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REVIEW OF FACTORS IMPACTING  
COST BENEFIT ANALYSIS (CBA)  
FOR IMPLEMENTING IMPROVEMENTS  
TO THE AIR FORCE TECHNICAL  
ORDER SYSTEM

THESIS

Susan J. Bergin, Lieutenant, USAF

Terry A. Parsons, Captain, USAF

AFIT/GLM/LAS/94S-2

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DEPARTMENT OF THE AIR FORCE  
AIR UNIVERSITY

**AIR FORCE INSTITUTE OF TECHNOLOGY**

Wright-Patterson Air Force Base, Ohio



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REVIEW OF FACTORS IMPACTING COST BENEFIT ANALYSIS (CBA)  
FOR IMPLEMENTING  
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THESIS

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

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September 1994

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## Preface

The purpose of this thesis was to formulate a Cost Benefit Analysis method to be used when deciding which format of Technical Orders should be purchased for a system or program. Due to shrinking Department of Defense budgets, Program Managers required a standardized format to evaluate costs and benefits of the three Technical Order formats: paper, computerized and automated. This analysis is general in nature; therefore, it can be applied to a large variety of programs with minimal change.

In completing this research, we received invaluable assistance and support from several individuals. We would like to thank our advisors, Dr. Norman Ware and Prof. Arthur Munguia, for their excellent guidance and patience throughout the thesis process. We would also like to thank Mr. Clyde Chapman for all of the information he provided us and for validating the processes we used. Thank you to Major David Christensen for allowing us to borrow his *Expert Choice* software and for acting as an additional advisor and reader. We would also like to thank Tammy Parsons for her support and patience during this research effort. Finally, we would like to thank all the many individuals who took time out of their busy schedules to participate in the interview process.

Susan J. Bergin

Terry A. Parsons

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### Abstract

This research focused on developing a Cost Benefit Analysis process for Program Managers to implement when deciding what technical order format--paper, computerized or automated--to purchase. Factors which determined the outcome are costs (life cycle cost considering technical order format); qualitative issues (characteristics which are benefits of a technical order format); and system responsiveness (time required to develop or modify a technical order in each format).

A literature review revealed problems with the paper technical order format, management infrastructure, quantitative cost estimates for different formats, and different techniques which could be used for a cost benefit analysis. Structured interviews were used to gather, from functional experts, subjective data and historical data about technical orders. The data collected was then used in one of three measurement techniques: 1) a simulation model to estimate the amount of time required to develop and modify each technical order format; 2) a life cycle cost analysis spreadsheet to evaluate the cost of each format; or 3) an analytical hierarchy to determine which technical order format is the best. On the basis of the estimations and assumptions made for this analysis, the research determined that the automated technical order format is the best format.

REVIEW OF FACTORS IMPACTING COST BENEFIT ANALYSIS (CBA)  
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IMPROVEMENTS TO THE AIR FORCE TECHNICAL ORDER SYSTEM

I. Introduction

**Definition of Problem**

The shrinking Department of Defense (DOD) budget has caused DOD acquisition and logistics communities to look for innovative ideas to make weapon system acquisition and life cycle support more cost efficient. Technical Orders (TO) are a major portion of the total life cycle cost of a weapon system. Today's weapon systems are becoming increasingly more difficult to buy and support because of leading edge technology. As a result, the quantities and costs of technical orders are increasing at an alarming rate. DOD needed a strategy to control the changes to the acquisition and logistic support processes. Accordingly, Continuous Acquisition and Life-cycle Support (CALs) is a DOD and industry strategy to streamline the processes for weapon system acquisition and logistical support.

CALS is a strategy to transition from paper intensive acquisition and logistic processes to a highly automated and integrated mode of operation for the weapon systems of the 1990s. It focuses on the generation, management, maintenance, distribution and use of, as well as access to, technical orders. CALS will eliminate the development of duplicate data and will also facilitate data integration,

exchange, and access among government and industry maintained databases.

DOD Instruction 5000.2 requires that all Program Managers perform a cost benefit analysis to determine if conversion to CALS initiatives is cost effective for their program. However, over the past eight years, many Air Force agencies have implemented CALS standards on their technical order systems, without first determining if implementation was cost effective. The Air Force CALS office and System Program Offices (SPOs) are interested in determining how cost efficient Technical Order (TO) improvements have been since initial implementation of CALS initiatives in 1985.

#### **Purpose of Research**

The purpose of this research was to develop a cost-benefit analysis tool for decision maker's to use when choosing among alternative TO formats: paper, computerized, and automated. Air Force Program Managers (PMs) could utilize this tool to determine if computerization or automation of their weapon system TO's, in accordance with CALS initiatives, is cost effective. To accomplish this, research was conducted to answer the following investigative questions about Continuous Acquisition Life-cycle Support (CALS) and Technical Orders (TOs):

- 1) What life-cycle costs, quantitative and qualitative, are associated with the

computerization and automation of the Air Force TO process?

2) What are the benefits, quantitative and qualitative, associated with the computerization and automation of the Air Force TO process?

3) What CBA approach is most appropriate for assessing the economic consequences of computerization and automation of the Air Force TO process?

### **Research Techniques**

The research employed several different techniques to address the investigative questions. First a comprehensive literature review was conducted to set a baseline for this thesis effort. Once a baseline was established, the literature review and interviews of TO functional experts were used to answer investigative questions 1 and 2. A combination of simulation modeling, life cycle cost analysis, interviews, and *Expert Choice* software was used to answer investigative question 3. This research is limited to analyzing cost-benefit analysis methodologies for the Air Force Technical Orders, which are a part of the total acquisition and logistic support systems affected by CALS..

For this research, 'Paper TOs' are defined as a technical order provided and used in its original paper format. A 'Computerized TO' is simply a paper technical order which has been formatted into computer files. An 'Automated TO' is a technical order which has been placed into a database which can be manipulated. These terms will

be used throughout this paper and will be key in defining the findings of our research.

## **Background**

**About the Acronym 'CALs'.** The acronym 'CALs' entered the lexicon of the Department of Defense (DOD) in the form of a recommendation by a 1984 task force that studied ways to improve logistics support processes for weapon systems. At its introduction, 'CALs' was an acronym for 'Computer-Aided Logistics Support.' However, efforts to implement the CALs strategies over time revealed that the term 'Computer-Aided Logistics Support' was much too limited to encompass the changes contemplated by the 1984 task force. Consequently, in 1988, 'Computer Aided Logistic Support' was replaced with 'Computer-aided Acquisition and Logistics Support'. In 1993, Computer-aided Acquisition and Logistic Support was again replaced by 'Continuous Acquisition and Life-cycle Support' as the meaning of the acronym 'CALs'. The changes reflected a new emphasis on continuous process improvement and life cycle support. For clarity, this thesis will use 'CALs\*' as the acronym for 'Computer Aided Logistics Support', 'CALs\*\*' as the acronym for 'Computer-aided Acquisition and Logistic Support', and 'CALs' as the acronym for 'Continuous Acquisition and Life-cycle Support'.

In June 1985, the Joint Industry/DOD Task Force issued a five volume report (IDA R-285) which presented the

strategy to transition weapon systems support processes from a paper to an automated environment. This report, a direct result of the growing complexity of modern weapon system support, initiated the CALS\* program. CALS\* required new weapon system technical orders (TOs), engineering drawings, and other forms of acquisition data to be developed, by contractors, in a computerized format and delivered to DOD buying activities. The intent was to save both time and money by making use of modern computer technology to alleviate the burden of supporting paper processes.

In an effort to be the first to implement DOD policy, each branch of the service implemented its own version of the DOD guidance, resulting in significantly different and incompatible systems. On 5 August 1988, the Deputy Secretary of Defense issued the MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS AND DIRECTOR, DEFENSE LOGISTICS AGENCY, Subject: Computer-aided Acquisition and Logistics Support (CALs). This memorandum directed the use of CALs\*\* standards to ensure compatibility within DOD components and contractor data bases. Then, in 1991, the DOD created a joint military program office to implement CALs\*\* throughout the DOD by creating policy, specifying a standard architecture, and managing and controlling resources. This joint program office was designated the Joint Computer-aided Acquisition and Logistic Support (JCALS) program. In August 1993, the CALs\*\* program name was changed to 'Continuous Acquisition and Life-cycle Support (CALs).'



The history of the CALS program indicates that computer technology is in a very fluid environment. Leading edge technology is very expensive and can become outdated and of little value in a short period of time. CALS has changed numerous times since its beginning in 1985. The propensity for change must be considered when designing new automated computer systems; these new systems must incorporate flexibility. Because of their universal applications, CALS standards are great ideas which have the potential to revolutionize the military acquisition and logistics system. The next section discusses the changes in the system and system name.

**Technical Order Management System.** This section provides an overview of recent implementation of CALS strategies to the Air Force Technical Order System (AFTOS). It also includes a discussion on AFTOS, Air Force Technical Order Management System (AFTOMS), Joint Uniformed Services Technical Information System (JUSTIS), and Joint Continuous Acquisition and Life-cycle Support (JCALS).

AFTOS was the Air Force's TO management system until the late 1980's, but it was criticized for being highly ineffective and inefficient. The system was designed in the 1940's and it was insufficiently updated to make use of current computer technology, and was also paper intensive throughout the entire life cycle of a system. Under AFTOS, TO management was divided, according to weapon system, among six different centers. The increasing complexity of weapon

systems and the growing number of TOs have put a strain on the processes required for system support. CALS is a DOD and industry strategy developed to automate and streamline acquisition and life cycle support.

To implement the CALS strategy, in 1988 the Air Force proposed the Air Force Technical Order Management System (AFTOMS) which streamlined TO management. AFTOMS was replaced by the JUSTIS program in 1990; subsequently, JUSTIS was replaced with the JCALS program in 1991. JCALS retained most of the functional management structure established by AFTOMS. Its main emphasis is on the standardization of the TO management policy throughout each of the DOD branches.

JCALs is the streamlined TO management system of the 1990's. It changed the management structure from a system in which six different centers managed different parts of a weapon system to a four-tier hierarchy. The top of this hierarchy, The Central Technical Order Agency (CTOA), is responsible for overall management of the Air Force TO system. The second tier, Regional Centers (RC), is responsible for acquiring and distributing specific TOs. Each RC comprises a number of Weapon System and Component Tech Order Centers (TOCs). The component TOCs will eliminate the duplication of effort by each weapon system managing its own TOs for components (1:2-5). The third tier are data centers or libraries located at each operating base. The fourth tier, Work Areas, will receive TOs in

digital form via base libraries (See Figure 1 for functional flow of information).

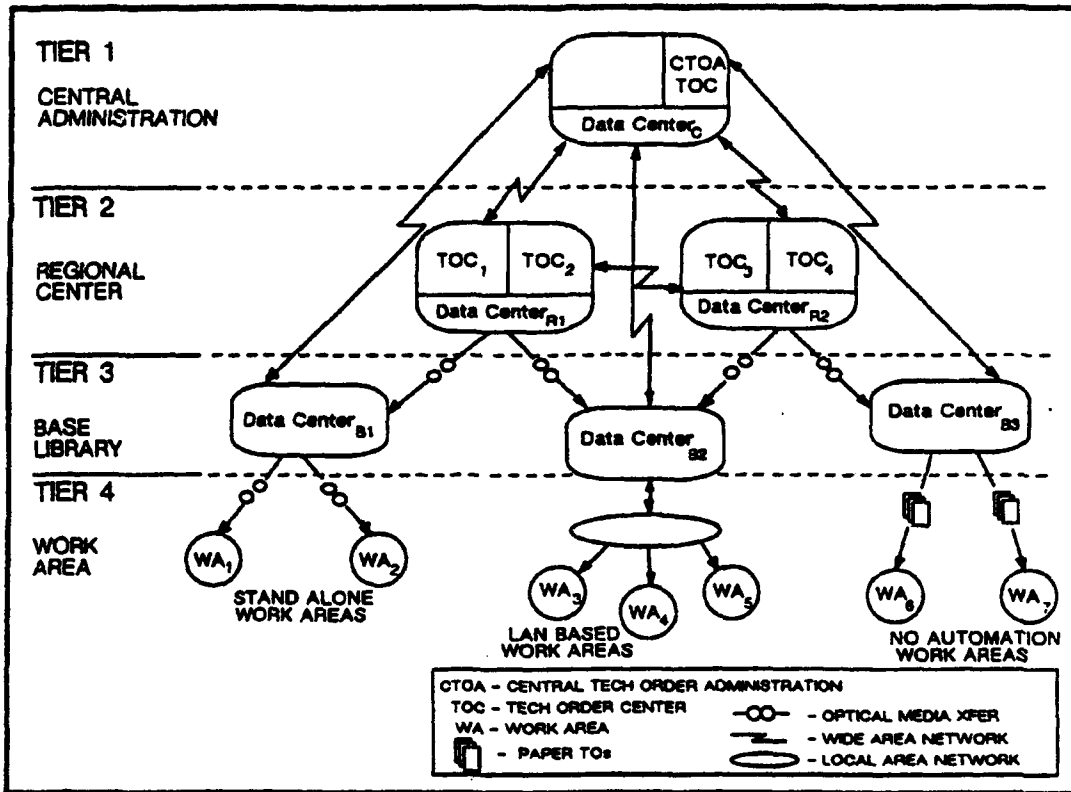


Figure 1: JCALS Functional Flow of Information (1:2-6)

To accomplish its mission, JCALS utilizes paper and digital TO products (Types A, B and C explained in Chapter II). Under JCALS, paper TOs are to be converted to digital format whenever it is economically advantageous to do so. To aide in conversion, JCALS will incorporate Integrated Electronic Technical Manuals (IETMs) as the technology develops. IETMs depend largely on new technologies and standards such as Standardized General Mark-Up Language (SGML).

**Key Technology.** Standardized General Markup Language (SGML) is the international standard being developed for

CALS implementation of IETMs. SGML utilizes tags to mark blocks of text that make up a mini-database. To utilize this powerful new technology, technical writers need to change the way they write. Instead of concentrating on format, writers must tag information or procedures for a specific subject so it can be used many times without rewriting the procedure or information.

Software based on the SGML standard has been developed for inputting, as well as converting, information into SGML format. The two key international SGML standards, Document Style Semantics and Specification Language (DSSSL) and Standard Page Description Language (SPDL), are currently in draft and will be completed in the near future. JCALS stands ready to incorporate these standards when they are completed.

### **Thesis Overview**

Chapter II, Literature Review, presents the history of CALS and the Air Force TO Management System, and discusses capital budgeting and cost-benefit analysis (CBA) processes and how these processes can be applied to an Air Force TO format decision.

Chapter III, Methodology, contains a description of the analysis techniques used in this study. Structured interviews were conducted with functional experts from

System Program Offices (SPOs) and Air Logistic Centers (ALCs).

Chapter IV, Analysis and Findings, is the analysis of the literature review and structured interviews. A structured interview was developed to determine benefits or "qualitative issues" for each TO format. A computer simulation model was developed from the information obtained during the literature review and structured interviews. Simulation modeling was used to analyze the TO "system responsiveness" of each TO format. A spread sheet was developed to provide "cost" data for each TO format. Appendix 8 lists the assumptions made to develop the Life Cycle Cost Analysis (LCCA). *Expert Choice* software, which utilizes Saaty's Analytical Hierarchy Process (AHP), was used to evaluate quantitative and qualitative costs and benefits. The three criteria evaluated for this CBA were qualitative issues, cost, and system responsiveness.

