performed, thus leading us to a convergence of answers among the experts (10:7).

Appendix B: The Kepner-Tregoe Approach to Decision-Making

Background

The Kepner-Tregoe approach to decision-making is founded on the scientific method of problem-solving. The authors of this heuristic approach to decision-making state that while

> the scientist and the doctor go through elaborate courses of training in order to learn objective methods of using information in the solution of technical problems, . . . the manager, however, who must constantly analyze problems and make decisions, and who, therefore, perhaps more than anyone else needs efficient ways of working with information, has been left to shift for himself. The result is usually . . . a hit-and-miss approach based on a mixture of experience and guesswork [25:40].

The Kepner-Tregoe approach is an "orderly system for processing information, a system in which certain steps follow others in a fixed order [25:40]." It is used to compare several different alternative courses of action. The authors identify seven basic concepts of decision-making:

1. Establish decision objectives

2. Classify the decisions as to importance

3. Develop alternative actions

4. Evaluate alternatives against the established objectives

5. Select tentative decisions (the alternative which best achieves all objectives)

6. Explore the tentative decision for possible future

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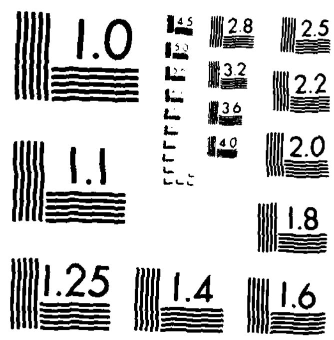

MICROCOPY RESOLUTION TEST CHART
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adverse consequences

7. Control the effects of the final decision by taking other actions to prevent possible adverse consequences from becoming problems, and make sure the actions decided on are carried out (25:46-50).

Procedure

The procedure for accomplishing the Kepner-Tregoe approach follows very closely to the seven basic concepts identified above. First of all, the manager must identify the objectives which he intends to accomplish. It could be an objective which satisfies an organizational goal, or it could be one which will solve a known problem (25:48).

Once all objectives are listed, the manager determines which objectives are "MUSTS" (a requirement which cannot be compromised) and which are "WANTS" (objectives where the manager gets the best possible performance from a decision -- subject to bargaining). The "WANTS" are then rank ordered and weighted from 1 to 10 with 10 being the highest (25:48).

The manager then decides alternate ways of getting the job done, and the alternatives are evaluated against the "MUSTS" and "WANTS." If an alternative does not satisfy all "MUSTS," it is discarded. Each alternative is rated from 1 to 10 against each "WANT" objective, and the rating is multiplied by the weighting for that objective. The amounts for each objective are then summed to obtain a total score for each alternative (25:48-49; 25:196-199).

One or two alternatives with the highest scores are selected as tentative decisions, and the manager attempts to find adverse consequences with each. The adverse consequences are given probabilities of occurring (rated from 1 to 10, with 10 having the greatest probability of occurrence), and they are also rated from 1 to 10 as to the impact of the consequence should it actually occur. The rating is multiplied by the probability, and all values are summed for each alternative. This amount is then subtracted from the score obtained during the selection process, and the alternative with the greatest overall value is the decision which best serves the manager's interest (25:49-50; 25:201-205).

It is important to note that as in any decision-making technique, the final decision to go or not go with a particular alternative rests with the manager, regardless of the value obtained from the model.

Appendix C: The Kendall Coefficient of Concordance: W

Background

The Kendall Coefficient of Concordance was developed as a technique to ascertain the "overall agreement among k sets of rankings [33:229]." This measure has been found quite useful in studies of intertest or interjudge reliability. The coefficient of concordance is "an index of the divergence of the actual agreement shown in the data from the maximum possible (perfect) agreement [33:230]."

Procedure

The first step in performing the Kendall Coefficient of Concordance is to set up a table with the various judges ("experts" in our thesis) along the left-hand column and the items to be ranked (criteria in our thesis) along the top row. The table is then filled with the rankings of each judge for each criterion (See Table XI for an example).

TABLE XI

Ranks Assigned to Acquisition Data Decision Criteria by Ten "Experts"

	Criteria							
	a	b	c	d	e	f	g	h
Expert #1	1	4	8	6	2	3	7	5
Expert #2	3	5	7	6	1	4	2	8
.							.	
.							.	
.							.	
Expert #10	2	4	8	7	1	3	5	6
SUMS	21	43	75	62	15	36	41	69

As you can see from this example, the degree of agreement among the ten experts is reflected by the degree of variance among the eight sums of ranks. "W, the coefficient of concordance, is a function of that degree of variance [33:230-231]."