Chapter V, Conclusions and Recommendations, contains conclusions drawn from the data and recommendations based on the analysis results. In addition, Chapter V presents recommendations for future research.

## II. Literature Review

### Introduction

This chapter 1) summarizes the Continuous Acquisition Life-cycle Support (CALs) history; 2) compares the processes for developing paper and digital Technical Orders; 3) describes the structure of and recent changes to the Air Force TO system; 4) presents a key international standard required for IETMs; 5) analyzes the capital budgeting process; and 6) presents various accepted approaches to performing Cost Benefit Analyses (CBA).

### CALS History

In 1984, the Institute for Defense Analysis conducted a study of new computer technology applications to improve the logistics support process. This task force made the following recommendations: 1) change from a paper intensive to an automated logistical and technical information system; and 2) acquire and distribute logistics and technical information in computerized format for new weapon systems (2:4). In September of 1985, the Deputy Secretary of Defense issued a memorandum which approved the transition from paper to automated weapon system support processes. This memorandum initiated the Computer-Aided Logistics Support (CALs\*) program.

In August 1988, the Deputy Secretary of Defense issued another memorandum which directed the use of CALS\*\* standards. According to DODI 5000.2:

Technical data that are required as deliverables, including technical manuals, engineering data, and logistics support analysis data, should be required to be prepared and delivered in digital form unless clear convincing analysis shows this not to be cost-effective when assessed across the life-cycle.  
(3:6-N-3)

The analysis is required if the acquisition officials wish to deviate from the new policy of obtaining digital acquisition and logistics support data. Therefore, it is possible, but not advisable, for an organization to implement CALS without conducting an analysis.

The CALS\* program name was changed to Computer-aided Acquisition and Logistic Support (CALC\*\*) to emphasize acquisition involvement. DOD created a joint office, composed of the Defense Logistics Agency and each branch of the military, to standardize CALS initiatives. This joint office was named Joint Computer-aided Acquisition and Logistics Support (JCALS\*\*). The Army was appointed as the lead service to organize a single approach to standardizing computer hardware and software for DOD purposes.

In August of 1993, the CALS\*\* program name was again changed to Continuous Acquisition and Life-cycle Support (CALC) to reflect the new emphasis on continuous improvement as advocated by Total Quality Management (TQM). The word logistics was deleted because it was a term closely related

to the military support system. CALS is now an industry wide movement involving more than just the military community. The term acquisition, within the CALS definition, refers to smart ways of acquiring data so it can be used efficiently (4:44). In addition to the CALS name change, JCALS was updated to Joint Continuous Acquisition Life-cycle Support; this mirrored the CALS change.

The government has taken the lead to develop and organize CALS standards for industry. The computer environment is so fluid that the government must take the lead and assume the financial risks that are prevalent in the early stages of implementation. These risks are offset by the enormous amount of savings the government may realize in the future.

The CALS standards have grown to encompass the entire acquisition and logistic processes affecting all DOD and government contracts. The Defense Department has committed more than \$5.2 billion to current or planned CALS projects (5:50). Although CALS was originally intended to improve military logistics systems, it has grown into a national, as well as international, movement to interchange data (6:24). This movement, a key factor in the digital revolution, has a potential impact equivalent to the Agricultural or Industrial Revolutions (7:12). CALS has developed into a paradigm. CALS standards are a set of rules that do two things: they establish boundaries and they direct behavior inside those boundaries (8:15).



## **Paper Versus Digital**

These two words represent opposite ends of the spectrum when it comes to acquisition and logistic support systems. As weapons become increasingly more sophisticated, the quantity and price per page for technical orders and engineering drawings increase. Simply transforming this information into computerized form will reduce the volumes of paper, but it does not solve the problems of the TO system (9:17). The current TO system is slow, inefficient, and costly due to duplication of effort. For instance, Logistics Support Analysis (LSA) is used in the acquisition process to design and evaluate a new weapon system. LSA is also used to produce technical manuals, but the LSA record must be rewritten for use as TO's. The process duplicates effort because the LSA was not designed to efficiently feed information into TO's. The solution involves gearing the LSA to a process of building a database of technical manuals by automation (10:4). In other words, write once and use many times.

During the transition period from paper to digital manuals, there exists three types of technical manuals. Type A manuals are paper based manuals, and Type B manuals are digital representations, with page orientation, of the paper manuals. A Type C manual is an Interactive Electronic Technical Manual (IETM) that utilizes data base search techniques to search the digital manuals. Both Type B and Type C manuals use the SGML standard for tagging documents.

However, Type C manuals are significantly different from Type A or B. They have no page orientation and the user must rely entirely upon data base search techniques (11:42).

### **Deficiencies of Paper TOs**

The Institute for Defense Analysis highlighted numerous problems with paper technical orders. As was stated above, as weapons become increasingly more sophisticated, the quantity and price per page for technical orders increase. For example, a C-5, which was purchased in the 1960's, required 600,000 pages of support documents costing \$95 per page, while the B-1B, purchased in 1980's, required 1,200,000 pages of documents at a cost of nearly \$1,000 per page (1:D-2).

The services manage hundreds of thousands of documents and millions of pages of information which require over 20 million cubic feet of storage space to house. Additionally, more than \$10 million per year is spent on postage and mailing costs (12:4). The USS Vincennes carries 23.5 tons of paper above the main deck, which is more tonnage of paper than weapons (11:21). The current paper system is very expensive. The cost for one page can be as high as \$2,000 due to the initial research, engineering, editing and writing costs associated with a new weapon system(11:23). The paper system also produces inaccuracies because of pressures to field weapon systems on schedule and under

budget. Today's weapon systems contain leading edge technology, a fact which also increases the workload on technical writers.

**System Deficiencies.** Numerous deficiencies are inherent to the paper TO system: slowness, costliness, and inaccuracy. The TO process is slow, partly because contractors frequently fail to provide installation level TOs in time for Air Force verification. Nearly 500 days may be required to fully implement a routine change in some cases.

TOs are expensive to develop, costing an average of \$1,000 per page. In addition, the fact that the Air Force does not separate the cost of TO preparation from the cost of a weapon system makes cost benefit analysis difficult (1:1-6).

The TO system is fraught with inaccuracies. Changes may arrive with pages missing, pages out of sequence, and/or pages that are unreadable. The wrong TO or wrong quantities of TO's are often received by a program office. Sometimes users do not establish accurate requirements for TO's. The tendency exists to conduct desk top analysis instead of actual performance of tasks for TO validation. Increasing use of off the shelf contractor furnished manuals, which do not conform to military standards, confuse maintenance and operations personnel and complicate the system even further. All these sources of inaccuracies influence the operation and maintenance of USAF weapon systems. From 1977-1986, 88

mishaps (damages exceeding \$85 million) indicated inaccurate technical data was a contributing factor (1:1-6).

The Air Force TO management system is 20 years old, slow, costly and inaccurate. The system is being converted to digital data, but paper will exist for many years to come. The key is to utilize digital data processes whenever it is economically advantageous.

**Required Solutions.** Improvements are required to shorten distribution times, maximize the accuracy, and enhance the overall efficiency and effectiveness of the system. To meet these objectives hardware and software were updated with the latest computer technology to create an automated infrastructure to handle the flow of TOs and information throughout the system. AFTOMS was the first plan to automate the TO system; it was proposed in 1988 based on a DOD Task Force recommendation to implement CALS standards within the TO system. In 1991, JCALS replaced AFTOMS and added emphasis to establish common specifications, standards and management structures throughout all DOD agencies.

#### **The Air Force Technical Order System (AFTOS)**

**Purpose of TOs.** The purpose of the Air Force TO system is to provide Air Force personnel written guidance for operating, maintaining, inspecting, servicing, supplying,

and modifying weapons system components. Additionally, TOs are used for training purposes (13:3-1).

**History of TOs.** The current Air Force TO system is an extremely large, paper oriented, logistic support system whose operating procedures were defined in the 1940's. This system provides the official medium for distributing technical information, safety procedures, and instructions pertaining to Air Force weapon systems. The original functional structure of AFTOS is illustrated in Figure 2 (13:1-4). Currently, there are well over 200,000 active TOs and five million new/revised pages per year managed by six different centers and divided by specific weapon systems (11:24). A TO is approximately 100-150 pages in length and is approximately 60 percent text and 40 percent graphics. The total TO data base is approximately 20 million pages (1:1-2).

**General Description.** Air Force Regulation 8-2 established AFTOS as a medium for disseminating technical information, instructions, and safety records pertaining to Air Force systems. Eleven documents establish the TO system and assign responsibilities related to the acquisition and management of TOs. The three basic steps to the TO process are create, deploy and manage.

**Create TOs.** The create process consists of planning, developing, and reviewing. The first function, planning,

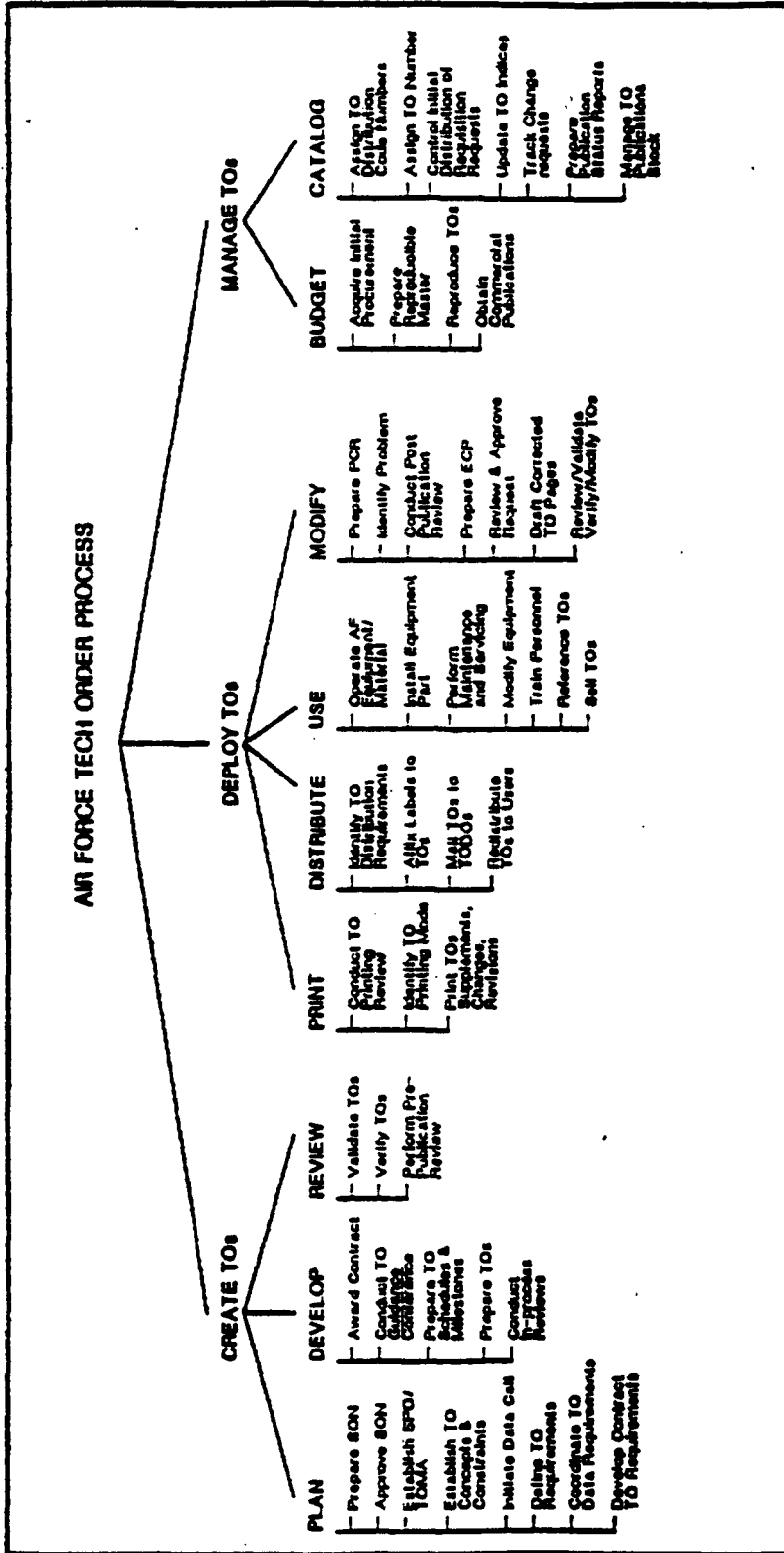


Figure 2: Functional Structure of the Air Force TO System

begins with the approval of a Mission Need Statement (MNS) and an Operational Requirements Document (ORD). Figure 2 references a Statement of Need (SON) which has been replaced by the MNS and ORD. An effective Technical Order Management Agency (TOMA) must be established within the System Program Office as early as possible. A TOMA may consist of one person or a group of people; either way, TOMA is the reference name. The TOMA, with the support of the prime Air Logistic Center (ALC), develops a Technical Manual Management Plan (TMMP). This plan provides guidance for all TOs produced to support a major acquisition program. The inputs to the planning function are the MNS, the Integrated Logistic Support Plan (ILSP), and current technology for hardware and software. The output is the TMMP.

The second function, development, represents the activities necessary to produce a draft version of the TO requirements. The TOMA ensures the contractor's Technical Manual Publication Plan (TMPP) is compatible with the TMMP. The TMPP is developed by the contractor and is legally binding; therefore, the contractor is responsible for all problems that develop during the contract period. Inputs to the development function are the Logistic Support Analysis Record (LSAR) data, system design data, TMMP, and applicable existing TOs. Outputs include the TMPP and a draft TO.

The third function, review, is the final step in the create process. The draft TO is validated by the contractor and verified by the Air Force. This ensures that the

manuals will provide explicit, technically accurate, safe procedures. The input to this process is the draft TO and the output is an approved preliminary TO. After Review, the draft TOs are ready for deploying (13:3-1).

**Deploy TOs.** The approved TOs are printed, distributed, used, and modified as required during the weapon system's life cycle. The first function of the deploy process is the printing of TOs. There are two inputs to the printing function; 1.) approved TOs and 2.) approved changes, revisions and/or supplements to TOs. The outputs are printed TOs, changes and supplements.

The next deploy function is to distribute the printed TOs, changes and supplements. Normally, the Government Printing Office (GPO) contractor is responsible for distribution in accordance with the instructions and mailing labels provided by the TOMA. The TOs are distributed to regional Technical Order Distribution Offices (TODOs) and are, in turn, distributed to the appropriate users. Inputs to this function include: the printed TOs and changes to TOs, as well as numerous forms and labels detailing distribution locations and quantities. Output is an approved new TO or a changed TO.

Operators and maintainers use TOs to support the equipment that supports the Air Force mission. TOs provide instructions for operating, maintaining, servicing, supplying, and modifying weapon systems. The input to the last function, modification, is a printed TO that has been



in use; the output is a changed TO that returns to circulation. The changes and corrections are documented on an Air Force Technical Order Form 22 (AFTO 22).

Once an AFTO 22 is initiated the modification function begins. TOs can be modified by supplementation (add data within sections contained in the basic TO), changes (replace pages in basic TO), and revision (produce a subsequent edition of the TO). Time Compliance Technical Orders (TCTO) may affect existing TOs. TCTOs may direct a change to equipment and thus require a change to TOs for operating or maintaining that equipment. When TCTOs impact existing TOs, updates to all affected TOs are issued concurrently with the TCTO. Inputs to this process are AFTO Form 22, AFTO Form 27, and printed TOs, while the outputs are approved changes, revisions, supplements, or TCTOs (13:3-1).

**Manage TOs.** A key ingredient to the success of the TO process is effective management. Management of the TOs occurs over the entire life cycle of the weapon system. Two sub-functions make up the management function: budgeting and cataloging. The TOMA and TO Distribution Control Authority (TODCA) are responsible for effective management and coordination among all affected organizations.

The TOMA is responsible for managing the acquisition of TOs and is also required to deliver a final TO to the appropriate ALC (13:6-1). The TOMA is responsible for estimating costs associated with acquiring the necessary TOs. Normally, historical information is used for

predicting future costs and arriving at a budget. Predicting future costs for digital data is more difficult because there is little or no historical information on digital data available within a SPO. During acquisition, the acquiring agency is responsible for funding the budget. Once the weapon system is delivered to the operating command, operations and maintenance funds are used for reproduction of existing TOs that are changed or revised. See Figure 3 for a flow diagram of the TO production process (1:1-5).

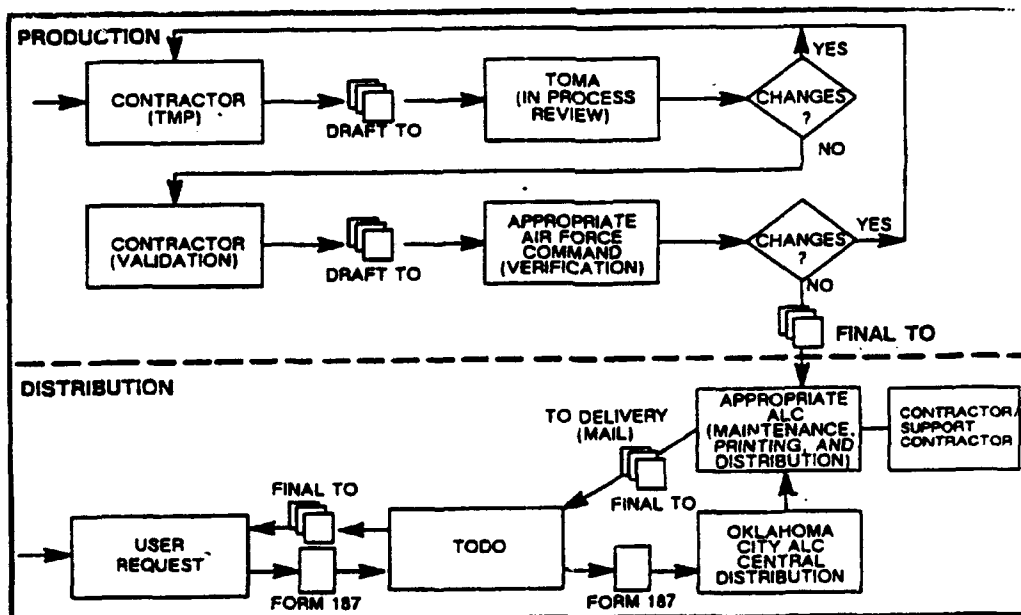


Figure 3: Flow Diagram of TO Production Process

The appropriate ALC is responsible for the cataloging functions associated with TOs. The ALC's TODCA is primarily responsible for this function, which includes activities relevant to numbering, indexing, managing, and distributing TOs, in addition to improving the Air Force TO System. The

primary ALC reviews all requests for TO numbers. Oklahoma City ALC approves the TO numbers for all non-nuclear system TOs and San Antonio ALC approves the nuclear related system TOs. The primary ALC TODCA manages the initial distribution and requisition of TOs. The appropriate ALC is then responsible for maintaining, printing, and distributing approved TOs.

#### **Deficiency of AFTOS System**

**Complexity.** The AFTOS contains over 200,000 TOs managed by 8 different prime ALCs and 6,000 TODOs (11:24). In fiscal years 1983 through 1986, there was an average of 8,017 requests for new TOs with a 98 percent fill rate. The current TO inventory data base is approaching 20,000,000 pages (13:F-1) and there are over 50,000,000 pages of unprinted TOs. Seventy to ninety percent of all printing is accomplished by civilian contractors. Fifty five military specifications/standards have the ability to impact a TO, and over 350 forms are used throughout the AFTOS (1:1-6). Approximately 150 reports are generated monthly to assist the ALC TODCA in managing the TO stock level and the status of publications requiring review (13:F-1).

#### **JCALs**

**Purpose.** JCALS streamlined the flow of technical information by introducing automated processes within the TO

system. JCALS institutionalized international computer standards within all DOD agencies. This standardization throughout the DOD will help eliminate duplication of effort.

**History.** In October 1985, an Air Force Program Management Directive (PMD) established a CALS\* Management Integration Office (MIO). The MIO was responsible for planning, developing, and implementing CALS\* initiatives within the Air Force (1:1-1).

The AFTOMS plan, now referred to as JCALS, adopted a seven-to-ten year period for implementation. The designers intended the new system to evolve from the AFTOS by integrating existing assets with future modules. The current system operates in parallel (1:2-1). Also, JCALS assumed the new system would allow the Air Force to accept and efficiently use digital TO data from contractors.

**Structure.** JCALS established a 4-tier hierarchy: 1) General Administration (Central Technical Order Administration (CTOA)), 2) Acquisition and Production (Regional Centers), 3) Ordering and Distributing (Base Libraries), and 4) Applications (Work Areas). See Figure 1 for the flow diagram of information path flows (1:2-6).

The CTOA's control of the entire system's technical information and the assignment of single TO Centers (TOCs) to each weapon system are key organizational features of JCALS; they provide accountability and control over the complete life cycle of a TO. TOCs are staffed by personnel

with strong backgrounds in weapon system technical data. Base Libraries/Data Centers are staffed by people highly skilled in computer disciplines. During the transition period from paper to digital manuals, there will exist three types of technical manuals--Types A, B and C--or similar parallel systems.

JCALs was designed to be an integrated system that can accommodate all types (A, B, and C) of TOs. The concept was designed to accept Type C TOs when they become available. With JCALs, the acquisition process is standardized. The management and the operations of the CTOA and Regional Centers provide a single point of contact for questions and eliminate duplication of effort by each weapon system office managing its own component TOs. Automation flexibility at the work area level allows Commands to proceed at their own pace by selecting configurations that best suit the individual unit's needs.

Simply transforming TOs into digitized form will reduce the volume of paper used to produce the final product. It will also save time and space; however, it does not solve all the problems with the current TO system (9:17). Eventually, the digital copy of the TO must be printed on paper, or a computer screen must be available at the job site, for the technician to use. The latter solution would be inefficient for the technician, causing him/her to have to scroll through the computer screen searching for the procedure required.

This inefficiency is why Interactive Electronic Technical Manuals (IETM) are needed. IETMs contain all the information of a paper TO and are similar to a small data base where the technician can search the menu with simple commands. IETMs have no page orientation; instead, they contain information that is tagged according to the key international standard necessary to implement IETMs called Standard Generalized Markup Language (SGML).

### **Standard Generalized Markup Language**

**General Information.** Until recently, the technology was not available to support digital data. Even today, software and hardware are still being developed to integrate software systems and make digital manuals easier to use. Digital manuals cost considerably less to store and update than paper ones.

Standard Generalized Markup Language (SGML) is the international standard for marking text with tags so the document can be retrieved and displayed in different output formats. The idea is to standardize computer files much as pipe fittings and electrical outlets are standardized (5:50). SGML makes it possible to use electronic files/manuals as databases by using SGML sets of rules to describe components of documents such as headings, paragraphs, and tables. Currently, software that utilizes these standards is difficult and expensive to implement

(5:51). Once SGML is fully developed; however, it will help make digitized manuals more user friendly.

SGML, first released in 1986, is a standard for document description published by the International Organization for Standardization (IOS). It uses ASCII characters (ASCII is accepted by virtually all publishing systems) for both content and markup. Since ASCII characters are read by most computers, SGML documents can be easily exchanged among computers. Perhaps the greatest feature of SGML is its flexibility. Information does not become outdated when publishing equipment or programs are updated. The information becomes independent from the program that created it (14:211).

Dedicated work continues in the development of new standards that will be compatible with SGML and that will expand its implementation by making output more easily automated. Document Style Semantics and Specification Language (DSSSL) is a standard that defines a language that specifies how to build an SGML document. Standard Page Description Language (SPDL) is the standard to transform the digital document into output or a formatted page. Both DSSSL and SPDL are now draft standards and very close to being complete (14:217). Conversion to IETMs will take place on a large scale (14:217) once the standards are complete.

**SGML Implementations.** Worldwide revenues for products related to SGML will more than double by 1995,

according to Inter Consult, a market-research firm specializing in the computer-publishing market. The study predicts that steady growth is due to the shift toward electronic delivery of documentation required in manufacturing, military, telecommunications, and service fields. As part of the shift, Control Data systems announced it will be converting its paper documentation system to electronic manuals, joining Novell and Silicon Graphics (15:32).

Lockheed, with the participation of the Georgia Institute of Technology, is delivering technical manual data for the C-130 Hercules transport to Warner Robins Air Logistics Center on a \$20 million Air Force contract. The manuals are being composed according to CALS standards using SGML (16:58). Using SGML techniques, Ontario Hydro has automated its nuclear power plant documentation bringing the existing 20,000 pages of documentation on-line (17:383).

### **Estimated Savings**

Estimated savings is a quantitative benefit for implementing an improvement to a system. This section will present estimated and actual savings gained due to CALS strategies. The example used previously for the LSA and technical manuals is estimated to save 25 percent of aggregate costs. The reference did not give an estimate of



the costs associated with changing to the improved system (10:5).

In an example of savings gained, CALS standards were applied to a recent modification to the KC-10 on-board loader project. The Development Manufacturing and Modification Facility at Wright-Patterson AFB designed prototype and production units of the On-Board Loader. They transferred this design to Warner Robins Air Logistics Center for manufacturing. Because the two bases have different Computer Aided Engineering programs Warner Robins could not use Wright-Patterson AFB software. Thanks to CALS technology the two systems are now integrated. The result is 2,000 to 3,000 man-hours of savings for this single project. No data was available for the costs associated with integrating these two systems (18:15).

Under the current engineering drawing system, the DOD spends millions of work hours revising engineering data from paper and other forms. The DOD could save millions of work hours if intelligent digitized data were distributed on all weapon systems (19:38). Once again the reference did not provide information on how much it would cost to change the entire system over to an intelligent data system. The stories of savings are numerous; however, more information is required before deciding to implement CALS standards on a given program. It would be a mistake to implement CALS in every situation, unless it is cost effective. Currently,

there is no auditing process that will provide verification and validation for the amount of time and savings generated by implementing CALS standards and Integrated Data Base management (20:21).

### **Economic Analysis**

Economic analysis is a four-step process: 1) identification of possible projects; 2) data collection, 3) determining the best project, and 4) evaluation of implemented projects (21:5). "'A good economic analysis systematically examines and relates costs, benefits, and risks of various alternatives'" (21:6).

Costs are normally the easiest to determine, but benefits and risks can be much more difficult to estimate. Costs can be provided by a contractor's estimate, or estimated from historical information. Standard capital budgeting procedures can be used to conduct a cost analysis to determine the best project--the project with the lowest life cycle cost. However, a good economic analysis is normally not based on cost alone

As stated above, a good economic analysis considers costs, benefits, and risks. The standard capital budgeting analysis is not designed to handle qualitative factors or benefits and risks. Capital budgeting can be used to

estimate costs but another tool is required to combine quantitative and qualitative factors. Therefore, capital budgeting analysis must be combined with another decision making tool in order to accomplish a good CBA or economic analysis. A complete economic analysis should be considered as one of the inputs required to make a proper decision concerning the use of resources, and not as the decision making process itself (22:8).

The next part of this chapter describes various capital budgeting analysis and decision making tools that can be used to conduct the economic analysis portion of a CBA. The analysis in Chapter IV utilizes the net present value method for capital budgeting and Saaty's AHP for a decision making tool.

### **Capital Budgeting Analysis**

Capital budgeting is a quantitative Economic Analysis technique that the Air Force could use for TO system improvement decisions. Capital budgeting and cost analysis involves long term planning decisions for investments using both quantitative and qualitative cost information. This process is tailored for projects, or for the life of a project, not a specific time period. The process aims at minimizing life cycle costs, costs incurred over the life of

the system. Because this is a long range plan most of the costs should be variable and not fixed.

There are four steps to the capital budgeting and cost analysis process:

1. Analyze quantitative financial aspects of a project.
2. Analyze qualitative non-financial aspects of a project.
3. Finance the project.
4. Implementing the project & monitoring its performance. (23:673)

Only relevant costs, future costs that differ among alternatives, should be used in the analysis.

**Four Capital Budgeting Factors.** A manager must consider four capital budgeting factors: Quantitative/financial, quantitative/non-financial, qualitative/financial, and qualitative/non-financial. The quantitative/financial factors can be analyzed by one of the four methods outlined below. Sometimes assumptions and predictions can be made to obtain a quantitative/monetary cost or savings, and sometimes a manager must make decisions based on all four categories of factors.

**Step One.** The most difficult aspects of capital budgeting are identifying the project and predicting the outcomes. Simulation modeling can be used to improve the accuracy of predicting outcomes of a complicated decision. When a model is used, the inputs to the model are predicted

and the outcome of the entire system is provided by the model. Also, modeling can help quantify benefits; the results are easier to use in capital budgeting and economic analysis. Analyzing the quantitative and financial aspects of a project may be accomplished using one of four different methods: Discounted Cash Flow (DCF) Method, Payback Method, Accrual Accounting Rate of Return (ROR), and Break-Even Time (BET) Method (23:674).

**Discounted Cash Flow.** When comparing alternatives, DCF considers the time value of money. A dollar today is not worth a dollar one year from now because of inflation and return on investments demanded by profit seeking companies. DCF uses a dollar value or interest rate of return to compare costs and benefits of alternatives. There are two types of DCF: net present value and internal rate of return.

The Net Present Value (NPV) method gives current dollar value of cost and savings in today's dollars. If inflation is ten percent, or a company requires a ten percent return on the investment, then a 100 dollar payment 1 year from now is presently valued at approximately \$91.

Internal Rate of Return (IRR) provides an interest rate of return at which expected outflows equals expected inflows. The higher the value of the IRR the better the investment. An IRR imparts the same information as a NPV but it is presented in a different form. For example, if the expected inflow this year equaled 91 dollars and the

expected outflow one year from now equaled 100 dollars, an IRR of ten percent would be required.

**Payback.** The Payback Method is another system for analyzing quantitative financial aspects of a program. This method provides information on the amount of time the required to recoup investment costs. It is computed by dividing total investment outflow costs by the yearly savings from the investment. This number is straight forward, easy to compute, and used when a quick, approximate solution is required. The objective is to minimize the payback time. This method does not account for the time value of money, or the life cycle profitability of a project. For example one project may have a smaller payback time but less of a life cycle than an alternative project. If the decision was based on payback time alone the decision would be erroneous.