The following equation is used to calculate W:

$$W = \frac{s}{(1/12)(k\times k)(N^3 - N)} \qquad (5)$$

where: k = the number of "experts" interviewed

N = the number of criteria to be ranked

s = sum of the squares of the observed deviations from the mean of the SUMS

$$s = \sum\left(R_i - \frac{\sum R_i}{N}\right)^2 \qquad (4)$$

In the example above, $s = (21 - 45.25)^2 + (43 - 45.25)^2 + (75 - 45.25)^2 + (62 - 45.25)^2 + (15 - 45.25)^2 + (36 - 45.25)^2 + (41 - 45.25)^2 + (69 - 45.25)^2 = 3341.5$

$$W = \frac{3341.5}{(1/12)(10\times 10)(512 - 8)} = .796 \qquad \left(0 < W < 1\right)$$

A high or significant value of W implies that the experts are applying the same standard in ranking the criteria under study (33:237).

When N is greater than seven, the expression given in the following formula is approximately distributed as Chi Square with N - 1 degrees freedom.

$$\text{Chi-Square} = k(N - 1)W \qquad (6)$$

If the value of Chi-Square as computed from Equation (6) equals or exceeds that shown in the Chi Square table in Appendix E for a particular level of significance and a particular value of df [7], then the "null hypothesis that the k [10] rankings are unrelated may be rejected at that level of significance [33:236]."

Appendix D: Small-Sample Inferences about the Difference Between Two Population Means: Independent Sampling

Background

Often times you want to make inferences about the differences between two populations' means. In order to use this test, you must make the following assumptions:

1. Both sampled populations have relative frequency distributions that are approximately normal;

2. The population variances are equal;

3. The samples are randomly and independently selected from the populations.

Procedure

STEP #1: Calculate the mean for samples 1 (high item value) and sample 2 (low item value), the standard deviations for samples 1 and 2, and the pooled estimator, s_p^2, using the following equation:

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \qquad (2)$$

STEP #2: Calculate the t-statistic using the following equation:

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - 0}{\sqrt{s_p^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \qquad (3)$$

STEP #3: If the test statistic is greater than the t value in Appendix E at $(n_1 + n_2 - 2)$ df and an appropriate level of significance, reject the Null Hypothesis that there is no difference between the two decision points (7:340).

Appendix E: Abbreviated Chi-Square and Student's t-Tables

TABLE XII

Chi-Square Table

DEGREES OF FREEDOM	LEVEL OF SIGNIFICANCE .100	.050	.025	.010	.005
5	9.23635	11.0705	12.8325	15.0863	16.7496
6	10.6446	12.5916	14.4494	16.8119	18.5476
7	12.0170	14.0671	16.0128	18.4753	20.2777
8	13.3616	15.5073	17.5346	20.0902	21.9550
9	14.6837	16.9190	19.0228	21.6660	23.5893
10	15.9871	18.3070	20.4831	23.2093	25.1882
11	17.2750	19.6751	21.9200	24.7250	26.7569
12	18.5494	21.0261	23.3367	26.2170	28.2995
13	19.8119	22.3621	24.7356	27.6883	29.8194
14	21.0642	23.6848	26.1190	29.1413	31.3193

Source: (7:899)

TABLE XIII

Student's t-Table

DEGREES OF FREEDOM	LEVEL OF SIGNIFICANCE .100	.050	.025	.010	.005
1	3.078	6.314	12.706	31.821	63.657
2	1.886	2.920	4.303	6.965	9.925
3	1.638	2.353	3.182	4.541	5.841
4	1.533	2.132	2.776	3.747	4.604
5	1.476	2.015	2.571	3.365	4.032
6	1.440	1.943	2.447	3.143	3.707
7	1.415	1.895	2.365	2.998	3.499
8	1.397	1.860	2.306	2.896	3.355
9	1.383	1.833	2.262	2.821	3.250
10	1.372	1.812	2.228	2.764	3.169

Source: (7:887)

Appendix F: Structured Interview Questionnaires

Survey #1

INSTRUCTIONS:

The following questionnaire contains a list of criteria used to determine if acquisition data should be purchased for a particular item. We ask that you circle the number that most closely corresponds to your opinion as to whether or not the criterion is important. If you feel that the criterion is of little importance in determining whether or not acquisition data should be purchased, circle a zero. If the criterion is somewhat desirable, circle a one, and so on. If you rate a criterion as a zero or a five, please comment as to why you chose this rating. Question #12, Part II, allows you to add any further criteria you feel may be appropriate.