**Accrual Accounting Rate of Return.** The next method is the Accrual Accounting ROR. This method utilizes traditional financial accounting methods, which measure profitability, and ignores the time value of money. It is calculated as an accounting measure of income divided by investment. The higher the ROR the better the project. This method is not as accurate as DCF because it utilizes accounting averaging techniques which ignore the time value of money. Use of this method will not always result in the selection of the best alternative. However, managers that use DCF methods will be criticized in the short run when

executives compare income statements with results from NPV or IRR methods.

**Break-Even Time.** The last method is the Break-Even Time (BET). This is defined as the time from the start of a project, date of idea, to when the cumulative present value of the cash inflow equals the cash outflow. The objective is to choose the shortest possible alternative BET. This method is extremely important in manufacturing industries where fierce competition means the first item available for sale captures the market.

**Which Method is Right?** There is not one method that is best for all situations. Each method presented above is appropriate depending on the situation. Each manager must decide which is the most appropriate for the decision at hand. One way to make this decision would be to list the advantages and disadvantages of each method for the particular situation. For example, a manager must decide if electronic technical manuals are more cost effective than paper technical orders. To do this he/she must determine which cost analysis method to use. The NPV method would be ideal for the TO scenario because of the accuracy gained by using DCF and the large amount of initial costs required to implement changes.

Complex real world problems are not as easy to solve as text book problems. The factors that managers must consider are far broader than the quantitative and financial factors required in capital budgeting decisions. Many

factors are difficult to quantify. These qualitative and non-financial factors can be as important as, or sometimes even more important than, the quantitative and financial factors.

**Step Two.** The four methods presented above are designed to give quantitative information for decision makers. The next step in the Capital Budgeting process is to analyze qualitative non-financial aspects of the project. Managers must also consider both types of information. Each manager must decide how to weigh each type of information before making the final decision. A manager may wish to obtain quantitative information using a capital budgeting method and then combine this with the qualitative factors affecting the decision. He/she can then prioritize the factors. In other words, the manager could list the advantages and disadvantages, qualitative and quantitative, for each project.

Both qualitative and quantitative financial information are analyzed by decision makers before implementing capital budgeting investments, and both have limitations. Qualitative and quantitative information may be based on predictions of perceived costs and benefits, which are not always 100 percent accurate. Estimates are least accurate when dealing with leading edge technology, because there is little or no historical information on the subject.

Even quantitative information can be highly subjective. For example, in order to obtain information on cost and



savings for implementing a capital investment, an estimate of costs and benefits, in monetary terms, must be made. Normally, these estimates can be obtained from historical information or collected from experts using a questionnaire or survey. Both quantities are estimates which are subject to bias and error, because all scenarios are different. If the item being considered for the capital investment is similar to another investment that was implemented in the past, then the information should be accurate enough for predicting cost and benefits. If there are no similar items to use for comparison, then the predictions are much more difficult.

How can qualitative and quantitative information be combined to make the decision? Qualitative information can be subjective, perhaps even more so than quantitative predictions. It is difficult to integrate qualitative with quantitative information in order to make a capital budgeting decision. The integration process can be biased and inaccurate; however, the analysis can be improved by using a sensitivity analysis (changing the factors and observing the outcome) and comparing predictions with historical information.

**Step Three.** The third step in capital budgeting is to finance the project. Once a decision is made on which project will be implemented it is time to gather and commit funds. In the military environment funding is becoming harder to accomplish because of shrinking budgets. In a

military situation, the budgeting process takes place many years in advance of project implementation.

**Step Four.** The final step is to follow through with implementation and to monitor the performance. The project may get out of control if it is not closely monitored. The decision to implement the project will be based on predictions; therefore, the information gained from monitoring the process could be very helpful in predicting future costs and savings.

#### **Decision Making Tools**

CBA decisions can be based on a single quantitative criterion such as NPV cost. In such a case, the choice of an optimal solution is not difficult; rating alternatives is only a matter of mathematically calculating the total cost or value to the organization. Once each solution is rated, the decision maker chooses the alternative with the lowest cost or greatest value (21:10-11).

Most decision-making methods may work well for a single criterion problem, but they may not be the most effective approach for a problem with several issues, such as the transfer to a new TO format. Because CALS requires several different issues, a Multiple Criteria Decision Making (MCDM) should be implemented. There are eight common approaches to MCDM: 1) Single Objective, 2) Goal Programming, 3) Interactive, 4) Compromise Programming 5) Electre, 6)

Parametric, 7) De Novo Programming, and 8) Analytical Hierarchy (21:13-16).

The first seven techniques are quantitative in nature. The decisions that result from using these techniques are commonly based on measurable characteristics, but they do not take into account the qualitative issues which are important to this study. "A MCDM is needed that can combine quantitative and qualitative factors into the ... decision" (24:37). Therefore, each of the first seven MCDMs can be used as a tool to aid the decision maker in performing a CBA, but a more comprehensive approach must be used to do the overall CBA.

#### **Saaty's Analytic Hierarchy Process (AHP)**

The eighth process, AHP "is a multilevel decision aid developed by Thomas Saaty in the 1970's" (21:17). It is one of the most popular aids to decision making developed in the past decade (25:57).

The Analytical Hierarchy Process is a rational and systematic approach for finding a solution to a problem. The method allows decision makers to partition large, manageable problems into smaller parts that are easier to handle. It provides decision makers with the ability to combine qualitative and quantitative criteria to form a rating for each alternative solution. These ratings may then be used as a basis for project selection (24:37).

The AHP method establishes ratings and rankings for each solution choice by using a system of pairwise comparisons. The ratings are then mathematically combined to develop an overall rating and ranking for each of the alternatives. The alternatives can be compared, regardless of their units, and an educated decision can be made. This method also provides a process for checking the consistency among the importance of the decision-maker's preferences of the multiple criteria (21:16).

The use of AHP includes the following steps:

1. Build a decision hierarchy by breaking the general problem into several issues, which are positioned within a hierarchical structure.
2. Gather relational data for the decision criteria. Relational data may exist in the form of quantitative relationships, or it may be generated through a series of pairwise comparisons of the decision criteria and alternatives.
3. Estimate the relative weights of the decision criteria using the proportional or the *eigenvalue* method (uses data to assign weights).
4. Aggregate the relative weights into a vector that will be used to rank the various decision solutions.  
(21:18)

Battin and Bender detail these steps completely in their thesis about economic analysis (21:18-28).

**Selecting Multiple Alternatives of AHP.** After establishing the ratings, the decision maker is provided with the best solution or the highest rated alternative.

Unfortunately, management may be able to select more than one alternative, or small differences in requirements between different decision situations may cause a need for a different solution. A combination of alternatives may be required. One possible solution to this problem is to use integer linear programming to choose the combination of alternatives that would give the largest combined rating. The values in the solution would indicate how many times each alternative should be implemented. Zero-one programming should be used to insure that solutions used only once will not be given too much weight. Zero-one programming is a subset of linear integer programming that restricts the values of possible solutions to either a zero or a one. The result is that a solution will either be chosen or not chosen. In this environment it is an important requirement that the ratings be additive. Therefore, the sum of one combination of ratings will be directly comparable to another (21:29).

**Consistency of AHP.** Because decision makers can be inconsistent, Saaty developed a technique for assessing the consistency of their judgments. The decision maker analyzes the maximum eigenvalue and the number of criteria in a pairwise comparison. Although this sounds difficult, there is now a computer program, Expert Choice, which accomplishes the analysis for the decision maker. Battin and Bender detail this method for us in their thesis. This measurement

allows decision makers to be confident in their solution choice.

**Criticism of the AHP.** In many applications of the AHP, two hierarchies, and hence, two output vectors, are associated with a given situation, one for its 'benefits' and the other for its 'costs'. Here the question arises as to how these two vectors should be combined to decide which alternative to implement (24:57).

Bernhard and Canada stated that ratios of data do not provide the decision maker with the "best" solution (21:42; 25:57), but their conclusion has been successfully rebutted by two counter arguments. First, it is inappropriate to separate items into costs and benefits if they can be measured in common units. Second, the integrity of their formula depends on the commonalty of the units involved.

### **Conclusion**

The history of the CALS program indicates that computer technology environment is very fluid. Leading edge technology, which is very expensive, can become outdated and of little value in a short period of time. CALS has changed numerous times since its beginning in 1985. The propensity for change must be considered when designing new automated computer systems; these new systems must incorporate flexibility. Because of their widespread applicability,

CALS standards are great ideas which have the potential to revolutionize the military acquisition and logistics system.

Joint Continuous Acquisition and Life-cycle Support has streamlined the management of TOs within the Air Force. The system's emphasis on process improvement is the key to incorporating state-of-the-art computer standards into the TO system as they become available.

Under AFTOS, the Air Force did not efficiently and effectively manage the increasing size and complexity of Weapon System TOs. The manually-oriented, paper processes and fragmented management structure caused the system to be inaccurate, slow, and costly.

JCALs utilizes an improved management structure and implements the use of new computer technology. The system has eliminated the burdensome paper processes for review and distribution of TOs. It's success can be contributed to the flexibility of its implementation. The system is designed for digital TOs to evolve over a 7-10 year period during which a parallel structure of paper and digital TOs harmoniously exist together.

IETMs are expected to be the next generation of TOs. These IETMs utilize SGML software standards, which are nearly complete. Development of IETMs will continue to thrive throughout all of DOD and industry. With JCALS in place the Air Force is positioned to take advantage of the latest in technology.

A great deal of literature is available that provides information about estimated savings from converting to digital TOs, but very little literature exists for costs. A good analysis must be based on both costs and benefits. Several cost benefit analysis methods have been presented, along with the advantages and disadvantages of each. Capital Budgeting is ideal for quantitative/monetary analysis. The NPV is an accurate measurement of life cycle costs for a large capital investment, such as changing TO format. Capital budgeting does not incorporate qualitative data effectively into the analysis; therefore, when using only capital budgeting, the decision maker is forced to consider two separate categories of information: qualitative and quantitative. A better method would be to implement Saaty's AHP.

Saaty's AHP combines the quantitative and qualitative information needed and provides one simple recommendation to the decision maker. Implementing improvements to the Air Force TO format requires evaluation of both qualitative and quantitative data. Therefore, the Analytical Hierarchy Process is an ideal approach to developing a CBA methodology for this application.

The literature review has provided an overview of CALS, JCALS, capital budgeting, and CBA techniques. Chapter III will present the methodology used to answer the investigative questions outlined in Chapter I.



### **III. Methodology**

#### **Introduction**

This chapter describes the methodology used to answer the investigative questions proposed in Chapter I. The purpose of this research was to identify a procedure for a SPO to use when conducting a Cost Benefit Analysis (CBA) before making a decision on whether or not to acquire digitized technical data. The literature review provided historical information about many areas including CALS and JCALS. In addition, various cost benefit analysis techniques were analyzed. Structured interviews were then conducted to gather data from functional experts. The functional experts' data provided inputs for determining benefits, building a computer simulation model, conducting a Life Cycle Cost Analysis, and performing a cost benefit analysis using Saaty's Analytic Hierarchy Process.

#### **Justification for Method Selected**

Because CALS is a relatively new initiative, no guidance exists on how program managers would accomplish a CBA to assess the cost effectiveness of implementing CALS strategies on weapon system support processes. In these days of shrinking budgets, it is important to maximize the value of a dollar; therefore, without a good CBA it is impossible to know if CALS implementation on a given program is cost effective.

Measurement data is important for management to justify continuation of a program. This research effort needed measurement data to determine the best CBA solution. In order to obtain this measurement data, a two fold approach was necessary: literature review and personal interviews. Research began by studying cost-benefit analysis techniques. After looking at various techniques, information and estimations were gathered to determine which technique was most appropriate for the situation. Measurement data was obtained from interviews and the literature review. The data was then transformed into decision making information by developing the LCCA, simulation model, and then conducting the CBA using Expert Choice software.

### **Methodology**

To answer investigative questions 1 and 2, structured interviews with members from System Program Offices (SPOs) and Air Logistic Centers (ALCs) were conducted. The interviews identified categorical costs and benefits of implementing the CALS initiatives. The interviewees also ranked, on a Likert scale, the benefits of alternative TO formats: paper, computerized, and automated. Forty-three interviews were conducted in SPOs, ALCs, and Matrix organizations. The number of interviews to be conducted was determined by the CALS office and the thesis committee. The interviews helped identify costs incurred and benefits

received for each TO format. The interview responses were analyzed to identify the qualitative and quantitative costs and benefits that are common and those that were organizationally dependent. A computer simulation model was developed to simulate the process the Air Force utilizes to develop and modify TOs. The model was used to analyze the system responsiveness--time to develop or modify a TO. Interview and literature review data were input into the simulation model. Sensitivity analysis was used to determine the effect of input changes.

Questions 1 and 2 established the essential benchmarks to determine costs and benefits for all three TO formats. The information collected from answering investigative questions 1 and 2 were input into Expert Choice software, which utilizes AHP. The "best" CBA method was defined as the method which has the capability to analyze quantitative and qualitative information. The AHP has this capability and; therefore, provides a format for decision makers to use in developing a CBA prior to implementing costly improvements. This aids in ensuring that resources are expended wisely. The CBA, which utilizes the costs and benefits identified in questions 1 and 2, is presented in Chapter IV.

Question 3 was answered by conducting an extensive literature review on CBA techniques, as well as structured interviews with functional experts from SPOs and ALCs. Methods for conducting cost benefit analyses were

researched. Each method was analyzed by comparing the type of costs and benefits, to decide which method was the most appropriate. This information was obtained from the interviews and literature review. "Most appropriate" is defined as the CBA method which can analyze quantitative and qualitative costs and benefits. The sources for CBA methods consisted of theses, pamphlets, books, and regulations.

### **Summary**

This chapter described the methodology used to answer the investigative questions. A combination of literature review and personal interviews were used to answer all the investigative questions. The next chapter will describe the interview, simulation model, cost analysis and the CBA method.

## IV. Analysis and Findings

### Introduction

The purpose of this research was to answer the following investigative questions about Continuous Acquisition Life-cycle Support (CALS) and Technical Orders (TOs):

- 1) What life cycle costs, quantitative and qualitative, are associated with the computerization and automation of the Air Force TO process?
- 2) What are the benefits, quantitative and qualitative, associated with the computerization and automation of the Air Force TO process?
- 3) What CBA approach is most appropriate for assessing the economic consequences of computerization and automation of the Air Force TO process?

In order to answer these questions, several different processes had to be utilized. This chapter details 1) the interview questions and format used; 2) the computer simulation models used; 3) the Life Cycle Cost Analysis (LCCA) developed; and 4) the Analytical Hierarchy Process (AHP) output developed from the research. The answers to the investigative questions will be presented in Chapter V.

### Interviews

**Formulation.** A structured interview was developed to gather information about CALS and TOs. The objective of this interview was to determine which characteristics are

benefits of different TO formats and what were the historical costs of these formats (See Appendices 3 & 4). After formulating our interview, we compared its contents to a C-17 TO Business Case Analysis conducted by the CALS Shared Research Center (CSRC), San Antonio (See Appendix 5). We found that most of the issues determined to be important to our study were also questioned in their study. This comparison validated our research by exhibiting that the issues discussed are important to System Program Offices (SPOs).