We also ask that you determine if a criterion should be a "MUST" or a "WANT". A "MUST" criterion is one which, in your opinion, absolutely must be present before acquisition data is to be purchased. If this criterion does not exist, the Government may not purchase the acquisition data. A "WANT" criterion is one which is desirable, but it is not absolutely necessary. Please check the appropriate box below each criterion. In addition, certain questions will ask for your opinion as to a criterion's definition. Please be as succinct as possible in your response.

Finally, Part III requests you to rank each criterion from most important to least important (A rank of "1" is most important). When ranking the criteria, you may have ties between items. If so, continue with the rank the next criteria would have had if there were no ties. For example, if you had to rank the five items listed below and you felt that two were equally important, your ranking might appear as follows:

Criterion	Rank
1. Design stability	5
2. Cost of the data	2
3. Complexity of design	1
4. Regulatory requirements	2
5. Expected inventory life	4

Include in the ranking any item that you added in question # 12 under Part II. You may use the blank spaces to add these criteria.

Thank you very much for your time and expertise.

PART I -- BACKGROUND

A. Position of the Individual (Job Title, Organization or Office Symbol)

B. Experience in your present job as well as total Government time.

PART II -- SURVEY QUESTIONS

A. Does the cost of the replenishment item have an impact on your decision to purchase acquisition data?

	MUST [ ]		WANT [ ]		
0	1	2	3	4	5
Low Importance/ No Influence	Desirable		Important		Vital

COMMENTS:

B. Does the design stability of the item based on the number of ECPs, point in time in the acquisition process, or the maturity of technology influence your decision? What would be your definition of design stability?

	MUST [ ]		WANT [ ]		
0	1	2	3	4	5
Low Importance/ No Influence	Desirable		Important		Vital

COMMENTS:

C. Does the expected life of the item in the inventory influence your decision to purchase acquisition data? How long or short must the time be?

	MUST [ ]		WANT [ ]		
0	1	2	3	4	5
Low Importance/ No Influence	Desirable		Important		Vital

COMMENTS:

D. Does the purchase cost of the acquisition data have an influence on your decision? What dollar ranges are applicable?

	MUST [ ]		WANT [ ]		
0	1	2	3	4	5
Low Importance/ No Influence	Desirable		Important		Vital

COMMENTS:

E. What are your organizational/regulatory requirements to purchase competitively whenever possible?

	MUST [ ]		WANT [ ]		
0	1	2	3	4	5
Low Importance/ No Influence	Desirable		Important		Vital

COMMENTS:

F. Does the possibility that the original supplier may go out of business affect your decision? On what do you base your decision? What probability of the vendor going out of business do you consider acceptable?

MUST [ ] WANT [ ]

0	1	2	3	4	5
Low Importance/ No Influence	Desirable		Important		Vital

COMMENTS:

G. Does the amount of fixed tooling required for the item influence your decision? What factors do you consider in evaluating the amount of tooling that exists?

MUST [ ] WANT [ ]

0	1	2	3	4	5
Low Importance/ No Influence	Desirable		Important		Vital

COMMENTS:

H. Does the anticipated quantity of the buy influence your decision? What quantity level is considered important?

MUST [ ] WANT [ ]

0	1	2	3	4	5
Low Importance/ No Influence	Desirable		Important		Vital

COMMENTS:

I. Does the amount of critical materials required for the item influence your decision? What is your definition of too much or too little critical materials?

MUST [ ] WANT [ ]

0	1	2	3	4	5
Low Importance/ No Influence	Desirable		Important		Vital

COMMENTS:

J. Does cost effectiveness (time and personnel requirements within your organization) enter into your decision to purchase acquisition data? What are these considerations?