After formatting the interview, we called various SPOs to identify an experienced representative who was willing to be interviewed. We received forty-three positive responses, representing four bases: four SPOs with 27 interviewees; one Air Logistics Center (ALC) with one interviewee; and two matrix organizations with fifteen interviewees. The structured interviews were facsimiled to the representatives before the personal interview; this allowed them to be aware of the topics of discussion and to accumulate any supporting data that was needed. After giving the representatives time to review the structured interviews, we contacted them again to establish personal interview dates.

The first step was to record which SPO was being interviewed, what TO format the SPO was currently using and the experience of the interviewee. These facts helped us identify causes of trends that resulted from the interviews. Next, the table of characteristics and related formats was

discussed and completed (See Appendix 3). The reasoning behind the responses was recorded to identify biases and trends of the interviewees. Finally, we collected the quantitative historical data for the SPOs latest TO acquisition.

**Results.** The summary output from the first page of the interviews is provided in the next five tables. The interviewees were asked to rank characteristics of an ideal TO. Table 1 is a compilation of characteristic ranks for the ideal TO. Column one lists characteristics considered. The interviewees were allowed to add or delete characteristics from Column one. Column two is the sum of the points received by each characteristic. Column three is the number of times a characteristic was ranked on the interviews. Column four is the average number of points received by each characteristic. The average was obtained by dividing column two by column three. Column five is the rank of each characteristic. This number was determined by ranking the average points received, lowest average first.

**TABLE 1: DATA FOR OVERALL RANKING OF CHARACTERISTICS**

<b>RANKING</b>	<b>TOTAL PTS</b>	<b># OF OBS</b>	<b>AVERAGE</b>	<b>RANK</b>
MAINTAINABLE	180	38	4.70	6
RELIABLE	107	31	3.45	2
SECURITY	252	38	6.63	9
ACCURACY	84	43	1.95	1
EFFICIENCY	128	37	3.46	3
EFFECTIVENESS	138	36	3.83	4
TIMELY	162	41	3.95	5
COST	248	32	7.75	10
DEPLOYABLE	241	42	5.73	7
FLEXIBILITY	195	23	8.47	11
SUPPORTABILITY	55	9	6.11	8

Tables 2-4 are a compilation of ranks of the characteristics for the paper, computerized and automated TO formats, respectively. The method used to calculate the rank is basically the same as the method used for Table 1, except a Likert scale from one to five was used to quantify the interviewees input. A score of one meant the interviewee definitely agreed that the characteristic was a benefit of that TO format; a score of five meant the interviewee strongly disagreed. The characteristic with the lowest average received the highest ranking.

**TABLE 2: DATA FOR PAPER FORMAT**

<b>PAPER</b>	<b>TOTAL PTS</b>	<b># OF OBS</b>	<b>AVERAGE</b>	<b>RANK</b>
MAINTAINABLE	109	31	3.51	7
RELIABLE	91	26	3.50	6
SECURITY	114	38	3.00	3
ACCURACY	110	41	2.68	2
EFFICIENCY	115	30	3.83	10
EFFECTIVENESS	120	34	3.53	8
TIMELY	102	34	3.00	3
COST	130	32	4.06	11
DEPLOYABLE	84	38	2.21	1
FLEXIBILITY	55	18	3.06	5
SUPPORTABILITY	34	9	3.78	9

**TABLE 3: DATA FOR COMPUTERIZED FORMAT**

<b>COMPUTERIZED</b>	<b>TOTAL PTS</b>	<b># OF OBS</b>	<b>AVERAGE</b>	<b>RANK</b>
MAINTAINABLE	34	18	1.88	3
RELIABLE	58	17	3.41	9
SECURITY	50	22	2.27	7
ACCURACY	43	22	1.954	5
EFFICIENCY	41	21	1.952	4
EFFECTIVENESS	70	22	3.18	8
TIMELY	55	26	2.12	6
COST	53	14	3.78	11
DEPLOYABLE	42	28	1.50	1
FLEXIBILITY	34	22	1.54	2
SUPPORTABILITY	31	9	3.44	10



**TABLE 4: DATA FOR AUTOMATED FORMAT**

<b>AUTOMATED</b>	<b>TOTAL PTS</b>	<b># OF OBS</b>	<b>AVERAGE</b>	<b>RANK</b>
MAINTAINABLE	55	38	1.45	2
RELIABLE	49	25	1.96	8
SECURITY	83	35	2.37	9
ACCURACY	56	36	1.50	4
EFFICIENCY	37	31	1.19	1
EFFECTIVENESS	62	37	1.68	6
TIMELY	53	34	1.56	5
COST	101	26	3.88	11
DEPLOYABLE	70	37	1.89	7
FLEXIBILITY	29	19	1.53	3
SUPPORTABILITY	29	9	3.20	10

Table 5 contains the ranks compiled from the previous four tables. This table allows us to compare how different formats are viewed, as well as determine if there is a difference of views when each TO format is compared to the ideal TO format.

**TABLE 5: OVERALL RANKING DATA FROM SURVEYS**

<b>OVERALL RANKS</b>	<b>PAPER</b>	<b>COMPUTER</b>	<b>AUTO</b>	<b>IDEAL</b>
MAINTAINABLE	7	3	2	6
RELIABLE	6	9	8	2
SECURITY	3	7	9	9
ACCURACY	2	5	4	1
EFFICIENCY	10	4	1	3
EFFECTIVENESS	8	8	6	4
TIMELY	3	6	5	5
COST	11	11	11	10
DEPLOYABLE	1	1	7	7
FLEXIBILITY	5	2	3	11
SUPPORTABILITY	9	10	10	8

When the interviewees ranked the characteristics, without regard to format, Accuracy was ranked as a definite first. As you can see in Table 5, accuracy was never ranked

first for an individual format. Some respondents decided to only rank the top five characteristics for a format, this meant the remaining characteristics were not considered benefits for a particular TO format. The data from the individual format rankings was used to make the pairwise comparisons in the AHP.

As stated in Chapter II, zero-one programming should be used to ensure that solutions used only once will not be given too much weight. Therefore, three responses provided by participants were not considered: price, usability and readability. The research team also decided that any characteristic receiving less than thirty observations in two or more categories should be removed from consideration. Therefore, flexibility, supportability, cost, and reliability were not considered. These two decisions reduced the number of qualitative characteristics used for the AHP from eleven to seven.

The data collected from page two of the interview was designed to provide information for the LCCA; however, the interview data was heavily slanted towards paper TOs. This slant was the result of the interviewees having limited experience with computerized and/or automated TO formats, as well as limited experience with cost information.

## **Simulation Models**

**Background.** According to Pritsker, models are descriptions of systems. Models are usually developed based on theoretical laws and principles; they may be scaled physical objects, mathematical equations and relations, or graphical representations (27:5). The research we conducted included the use of three different models, one for each TO format. The models predict the time required to develop and modify a TO.

To develop our models we used SLAM II. The state-of-the-art simulation language, SLAM, is the first commercial language that provided three different viewpoints in a single integrated format. It permits discrete event, continuous, and network modeling perspectives and/or combinations of the three (28:1). A network model is a graphical picture of a system. This approach decomposes a complex problem into its elements (27:7). Information can be obtained directly from the network diagram and it provides a basis for a qualitative or quantitative assessment and understanding of the mechanisms that are under the control of the decision makers (27:8-9). The SLAM II summary output report, found in Appendix 6, displays the statistical results for the simulation (27:98).

Our models (See Appendix 6) depict the steps that a TO follows. Due to differences in amount of time required to complete a task, a different model was developed for each TO format. Assumptions for each model had to be made, see

Appendix 6. We will present the model descriptions, discuss the differences between the three models, and present the output from the simulation.

**Description.** The model is a series of nodes (events occurring which change the state of the TO) and activities (time durations), See Appendix 5. In the models, a TO begins at the creation stage; 8000 TOs are created every year. It then enters a development stage with a time duration following the stage. The time duration depicts the amount of time required to develop the TO. After development, it enters a print stage, and a distribution stage. Each of these stages also has a time duration associated with it. After distribution, the amount of time required to develop or modify a TO is collected. Development time is collected for new TOs; modification time is collected for TOs already in use.

Once modification or development time is collected, the TO then becomes part of the functional TO system. There are approximately 200,000 Technical Orders presently in the system. All of these TOs are considered to be in use, and a percentage of the TOs in use are modified each year. Those that are modified are sent to the error node, where the model simulates modifications to the TO. The TO is re-distributed and returns to use until another modification is required. All three models start with the 200,000 TOs in the USAF inventory. We know that approximately eight thousand TOs are created annually; therefore, one thousand

are created every 46 days. If a TO requires a modification, it would begin at the fix stage and then follow the same remaining order of stages outlined above.

**Differences.** It follows that the three TO formats would not require the same amount of time to complete the stages listed above. These models contain rough order magnitude (ROM) estimates for all time distributions. Time distributions for the develop, print, distribute, and fix activities were estimated by the research team, based on the literature review and interviews, and then input into the appropriate model. The estimates and assumptions are listed in Appendix 7.

**Development.** The paper and computerized formats require the same amount of time to develop, because they both utilize the same process. The main difference between the two formats is the output. The paper format is delivered as paper TOs; whereas, the computerized formats are delivered as a computer file. The automated format can be developed more rapidly than the other two formats because of efficiencies obtained from using high technology processes. Once automation is embraced on a large scale throughout the DOD acquisition process, there will be a greater savings in time due to the learning curve.

**Print.** From interviews with experienced TOMAs, it was determined that paper technical orders require an average of ninety days to be printed; however, print time may vary from as little as ten days to as many as 365 days.

Computerized TOs are printed at the base library after electronic distribution. The printing time at the library requires an average of 20 days. Automated TOs are not printed; therefore, no time is associated with this activity. Distribution of a paper TO requires approximately fifteen days; however, automated and computerized formats are distributed over telephone lines; therefore, distribution requires only one day.

**Modification.** According to literature, eight percent of all paper TOs are modified each year. Modification of these TOs usually requires fifty days. In contrast, computerized TOs need modification six percent of the time, requiring fifty days on average, and automated TOs need modification three percent of the time, requiring forty-five days on average. All of the above differences were incorporated into their respective models; they caused significant variations in the output.

**Output.** The following table is a summary of the desired data obtained from running the three SLAM II models. The first column lists the format considered, the second column lists the number of days required to modify a TO, and the third column lists the number of days required to develop a TO.

TABLE 6: SLAM II OUTPUT

FORMAT	MODIFICATION	DEVELOPMENT
PAPER	230	574
COMPUTERIZED	75	444
AUTOMATED	47	356
TOTAL DAYS	352	1374

After obtaining this data, we added the total time to modify and divided each format time by the total time. We then found the reciprocal of these percentages. After finding the reciprocal, we added the numbers again and found the percentage for each format. This percentage was entered into the AHP. The following table contains the end product of the above calculations:

TABLE 7: PERCENTAGES ENTERED INTO AHP

FORMAT	MODIFICATION	DEVELOPMENT
PAPER	0.112	0.256
COMPUTERIZED	0.343	0.331
AUTOMATED	0.545	.413
TOTAL DAYS	1.0	1.0

### Life Cycle Costing

**Background.** Costs can be categorized according to the following four distinct phases of a project: 1) Research and development, 2) Acquisition, 3) Operations and Support, and 4) Disposal. Each project will follow a chronological path

through each phase. A Life Cycle Cost Analysis (LCCA) is normally accomplished at the system or program level, but can be beneficial for evaluating subsystems as well. The key to proper use of the LCCA at the subsystem level is to maintain a systems perspective, which is essential considering the impact of different alternative subsystems on the complete system. Maintaining this perspective requires the analyst to have a broad view of the process or the program.

If an alternative optimizes a subsystem, but not the complete system, then suboptimization has occurred, or the systems view has been violated. A military TO management system is a subsystem which affects the LCC of the entire weapon system. Appendix 10 is our example of using LCCA with a system view. The systems view has no room for suboptimization of the entire system. For example, the TO cost cannot be minimized at the expense of the whole system.

Each phase of a new project incurs costs. The risk associated with implementing new technology must be weighed along with the costs and benefits of the project.

Accordingly, when considering changes to the format of technical orders, one must consider the risks, costs and benefits. Cost and savings estimations are an analyst's attempt to predict the future. Historical data is normally used in the estimation process; this practice is itself risky. However, when no historical data exists, and new technology is being developed, the risks are even greater.



This research uses the systems approach to determine the overall effect of the life cycle costs of three different alternative formats for technical orders. The system approach requires an analysis of the LCCs for the entire system. The analyst must determine what impact a TO format has on the entire life cycle cost of a system. The weapon system life cycle costs for each format must be estimated and compared. Once the most cost effective format is chosen, the data can be weighted and input into the AHP.

**Development.** When developing the LCCA for TOs, we made several assumptions; detailed in Appendix 8. The data we used to formulate the equations were obtained from the literature review, interviews, and an Armstrong Laboratory study. This analysis contains rough order magnitude (ROM) cost estimates, which were developed by the research team, when literature review and interview data did not provide the data.

Cost estimates for the automated TO format were obtained from the Armstrong Laboratory cost benefit study conducted on the F-16 aircraft (29). Our study converted the Armstrong Laboratory's ROM estimates into unit costs for one aircraft and/or TO page, which we then used in the LCCA equations. The costs were divided into two categories, non-recurring and recurring.

**Output.** The formulas used for computation of the LCC and the output from LCCA can be found in Appendices 9 & 10. Using 1700 aircraft, 575,000 TO pages and a period of ten

years for our input; we computed a sample LCCA (See Appendix 10). From this LCCA, we determined the costs in the following table:

TABLE 8: SUMMARIZED LCCA OUTPUT

FORMAT	TOTAL COST	NET PRESENT VALUE
PAPER	\$5,986,738,500	\$4,338,823,381
COMPUTERIZED	\$4,582,706,000	\$3,389,875,881
AUTOMATED	\$2,096,420,700	\$1,553,697,556

The total costs were computed as direct, then year dollars. The net present value is the total cost converted to present year dollars. These totals were weighted and used as inputs to the AHP.

### Saaty's Analytical Hierarchy Process

**Overview.** As discussed in Chapter II, AHP is a rational and systematic approach for finding a solution to a problem. It allows a large problem to be broken down into smaller, more manageable segments. AHP allows both qualitative and quantitative criteria to be compared at the same time, using a system of weights. We used AHP to compare the output from the interviews, the LCCA, and the SLAM II model. To apply AHP to the information we used a software program titled *Expert Choice* (30). *Expert Choice* is an interactive program that can be run on personal computers; it is designed to apply Saaty's Analytic Hierarchy Process to the obtain the solution of problems.

*Expert Choice* helps the user establish a matrix of pairwise comparisons by asking a series of interactive questions that systematically develops the relative importance (weights) of the characteristics (31:29). An AHP decomposes a decision problem into three stages: 1) goal, 2) levels of evaluation criteria, and 3) alternatives.

Figure 4 is the completed hierarchy for our study. It resulted from compiling several smaller steps: 1) creating a hierarchy using the information from the interviews; 2) developing a hierarchy from the SLAM II data; 3) determining the weighted data from the LCCA; and 4) and combining the three inputs into a final hierarchy.

**Step 1.** The interviews asked functional TO experts to rank eleven characteristics on the basis of their desirability for TOs. Only seven of the eleven were found to be highly desirable, these seven were used in creating a hierarchy for the "qualitative issues" (QI). The goal of the qualitative issues hierarchy was to compile weights for the three TO formats with respect to the characteristics. This was accomplished by placing the ranked seven characteristics (alternatives), as determined by the interviews, under each TO format (evaluation criteria). The characteristics were entered in the order that they were ranked and weighted accordingly (See Appendix 11). This hierarchy provided us with an overall ranking of the seven characteristics and weights for each of the three formats.

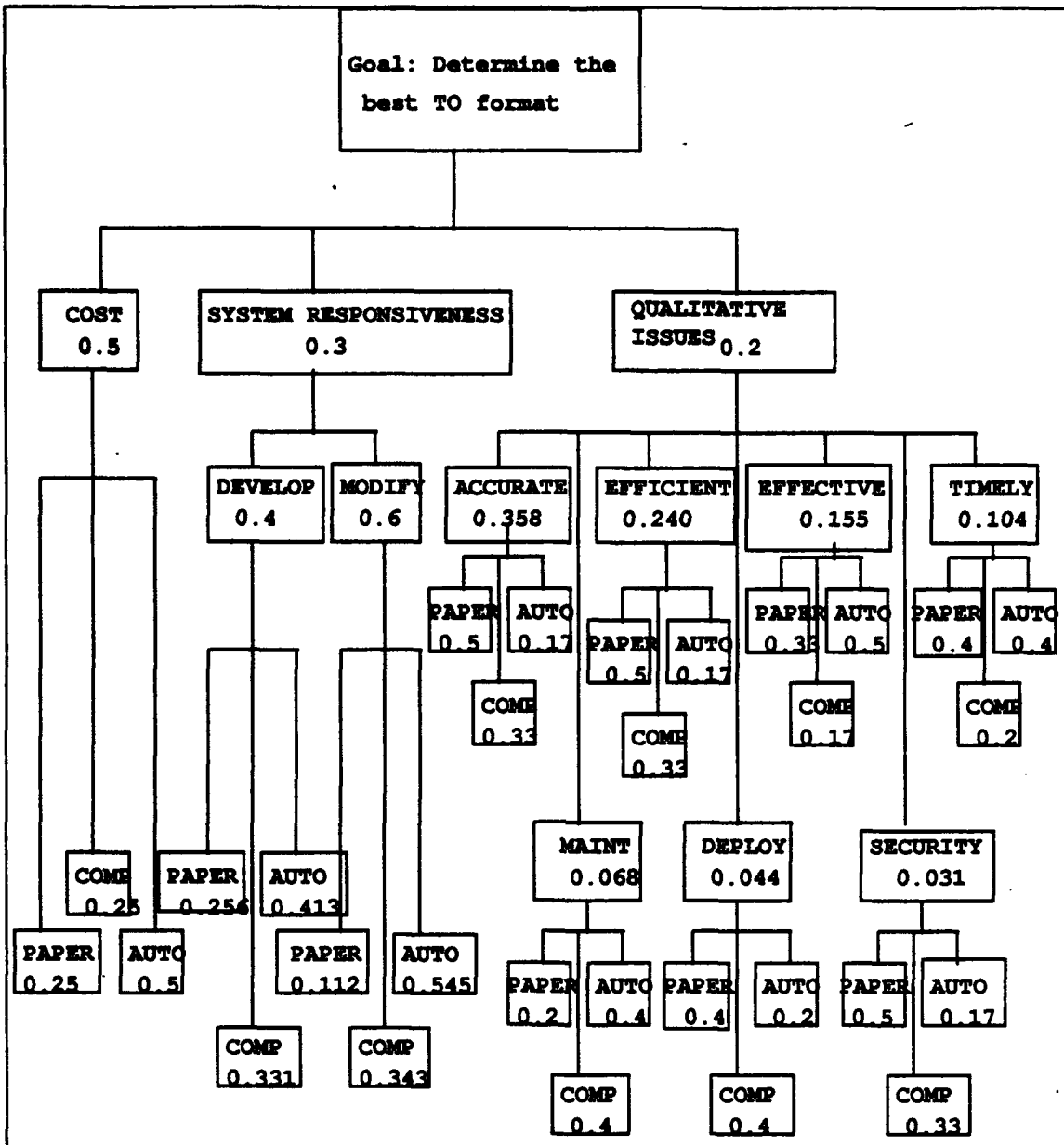


Figure 4: Analytical Hierarchy of Cost Benefit Analysis

**Step 2.** A "system responsiveness" hierarchy was created to determine which format was the most responsive to development and modifications of TOs and to compile weights for each format. The characteristics were develop and modify; the alternatives were paper, computerized, and automated. The output from the SLAM II model was stated in

number of days required to either develop or modify a technical order. We ranked the three formats with respect to number of days required (lowest number receiving the highest ranking). Because most of the TO life cycle is spent in use or modification, the research team determined that modification should be weighted heavier than development. The decisions and data were input into *Expert Choice* and the resulting hierarchy is in Figure 4.

**Step 3.** A "cost" hierarchy was created by simply ranking the costs as computed by the LCCA. The lowest cost format was ranked highest. This ranking produced the weights required for input into the final hierarchy.

**Step 4.** The goal of the final hierarchy (See Figure 4) was to determine which TO format was the best for SPO managers to purchase. To develop this hierarchy we combined the three previous hierarchies. Level one criteria were cost, system responsiveness and qualitative issues. Level two criteria were the combination of criteria from the system responsiveness and qualitative issues hierarchies. The alternatives were paper, computerized and automated. The weights for the level one criteria were determined by the research team. The numbers were subjectively assigned using information from the literature review and an interview with Mr. Clyde Chapman from ASC/AL. Mr. Chapman was chosen because of his broad experiences with AF TOs (33). Each decision maker may have a different opinion about the weights given to each criterion. For example, a

particular PM may decide on weights of 0.5 for QIs, 0.3 for cost and 0.2 for system responsiveness, depending on the needs of the particular system. The weights for the alternatives and level two criteria were all calculated in the previous hierarchies.

**Summary.** The compilation of the smaller hierarchies allowed easier formulation of the final hierarchy. This hierarchy allowed us to weigh qualitative and quantitative issues at the same time and to reach a justifiable decision (discussed in Chapter V).

### **Conclusion**

This chapter details the processes utilized to: 1) collect and evaluate the information from the interviews; 2) determine the amount of time required to develop and modify a TO in each format; 3) determine costs associated with different formats of technical orders; and 4) develop our final hierarchy and determine the best TO format.

First, we discussed the interviews and the assumptions made to ensure that the final list of characteristics used was valid. Next, we discussed the SLAM II simulation model and the number of days required by each format to develop or modify a TO. Then, we discussed the assumptions and equations used to formulate the life cycle cost analysis. Finally, we presented the process used to formulate the

hierarchy; this hierarchy aids in determining which format is the best for a manager to purchase.

Chapter V answers the investigative questions and presents the results and conclusions of the research.

## V. Conclusions and Recommendations

### Thesis Conclusions

Today's Program Managers (PMs) are placing increasing emphasis on efficiency over the life cycle of a weapon system. The driving factor behind this emphasis is budgetary constraints. Life Cycle Costs can be significantly reduced by improving the processes used to develop and operate today's weapon systems. The cost for technical data is a major contributor to the total life cycle cost of a system; however, the quantity of pages and cost per page for paper technical orders (TOs) are increasing at an alarming rate. Computer technology can be used to improve the TO system and thereby lower the cost for technical data and the life cycle cost of a weapon system.

The purpose of this research was to develop a method for conducting a cost benefit analysis prior to implementing changes to the format of a TO. Towards that ends, we sought to answer the following three investigative questions:

**Investigative Question One.** "What life cycle costs, quantitative and qualitative, are associated with the computerization and automation of the Air Force TO process?" This question was answered by the data from interviews and the life cycle cost analysis.

Each interview consisted of two parts: the first part gathered information on the qualitative benefits of the ideal TO and each TO format, while the second part



concentrated on the quantitative costs of each format. The second part of the interviews were used to answer investigative question one. The Life Cycle Cost Analysis (LCCA) used a systems approach to estimate the quantitative life cycle costs. Data from the interviews and the literature review were used to estimate costs for the LCCA.

Response to the second part of the interview was very limited. Only six of the 43 interviewees provided answers to the second part, and the information given was limited to costs for paper format only. Costs for paper TOs varied from \$1,000 to \$2,500 per page for a new TO and \$246 to \$925 per page for changes. The interviewees did not provide all the information requested due to lack of experience with computerized and automated TOs, as well as to lack of familiarity with costs. Appendix 3 contains a blank interview form and a summary of responses to part one of the interviews. Appendix 4 is a summary of the responses obtained from part two of the interviews. Although Continuous Acquisition Life-cycle Support (CALs) has been in existence since 1985, a limited amount of information, concerning computerized and automated TOs, has been passed on to the working level technical order managers (TOMAs). Also, there was a noticeable lack of information about costs, as evidenced by the fact that only six out of 43 responses contained answers to the second part of the interview.

The best source for quantitative costs was the Armstrong Laboratory (AL) cost benefit study conducted on the F-16 aircraft in 1993 (29). This study was used as a starting point for developing the LCCA. The total costs in the AL study were divided by either the number of F-16s or the number of TO pages to determine a per unit cost. Unit costs were needed for developing the LCCA spreadsheet, which was used to estimate the overall life cycle costs for a system. The spreadsheet, as developed, is a generic tool which can be used by any TOMA or PM to help choose either TO conversion or new TO acquisition. The user would need to enter the number of aircraft, the life cycle of the weapon system, and the number of TO pages. We used 1700 aircraft, 10 years and 575,000 pages of TOs for our LCCA.

Costs were categorized as recurring and non-recurring. The non-recurring costs are fixed costs to be incurred within the first year, while the recurring costs are variable costs that are incurred on a yearly basis thereafter. The non-recurring costs are: consulting, data acquisition, hardware, software, telecommunications, and training (Note: Data conversion replaces data acquisition, when the purpose of the analysis is to assess converting paper format TOs into computerized or automated formats).

The recurring costs are: TO usage, training, TO changes, troubleshooting, communications, hardware maintenance, software maintenance, mishaps due to TO errors, mailing costs, telecommunication costs, and AF TO management

manpower. Appendix 9 contains the formulas that were used for each cost category, and Appendix 10 contains the numerical answers for our example. The spreadsheet also discounts the life cycle cost with a discount rate of seven per cent.

The quantitative life cycle costs for our scenario are \$4,338,823,381 for the paper, \$3,389,875,881 for the computerized, and \$1,553,697,556 for automated TO formats. The automated format has the lowest cost and, hence, is the preferable choice, when considering costs. One must keep in mind that the automated and computerized cost formulas in the LCCA are estimates and have not been confirmed by actual historical data; therefore, there is more risk associated with automated and computerized TO formats:

**Investigative Question Two.** "What are the benefits, quantitative and qualitative, associated with the computerization and automation of the Air Force TO process?" This question was answered by data from the literature review, part one of the interviews, and the simulation model. Qualitative benefits obtained from the interview and quantitative benefits obtained from the simulation model were used to answer investigative question two.

Part one of the interviews asked TOMAs within the System Program Offices (SPOs) and Air Logistics Centers (ALCs) to identify benefits of an ideal TO and of each TO format: paper, computerized, and automated. The responses are summarized in Tables 1-5 of Chapter IV. Based on the

responses from 43 interviews, the top seven characteristics were used in our analysis as qualitative benefits. The remaining characteristics were omitted because of a low average score received or insufficient number of ratings by the interviewees. All characteristics which were not rated at least 30 times in two or more areas were discarded from the analysis and assumed to have negligible impact on the CBA. The qualitative benefits for TOs are: accuracy, efficiency, effectiveness, timeliness, maintainability, deployability, and security. Characteristic definitions are included on the interview form, Appendix 3.

In general, quantitative data is more commonly used by decision makers than is qualitative data. Therefore, a simulation model was developed to provide a quantifiable estimate for TO system responsiveness. The simulation model estimated system responsiveness, the time to modify or develop a TO, for the three different formats: paper, computerized, and automated. The model provided the number of days to develop or modify a TO for each TO format. The model ran for a five year period, and an average value was obtained from the simulation model output report. Based on the assumptions and results contained in Appendix 7, the automated format received the highest rating for both TO development and modification, requiring an estimated 356 days to develop and 47 days to modify. The computerized TO format required 444 days to develop and 75 days to modify.

The paper TO format required 574 days to develop and 230 days to modify a TO.

**Investigative Question Three.** "What CBA or decision making technique is most appropriate when deciding among alternative improvements for the Air Force TO system?" The literature review revealed different methods which could be used for conducting this analysis. We used *Expert Choice* to apply the analytical hierarchy process (AHP) because of the need to evaluate both quantitative and qualitative costs and benefits. The interviews and the literature review established that cost, system responsiveness, and qualitative issues (QIs) are three criteria which determine the best TO format. Costs (obtained from the LCCA) are quantitative; System responsiveness (obtained from the simulation model) is a quantitative benefit; and QIs (obtained from the interview process) are qualitative benefits.

Figure 4 in Chapter IV outlines the analytical hierarchy process used for our analysis. Based on the weights given to each of the criteria and the costs and benefits outlined in investigative questions one and two, the best TO format is the automated. The automated format received a rating of 0.45, the computerized format received a rating of 0.29, and the paper format received a value of 0.26. According to the Analytical Hierarchy Process the alternative with the largest rating is the best alternative; therefore, automated is the best TO format to purchase.

## **Recommendations**

**Lessons Learned.** We interviewed functional experts, concentrating specifically on TO managers or TOMAs. There were two reasons why we focused on TOMAs. First, we wanted information from people who are in the acquisition process and deal with TOs; and second, we were constrained by time and the number of people we could interview in the time frame available for this research. If time had permitted it, we would have interviewed PMs.

Our first interview agenda was too long and difficult; the interviewees could not provide the requested information. As a result, we received a limited number of positive responses and a great number of negative responses from our interviewees. The cumbersome format resulted in lack of participation by the interviewees. We corrected this mistake by placing the easier, subjective information in tabular format at the beginning of the interview. We consolidated four pages of questions into a table which fit neatly onto one page. We also moved the more difficult, quantitative historical questions to the back of the interview and made them optional.

**Follow on Research.** As mentioned in the lessons learned section above, we recommend additional interviews be conducted with Program Managers, financial management personnel, and TO users. The interviewers should concentrate on interviewing personnel having experience with computerized and automated TO formats. Our research

revealed that TOMAs are not always as much concerned about costs as perhaps a Program Manager would be. When asked to assess the relative importance of costs or qualitative issues (accuracy, maintainability, efficiency, effectiveness, efficiency, security, deployability, or timeliness) TOMAs responded overwhelmingly that the qualitative issues are more important. In other words, beneficial characteristics outweigh costs.

This analysis was based on rough order of magnitude estimates. Limited historical data is available for computerized and automated TO formats. Testing of these TO formats is taking place on many different weapon systems in many locations (for example the F-16 SPO at Wright-Patterson AFB and the C-130 at Warner Robins ALC). The estimates and assumptions used in this analysis can be verified or refined by including the data from future testing. It is important that good data be obtained from these tests, so that the results can be input into some form of a cost benefit analysis.

The last area of recommended future research is the computer simulation modeling of the entire TO system, or an individual program TO system (For example the F-16). Computer simulation is a powerful tool which allows the decision maker to predict outcomes without wasting resources. In other words, simulation will provide additional decision making data without having to conduct a

physical test on an actual weapon system, which would require expenditures of resources.