MUST [ ] WANT [ ]

0	1	2	3	4	5
Low Importance/ No Influence	Desirable		Important		Vital

COMMENTS:

K. Does the complexity of the design affect your decision? What criteria do you use to define a complex item?

MUST [ ] WANT [ ]

0	1	2	3	4	5
Low Importance/ No Influence	Desirable		Important		Vital

COMMENTS:

L. Are there other criteria that you consider important in your decision to purchase acquisition data which have not already been covered? If so, what are they?

	MUST [ ]		WANT [ ]		
0	1	2	3	4	5
Low Importance/ No Influence	Desirable		Important		Vital

COMMENTS:

PART III -- RANKING THE CRITERIA

Please rank the following criteria in order of importance (A ranking of "1" is most important). There may be ties.

	Criteria	Rank
A.	Cost of the replenishment item	______
B.	Design stability	______
C.	Expected inventory life	______
D.	Cost of the acquisition data	______
E.	Organizational/Regulatory requirements	______
F.	Original supplier's business solvency	______
G.	Amount of fixed tooling	______
H.	Anticipated quantity of the buy	______
I.	Amount of critical materials	______
J.	Time/personnel reqrmts. (Cost effectiveness)	______
K.	Complexity of design	______
L.	______________________________	______
M.	______________________________	______
N.	______________________________	______
O.	______________________________	______

Survey #2

Listed below are eleven criteria used by data personnel and program managers when deciding whether or not to purchase acquisition data. These criteria are listed in order of importance (#1 is most important; #11 is least important) based on the first set of interviews with acquisition data personnel.

We request that you now look at each criterion individually and weight each from one to ten, with a weight of one meaning that the criterion is relatively unimportant in deciding whether to purchase acquisition data, and ten meaning that the criterion is extremely important. DO NOT judge one criterion against another!

IMPORTANT !!!

You may not give a criterion a higher weight than the weight given to the previous criterion. For example, if you give criterion #1, Design Stability, a weight of 9, you may give criterion #2, Expected Inventory Life, a weight of 9 or less. Criterion #1 need not be weighted as a ten. Nor need you weight criterion #11 as a one. A sample weighting is provided for easier understanding:

NUM	CRITERIA	WEIGHT
1	Design Stability	9
2	Expected Inventory Life	7
3	Complexity of Design	7
4	Cost of the Replenishment Item	6
.	.	.
.	.	.
.	.	.
10	Original Supplier's Business Solvency	2
11	Amount of Fixed Tooling	2

NUM	CRITERIA	WEIGHT
1	Design Stability	______
2	Expected Inventory Life	______
3	Complexity of Design	______
4	Cost of the Replenishment Item	______
5	Anticipated Quantity of the Buy	______
6	Cost of the Acquisition Data	______
7	Amount of Critical Materials	______
8	Organizational/Regulatory Requirements	______
9	Time/Personnel Requirements (Cost Effectiveness)	______
10	Original Supplier's Business Solvency	______
11	Amount of Fixed Tooling	______

Appendix G: Procurement Method Codes and Suffix Codes

Procurement Method Code	Explanation
0	Not established.
1	Items screened and found to be already competitive.
2	Items screened and determined for the first time to be suitable for competitive procurement. A replenishment item will be included in this group only when the identification of PMC 2 is supported by the procurement history of the item, The alternative identification is PMC 1.
3	Items screened and found to be procured directly from the actual manufacturer or vendor, including a prime contractor who is the actual manufacturer.
4	Items screened and determined for the first time to be suitable for direct purchase from the actual manufacturer or vendor rather than the original prime contractor for the end items which these parts support. A replenishment item will be included in this group only when the identification as PMC 4 is supported by the procurement history of the item. The alternative identification is PMC 3.
5	Items screened and determined not suitable for competitive procurement or direct purchase and which, therefore, continue to be procured from a prime contractor who is not the actual manufacturer.

Procurement Method Suffix Code	Explanation
0	Not established.
A	Government's rights in data questionable.
B	Source control.

Procurement Method Suffix Code	Explanation
C	Procurement from approved source.
D	The data not available.
E	Status can be improved.
F	This item is phased provisioning.
G	Data is technically suitable and legally clear.
H	Inadequate data.
J	Restricted to the prime contractor.
K	Produced from class 1A castings.
L	Low dollar value of procurement.
M	Master or coordinated tooling.
N	Requires special test.
P	Rights to use data legally unavailable.
Q	Requires exceptional unique manufacturing processes.
R	Rights to use data restricted.
S	Security classification.
T	Qualified Products List (QPL).
U	This item is uneconomical to compete.
V	High reliability part.
W	Parts may be procured by the method indicated by the PMC if military or adopted industry specifications are substituted for the contractor's data which are subject to limited use rights.
Y	Design unstable.
Z	Necessary to ensure standardization and interchangeability.

Appendix H: Selected Experts' Comments on the Decision Criteria

1. Design Stability:

- A stable design is achieved whenever the item achieves all of the requirements specified in the Part I & II specifications.

- A stable design can never really be achieved. It is only stable in relative terms.

- A stable design occurs when the item is baselined for production.

2. Expected Inventory Life:

- Anything expected to be replaced in 4 years or less should be supported by the contractor.

- We us a rough estimate of 7 years in the inventory as a guide.

- To purchase data the item should be in the inventory at least 3 years after the production line stops.

- Approximately 5 years.

3. Complexity of Design:

- If the Air Force does not have the capability to maintain the item because of complexity a data package is useless.

- You cannot define or estimate "complex".

- With highly complex items it may be impossible to use a data package to procure from another source because the complexity of the data keeps the government from validating its completeness.

- We use a "guesstimate" as to item complexity.

4. Cost of the Replenishment Item:

- When purchasing data cost is always a concern.

- From a configuration management viewpoint, the cost of the item is not important, if AFLC wants the data we put it on the contract.

5. Anticipated Quantity of the Buy:

- Small quantities do not justify acquisition data.

- There is a trade-off between cost and the number and use of the item.

- The purchase of the appropriate data is independent of the number of items.

- Especially important with large, complex, costly items the Air Force will need the same data to support one item as 1000 of the items.

6. Cost of the Acquisition Data:

- An excessively high cost may preclude purchase, but "excessively high" is a function of the type data.

- Anything over 10% of the cost of the item is too much to pay for the data.

- The cost of the data should not exceed the cost of redesigning the item.

- As a rule, data cost should not exceed 40% of the overall contract price.

7. Amount of Critical Materials:

- No comments were received concerning this criterion.

8. Organizational/Regulatory Requirements:

- Competition is in, sole source is out.

- Competition is required to the maximum extent.

9. Time/Personnel Requirements (Cost Effectiveness):

- Unfortunately, a lack of people sometimes forces us to not purchase data.

- Not a factor, if data is needed it is bought.

- If data is essential it is purchased.

10. Original Supplier's Business Solvency:

- Any business that passes a pre-award survey is OK.

- This is a critical factor in the decision.

- This probability is hard to determine.

11. Amount of Fixed Tooling:

    - Fixture peculiarity and adaptability are major considerations.

    - Not a relevant factor.

    - A manufacturing concern, not a factor in data procurement.

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VITA

Captain David B. Filippi was born on 8 May 1958 in Vineland, New Jersey. After graduating from Sacred Heart High School in 1976, he attended the United States Air Force Academy, where he earned a Bachelor of Science Degree in History. He was commissioned in May 1980, and his first assignment was L.G. Hanscom Field near Boston, MA. As a Contract Negotiator, Captain Filippi spent two years in Research and Development and one year in the Directorate for Strategic Systems at the MITRE Corp. Captain Filippi was selected for, and attended the Air Force Institute of Technology in May, 1983.

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Despite a variety of regulations and directives on the subject of acquisition data, there are currently no published criteria which will aid Program Managers in their decision to purchase acquisition data for a particular item. This research effort proposes a heuristic decision-making model which will aid Program Managers or Data Managers in their acquisition data purchasing decisions.

The researchers first identified, through a literature search and a series of personal interviews, eleven criteria relevant to the acquisition data purchasing decision. These criteria were then ranked and weighted by acquisition data experts using a second set of personal interviews.

By rating items for which acquisition data was purchased and later used in a competitive reprocurement, and items for which no acquisition data was purchased, the researchers developed two decision points for their model. These two points dictate whether or not the model's user should purchase acquisition data for the item being rated.

The researchers tested the model by randomly selecting items for which a decision has already been made to purchase or not purchase the acquisition data. Each item was rated using the decision-making model and the model's recommended decisions were compared to the actual decisions made. This test procedure resulted in a 77.8% success rate where the model accurately predicted the actual decision made by the Program Manager.

The researchers recommended that further tests be performed to determine the ability of the model to predict various combinations of acquisition conditions, program types and purchase item types.

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