### **Conclusion**

This research developed a method for Program Managers to implement when deciding which Technical Order format to purchase for their programs. Costs, benefits, and a CBA procedure were identified by this research. These factors provide the PM with a logical decision making tool that utilizes qualitative and quantitative data. The results from this research can be applied to any program in the acquisition or sustainment arena.

This chapter lists the quantitative costs and the qualitative and quantitative benefits for all three TO formats: paper, computerized and automated. Once the costs and benefits were identified, we developed a decision making tool, based on the Analytical Hierarchy Process, to help the decision maker choose the best format for the applicable program. The quantitative costs for a TO format are: 1.) Non-recurring costs: consulting, data acquisition, hardware, software, telecommunications, and training; and 2.) Recurring costs: TO usage, training, TO changes, troubleshooting, communications, hardware maintenance, software maintenance, mishaps due to TO errors, mailing costs, telecommunication costs, and AF TO management manpower. The qualitative benefits for a TO format are:



accuracy, maintainability, efficiency, effectiveness, security, deployability, and timeliness. A quantitative benefit of any TO format is system responsiveness.

Through the use of a Life Cycle Cost Analysis, it was determined that the automated TO format had the lowest life cycle cost. It was also determined, by using simulation modeling, that automated TOs received the highest rating for system responsiveness. As a result of the interview process, we determined the paper format received the highest rating for QIs. After the data for the three criteria: costs, system responsiveness, and QIs; were input into the AHP software, we determined that the automated format was the best TO format (See Figure 4 and Appendix 11).

The costs, benefits and CBA method developed during this research effort can be applied to any program with minimal effort. The only independent variables required to be changed when using the CBA are quantity of TO pages, quantity of aircraft, and weapon system life cycle. However, additional accuracy can be obtained by further refining assumptions that were used to develop the simulation model, life cycle cost analysis and interview process. The appendices contain the assumptions used to develop the CBA as well as the results from the interviews, which were generalized by including many different System Program Offices.

The data that was input into the LCCA, simulation model, and AHP software contains estimates which may or may

not be accurate. Once further testing is accomplished, the results should be used to update and refine this analysis. The important point to remember is that risks will be incurred when implementing computerized and automated formats because they make use of new technology. The objective of future testing should be twofold: 1) to demonstrate computerization and automation of TOs and 2) to provide good historical data for input into a decision making technique.

## **Appendix 1: Glossary of Definitions.**

**Air Logistics Center (ALC):** Provides the operational technical order support required to field the weapon system. Responsible for all modifications of TOs.

**Analytical Hierarchy Process (AHP):** A rational and systematic approach for finding a solution to a problem. The method allows decision makers to partition large, manageable problems into smaller parts that are easier to handle. It provides decision makers with the ability to include qualitative and quantitative criteria to form a rating for each alternative solution.

**Capital Budgeting:** A quantitative Economic Analysis technique used for capital investment. Capital budgeting and cost analysis involves long term planning decisions for investments using both quantitative and qualitative cost information.

**Continuous Acquisition and Life-cycle Support (CALs):** A DOD and Industry strategy to transition from a paper intensive acquisition and logistics database to a highly automated and integrated database for weapon systems of the 1990's and beyond.

**Cost-Benefit Analysis (CBA):** An analytical procedure to investigate and compare the costs and benefits derived from implementing one alternative over other alternatives.

**Economic Analysis:** A four-step process: 1) identification of possible projects, 2) data collection, 3) determining the best project, and 4) evaluation of implemented projects; that is used to evaluate changes to an organization (21:5).

**Joint Continuous Acquisition Life-cycle Support (JCALS):** A joint program (Air Force, Army, Navy, Marines, and the Defense Logistics Agency (DLA)) organized to implement CALS throughout DoD agencies.

**Life Cycle Cost Analysis:** Analysis of all costs, using a systems prospective, throughout the entire life cycle of a program.

**System Program Office (SPO):** The integrated AFMC organization responsible for cradle-to-grave military system management (26:365).

**Technical Order Management Agency (TOMA):** A person or agency established to oversee the development and acquisition of technical orders.

## Appendix 2: Glossary of Acronyms

AFSC	Air Force Systems Command
AFTO	Air Force Technical Order
AFTOMS	Air Force Technical Order Management System
AFTOS	Air Force Technical Order System
AHP	Analytical Hierarchy Process
ALC	Air Logistics Center
BET	Break-Even Time
CALS	Continuous Acquisition Life-cycle Support
CBA	Cost Benefit Analysis
CSRC	CALS Shared Resource Center
CTOA	Central Technical Order Agency
DCF	Discounted Cash Flow
DOD	Department of Defense
DODI	Department of Defense Instruction
DSSSL	Document Style Semantics and Specification Language
IETM	Interactive Electronic Technical Manuals
ILSP	Integrated Logistics Support Plan
IRR	Internal Rate of Return
IOS	International Organization for Standardization
JCALs	Joint Continuous Acquisition Life-cycle Support
JUSTIS	Joint Uniformed Services Technical Information System
LCC	Life Cycle Cost
LCCA	Life Cycle Cost Analysis
LSA	Logistics Support Analysis
LSAR	Logistics Support Analysis Record
MCDM	Multiple Criteria Decision Making
MIO	Management Integration Office
MNS	Mission Need Statement
NPV	Net Present Value
ORD	Organizational Requirements Document
PM	Program Manager
PMD	Program Management Directive
QI	Qualitative Issues
RC	Resource Centers
ROR	Rate of Return
SGML	Standardized General Markup Language
SPDL	Standard Page Description Language
SPO	System Program Office
TCTO	Time Compliance Technical Order
TMMP	Technical Manual Management Plan
TMPP	Technical Manual Publication Plan
TO	Technical Order
TOC	Technical Order Center
TODCA	Technical Order Distribution Control Authority

TODO            Technical Order Distribution Offices  
TOMA            Technical Order Management Agency  
TQM             Total Quality Management

### Appendix 3: Interviews and Results

**Interview:**

This interview gathers subjective and objective information that will be used to develop a cost benefit analysis for implementing change to Air Force Technical Orders (TOs). Questions 1-6 are subjective (there are no right or wrong answers) and 7-15 are objective (based on historical information). Definitions of key terms are included at the end of this interview.

1. What weapon system(s) are you affiliated with?
2. In which area(s) do you have experience? (Acquisition, Sustainment, or Operations)
4. Which type of TOs do you have experience? (Paper, Computerized, or Automated)
5. In column 2, rank the relative importance of each characteristic (a rank of 1 means this characteristic is the most important characteristic for a TO).
6. Columns 3-5 are three alternative forms of TOs (see definitions below). Score each type of TO columns 3-5) on a scale from 1-5. (1) meaning definitely agree, (2) agree, (3) mostly agree, (4) mostly disagree, and (5) definitely disagree that the corresponding characteristic is a benefit for each type of TO (i.e. if you definitely agree that maintainable is a benefit for paper TOs then place a 1 in the row and column corresponding to maintainable and paper.

CHARACTERISTIC	RANK	PAPER	COMPUTERIZED	AUTOMATED
MAINTAINABLE				
RELIABLE				
SECURITY				
ACCURACY				
EFFICIENT				
EFFECTIVE				
TIMELY				
LOW COST				
DEPLOYABLE				
FLEXIBLE				
?				

\*\*\*The remaining questions are for TO acquisition personnel with financial /cost experience\*\*\*

7. What SPO or ALC are you affiliated with?
8. How many TO pages were purchased for your program?
9. Were the TOs paper, computerized, or automated?
10. What was the total cost for the TOs? Cost per page?
11. What cost benefit analysis method was used?
12. Was a cost benefit analysis required?
13. If no CBA was conducted do you think a CBA would be helpful? Can you recommend a CBA method?
14. What were the costs in the following areas:

AREA	INITIAL COSTS	ANNUAL COST
HARDWARE		
SOFTWARE		
TRAINING		
TELECOMMUNICATIONS		
CONSULTATION		
OTHER?		

15. If you purchased computerized or automated TOs, are the TOs currently in use? Are the users satisfied?

#### DEFINITIONS

PAPER TO: Technical Orders in paper form (Type A)

COMPUTERIZED TO: Paper TO on computer file (Type B or B+)

AUTOMATED TO: Computerized TOs within a data base that can be accessed according to subject. (IETM or Type C)

MAINTAINABLE: Relative ease to make changes, revisions, and corrections.

RELIABLE: Probability the TO will be available and accurate when required.

SECURITY: Ability to prevent unauthorized use of the TO.

ACCURACY: Probability the TO has the correct procedure.

EFFICIENT: Doing the job the smartest/quickest way possible considering costs.

EFFECTIVE: Doing the job the best way possible without considering costs.

TIMELY: Delivery of the TO at or before the system operation.

LOW COST: The relative cost of one system compared to other alternatives.



DEPLOYABLE: The ability to take the TO wherever it is needed (worldwide).

FLEXIBLE: The ability to incorporate new technology and or a better process with minimal disruption and costs.

**Interview Qualitative Results:**

SPO	B2-2				B2-3 (ALL)			
CHARACTERISTIC	RANK	PAPER	COMP	AUTO	RANK	PAPER	COMP	AUTO
MAINTAINABLE					2	4	3	3
RELIABLE					1	2	2	2
SECURITY	3	1	5	5	3	3		
ACCURACY	1	1	5	5	4	2	1	1
EFFICIENT					6	4	2	1
EFFECTIVE	5	1	5	5	8	4	3	1
TIMELY					7	2	3	4
LOW COST					9	2	3	4
DEPLOYABLE					5	4	2	2
FLEXIBLE					10	4	2	2
READABILITY	2	1	5	5				
USABILITY	4	1	5	5				
SPO	B2-4P				B2-5P			
CHARACTERISTIC	RANK	PAPER	COMP	AUTO	RANK	PAPER	COMP	AUTO
MAINTAINABLE	5	4	3	2	3	3	1	2
RELIABLE	4	3	3	2	2	2	5	3
SECURITY	6	4	2	3				
ACCURACY	1	2	2	2	1	1	2	4
EFFICIENT	3	3	4	3				
EFFECTIVE	2	4	4	4	4	4	4	1
TIMELY	7	5	2	3				
LOW COST	10	5	4	4				
DEPLOYABLE	8	5	4	4	5	5	3	5
FLEXIBLE	9	4	2	3				
SPO	B2-6P				B2-7 (P&C)			
CHARACTERISTIC	RANK	PAPER	COMP	AUTO	RANK	PAPER	COMP	AUTO
MAINTAINABLE	3	3	1	2	2	1	1	1
RELIABLE	2	2	5	3	3	3	3	3
SECURITY					10	5	3	1
ACCURACY	1	1	2	4	1	1	1	1
EFFICIENT					4	4	2	1
EFFECTIVE	4	4	4	1	6	5	5	5
TIMELY					5	5	3	1
LOW COST					7	1	3	3
DEPLOYABLE	5	5	3	5	8	1	5	5
FLEXIBLE					9	5	5	5

SPO	ASC/ALX	F-15			ASC/ALX	I-16		
CHARACTERISTIC	RANK	PAPER	COMP	AUTO	RANK	PAPER	COMP	AUTO
MAINTAINABLE	4	1	1	1	4	1	1	1
RELIABLE								
SECURITY	7	1	1	1	7	1	1	1
ACCURACY	1	1	1	1	1	1	1	1
EFFICIENT	5	2	1	1	5	2	1	1
EFFECTIVE	6	2	1	1	6	2	1	1
TIMELY	3	1	1	1	3	1	1	1
LOW COST								
DEPLOYABLE	8	1	1	1	8	1	1	1
FLEXIBLE	9	3	1	1	9	3	1	1
PRICE	1	1	1	1	1	1	1	1
SPO	ASC/ALX	T1A			ASC/ALX	JPATS		
CHARACTERISTIC	RANK	PAPER	COMP	AUTO	RANK	PAPER	COMP	AUTO
MAINTAINABLE	4	1	1	1	4	1	1	1
RELIABLE								
SECURITY	7	1	1	1	7	1	1	1
ACCURACY	1	1	1	1	1	1	1	1
EFFICIENT	5	2	1	1	5	2	1	1
EFFECTIVE	6	2	1	1	6	2	1	1
TIMELY	3	1	1	1	3	1	1	1
LOW COST								
DEPLOYABLE	8	1	1	1	8	1	1	1
FLEXIBLE	9	3	1	1	9	3	1	1
PRICE	1	1	1	1	1	1	1	1
SPO	ASC/ALX	RE			ASC/ALX	(EF-111)		
CHARACTERISTIC	RANK	PAPER	COMP	AUTO	RANK	PAPER	COMP	AUTO
MAINTAINABLE	4	1	1	1	4	1	1	1
RELIABLE								
SECURITY	7	1	1	1	7	1	1	1
ACCURACY	1	1	1	1	1	1	1	1
EFFICIENT	5	2	1	1	5	2	1	1
EFFECTIVE	6	2	1	1	6	2	1	1
TIMELY	3	1	1	1	3	1	1	1
LOW COST								
DEPLOYABLE	8	1	1	1	8	1	1	1
FLEXIBLE	9	3	1	1	9	3	1	1
PRICE	1	1	1	1	1	1	1	1

SPO	ASC	/ALX	ENGINES		ASC	/YO		
CHARACTERISTIC	RANK	PAPER	COMP	AUTO	RANK	PAPER	COMP	AUTO
MAINTAINABLE	4	1	1	1	2		1	1
RELIABLE					3		4	4
SECURITY	7	1	1	1	6			
ACCURACY	1	1	1	1	1		4	
EFFICIENT	5	2	1	1	4		1	1
EFFECTIVE	6	2	1	1	7			
TIMELY	3	1	1	1	8	1	2	2
LOW COST					5	2	3	3
DEPLOYABLE	8	1	1	1	9	3	3	3
FLEXIBLE	9	3	1	1	10	4		
	1	1	1	1	8	5	3	3
SPO	412	E-3A			412	/LGLL	EAFB	B-1B
	LSSL				LSS			
CHARACTERISTIC	RANK	PAPER	COMP	AUTO	RANK	PAPER	COMP	AUTO
MAINTAINABLE	3	4	3	3	2			2
RELIABLE	1		2	4	1	1	5	
SECURITY					3	2	2	1
ACCURACY	2	5	3	3	1	1		
EFFICIENT					5			
EFFECTIVE			4	1	6	2	3	3
TIMELY	7	1	5	3	4		2	
LOW COST	6	3	1	1	8	3		
DEPLOYABLE	5		2		8	3	1	1
FLEXIBLE					9		1	
SUPPORTABILITY	4	3	1	2	7	4	5	4
SPO	412	/LGLL	EAFB	B-2	412	(ACM)		
	LSS				LSS			
CHARACTERISTIC	RANK	PAPER	COMP	AUTO	RANK	PAPER	COMP	AUTO
MAINTAINABLE	2			2	2			2
RELIABLE	1	1	5		1	1	5	
SECURITY	3	2	2	1	3	2	2	1
ACCURACY	1	1			1	1		
EFFICIENT	5				5			
EFFECTIVE	6	2	3	3	6	2	3	3
TIMELY	4		2		4		2	
LOW COST	8	3			8	3		
DEPLOYABLE	8	3	1	1	8	3	1	1
FLEXIBLE	9		1		9		1	
SUPPORTABILITY	7	4	5	4	7	4	5	4

SPO	412LSS	/LGLL	EAFB	F-16	412LSS	EAFB		F-22
CHARACTERISTIC	RANK	PAPER	COMP	AUTO	RANK	PAPER	COMP	AUTO
MAINTAINABLE	2			2	2			2
RELIABLE	1	1	5		1	1	5	
SECURITY	3	2	2	1	3	2	2	1
ACCURACY	1	1			1	1		
EFFICIENT	5				5			
EFFECTIVE	6	2	3	3	6	2	3	3
TIMELY	4		2		4		2	
LOW COST	8	3			8	3		
DEPLOYABLE	8	3	1	1	8	3	1	1
FLEXIBLE	9		1		9		1	
SUPPROTABILITY	7	4	5	4	7	4	5	4
SPO	412LSS	/LGLL	EAFB	C-17	412LSS			AC-130U
CHARACTERISTIC	RANK	PAPER	COMP	AUTO	RANK	PAPER	COMP	AUTO
MAINTAINABLE	3	4	3	3	3	4	3	3
RELIABLE	1		2	4	1		2	4
SECURITY								
ACCURACY	2	5	3	3	2	5	3	3
EFFICIENT								
EFFECTIVE			4	1			4	1
TIMELY	7	1	5	3	7	1	5	3
LOW COST	6	3	1	1	6	3	1	1
DEPLOYABLE	5		2		5		2	
FLEXIBLE								
SUPPORTABILITY	4	3	1	2	4	3	1	2
SPO	C-130	3 P&C			C-130	1 P&C		
CHARACTERISTIC	RANK	PAPER	COMP	AUTO	RANK	PAPER	COMP	AUTO
MAINTAINABLE	7	5	4	2	4	4	3	2
RELIABLE	4	3	3	2	7	3	2	2
SECURITY	8	2	3	3	9	2	4	4
ACCURACY	1	2	2	2	2	3	3	3
EFFICIENT	5	3	2	2	5	4	3	3
EFFECTIVE	3	2	2	1	8	3	2	2
TIMELY	2	3	4	5	1	4	2	2
LOW COST	6	4	2	3	11	4	3	2
DEPLOYABLE	10	4	4	3	6	2	3	3
FLEXIBLE					10	4	2	2
SUPPORTABILITY								
USABILITY					3	4	2	2

SPO	C-130	2 P&C			F-15			
CHARACTERISTIC	RANK	PAPER	COMP	AUTO	RANK	PAPER	COMP	AUTO
MAINTAINABLE	8	1	1	1				
RELIABLE	1	3	3	3				
SECURITY	9	3	5	5	2	3	3	3
ACCURACY	2	1	1	1	1	1	1	1
EFFICIENT	5	2	2	2	4	4	3	1
EFFECTIVE	3	4	4	4				
TIMELY	4	3	3	3	3	1	1	1
LOW COST	7	3	4	4	7	4	3	3
DEPLOYABLE	10	4	3	3	6	1	3	3
FLEXIBLE	6	3	3	3	5	1	1	1
SPO	F-15				F-15			
CHARACTERISTIC	RANK	PAPER	COMP	AUTO	RANK	PAPER	COMP	AUTO
MAINTAINABLE								
RELIABLE								
SECURITY	2	3	3	3	2	3	3	3
ACCURACY	1	1	1	1	1	1	1	1
EFFICIENT	4	4	3	1	4	4	3	1
EFFECTIVE								
TIMELY	3	1	1	1	3	1	1	1
LOW COST	7	4	3	3	7	4	3	3
DEPLOYABLE	6	1	3	3	6	1	3	3
FLEXIBLE	5	1	1	1	5	1	1	1
SPO	F-15				F-16			
CHARACTERISTIC	RANK	PAPER	COMP	AUTO	RANK	PAPER	AUTO	
MAINTAINABLE					7	5	1	
RELIABLE					5	5	1	
SECURITY	2	3	3	3	9	5	3	
ACCURACY	1	1	1	1	3	5	1	
EFFICIENT	4	4	3	1	2	5	1	
EFFECTIVE					1	5	1	
TIMELY	3	1	1	1	4	5	1	
LOW COST	7	4	3	3	8	5	5	
DEPLOYABLE	6	1	3	3	6	2	1	
FLEXIBLE	5	1	1	1				

SPO	F-16				F-16		
CHARACTERISTIC	RANK	PAPER	AUTO		RANK	PAPER	AUTO
MAINTAINABLE	7	5	1		7	5	1
RELIABLE	5	5	1		5	5	1
SECURITY	9	5	3		9	5	3
ACCURACY	3	5	1		3	5	1
EFFICIENT	2	5	1		2	5	1
EFFECTIVE	1	5	1		1	5	1
TIMELY	4	5	1		4	5	1
LOW COST	8	5	5		8	5	5
DEPLOYABLE	6	2	1		6	2	1
FLEXIBLE							
SPO	F-16				F-16		
CHARACTERISTIC	RANK	PAPER	AUTO		RANK	PAPER	AUTO
MAINTAINABLE	7	5	1		7	5	1
RELIABLE	5	5	1		5	5	1
SECURITY	9	5	3		9	5	3
ACCURACY	3	5	1		3	5	1
EFFICIENT	2	5	1		2	5	1
EFFECTIVE	1	5	1		1	5	1
TIMELY	4	5	1		4	5	1
LOW COST	8	5	5		8	5	5
DEPLOYABLE	6	2	1		6	2	1
FLEXIBLE							
SPO	F-16				F-16		
CHARACTERISTIC	RANK	PAPER	AUTO		RANK	PAPER	AUTO
MAINTAINABLE	7	5	1		7	5	1
RELIABLE	5	5	1		5	5	1
SECURITY	9	5	3		9	5	3
ACCURACY	3	5	1		3	5	1
EFFICIENT	2	5	1		2	5	1
EFFECTIVE	1	5	1		1	5	1
TIMELY	4	5	1		4	5	1
LOW COST	8	5	5		8	5	5
DEPLOYABLE	6	2	1		6	2	1
FLEXIBLE							

SPO	F-16				F-16		
CHARACTERISTIC	RANK	PAPER	AUTO		RANK	PAPER	AUTO
MAINTAINABLE	7	5	1		7	5	1
RELIABLE	5	5	1		5	5	1
SECURITY	9	5	3		9	5	3
ACCURACY	3	5	1		3	5	1
EFFICIENT	2	5	1		2	5	1
EFFECTIVE	1	5	1		1	5	1
TIMELY	4	5	1		4	5	1
LOW COST	8	5	5		8	5	5
DEPLOYABLE	6	2	1		6	2	1
FLEXIBLE							
SPO	F-16				F-16		
CHARACTERISTIC	RANK	PAPER	AUTO		RANK	PAPER	AUTO
MAINTAINABLE	7	5	1		7	5	1
RELIABLE	5	5	1		5	5	1
SECURITY	9	5	3		9	5	3
ACCURACY	3	5	1		3	5	1
EFFICIENT	2	5	1		2	5	1
EFFECTIVE	1	5	1		1	5	1
TIMELY	4	5	1		4	5	1
LOW COST	8	5	5		8	5	5
DEPLOYABLE	6	2	1		6	2	1
FLEXIBLE							
SPO	F-16				B2-1	AUTO	
CHARACTERISTIC	RANK	PAPER	AUTO		RANK		
MAINTAINABLE	7	5	1		6		
RELIABLE	5	5	1		7		
SECURITY	9	5	3		9		
ACCURACY	3	5	1		8		
EFFICIENT	2	5	1		2		
EFFECTIVE	1	5	1		3		
TIMELY	4	5	1		1		
LOW COST	8	5	5		4		
DEPLOYABLE	6	2	1		5		
FLEXIBLE							



**Appendix 4: Interview Quantitative Results**

SPO		ASC/ALX	ASC/YO	F-16
Question 8	QUANTITY TO	5700	4	
	QUANTITY PAGES	1,140,000	2124	2 M PAGES
Question 9	FORMAT	PAPER	PAPER	PAPER/AUTO
Question 10	COSTS	\$580/PAGE	\$522,666 / \$246 PAGE	
Question 11	CBA	NO	NO	NO
Question 12	CBA REQUIRED	NO	NO	NO
Question 13	CBA WILL HELP	YES	YES	YES (BROOKS)
Question 14	COSTS CAPITAL EXP.		\$12000 PER WORK CENTER	
	TRAINING			
	COMPUTER SW			
	TELECOM			
	CONVERSION COST			\$70 M
Question 15		NO		TEST ANG @ IA
Question 16	CHANGES	\$3,420,000/YR	\$580/PAGE	\$1.5 M / YR

SPO		B-2	F-15	C-130
Question 8	QUANTITY TO	490 (DEL) / 2200 (ID)	5000	30,000 - 35,000
	QUANTITY PAGES	330,000	500,000	
Question 9	FORMAT	PAPER	PAPER	PAPER
Question 10	COSTS	\$825M TOT (\$2500/PG)	\$1000 NEW \$350 CHNG	\$1200 NEW \$925 CHANGE
Question 11	CBA	NO	NO	NO ( CONTR . PROPOSED)
Question 12	CBA REQUIRED	NO	NO	NO
Question 13	CBA WILL HELP	YES	YES	YES
Question 14	COSTS CAPITAL EXP.	\$300M	NONE	
	TRAINING		SYS 230 COST X (#) PEOPLE	
	COMPUTER SW		NONE	
	TELECOM		NONE	
	CONVERSION COST			
Question 15		TESTING	N/A	TESTING
Question 16	CHANGES	N/A	1500-2000 PAGES \$350-450K	5000 PAGES

## Appendix 5: CSRC Business Case Analysis

### Strategic Questions to be Answered by the C-17 T.O. Business Case Analysis

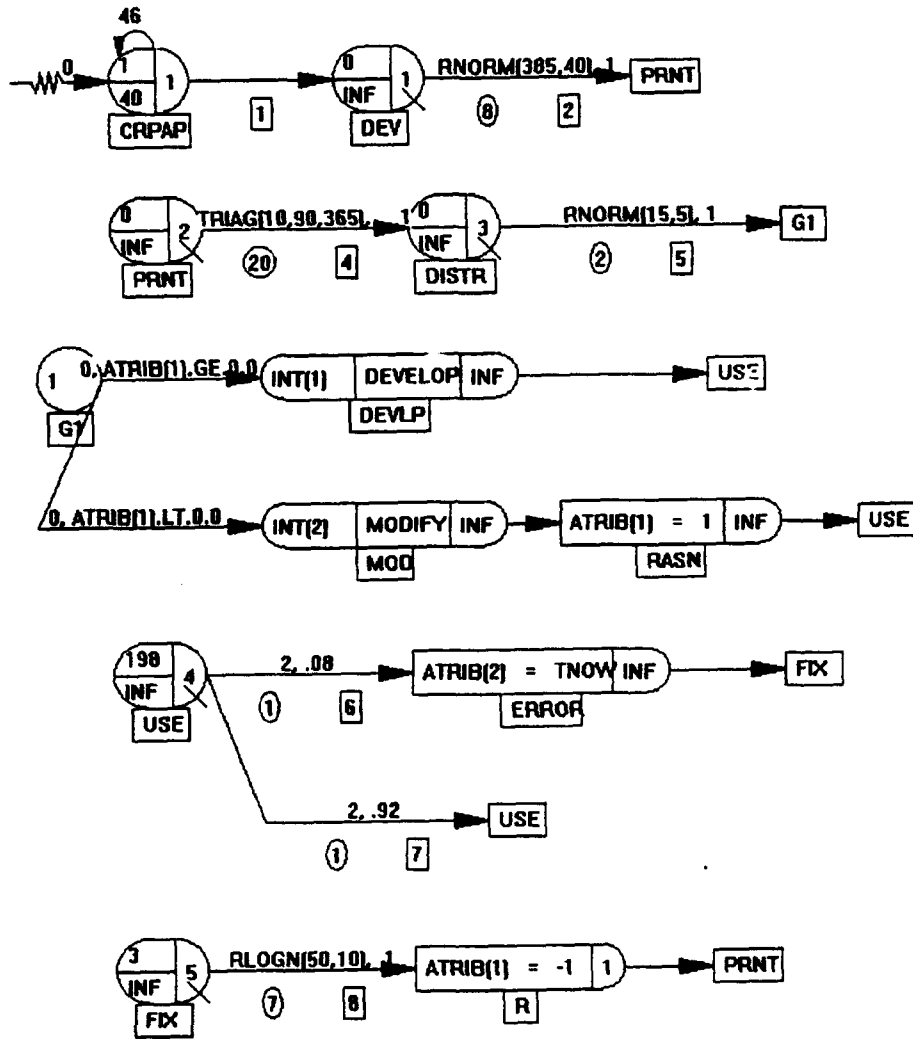
1. What is the cost of acquiring and maintaining paper Tech Orders?
2. What is the cost of acquiring and maintaining digital Tech Orders?
3. What is the cost of converting paper to digital today?
4. What is the cost of converting paper to digital when JCALS arrives?
5. What is the most you would be willing to pay McDonnell Douglas for paper changes?
6. What is the most you would be willing to pay McDonnell Douglas for digital changes?

#### Other Questions?

1. How much do C-5 T.O. changes cost?
2. What are the fixed and variable costs for changing and distributing paper T.O.s?
3. When compared with the C-5 program, how will C-17 T.O. costs differ based on...
  - a. # of aircraft deployed
  - b. basing modes
  - c. change in maintenance philosophy
  - d. # of personnel assigned to maintenance
4. C-5 T.O. changes are prepared by the prime contractor. Can costs be reduced if brought in-house or competed?
  - a. ATOS scenario
  - b. ADMAPS scenario
  - c. Competed scenario
5. Of all T.O. changes managed by TIRT, what percent are C-5 specific?
6. What are the non-financial benefits of digital T.O.s? (e.g. better educated workforce, timeliness, accuracy, motivations, etc.).
7. What are the indirect costs of TO change management?
8. What is the cost of the network infrastructure needed to support digital TOs?
9. How much does a Type A document cost? (type B-, B, B+, C)

## Appendix 6: SLAM II Models and Summary Reports

PAPER MODEL:



PAPER SUMMARY OUTPUT REPORT:

S L A M I I S U M M A R Y R E P O R T

SIMULATION PROJECT THESIS

BY PARSONS&BERGIN

DATE 6/ 1/1994

RUN NUMBER 1 OF 1

CURRENT TIME .1825E+04

STATISTICAL ARRAYS CLEARED AT TIME .0000E+00

\*\*STATISTICS FOR VARIABLES BASED ON OBSERVATION\*\*

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO.OF OBS
DEVELOP	.574E+03	.898E+02	.156E+00	.417E+03	.761E+03	28
MODIFY	.230E+03	.796E+02	.346E+00	.868E+02	.441E+03	81

\*\*FILE STATISTICS\*\*

FILE NUMBER	LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAIT TIME
1	DEV QUEUE	.785	.715	3	1	35.834
2	PRNT QUEUE	.000	.000	0	0	.000
3	DIST QUEUE	.152	.454	3	0	2.503
4	USE QUEUE	206.778	11.081	227	227	331.317
5	FIX QUEUE	.171	.758	6	0	3.751
6	CALENDAR	22.436	3.089	29	21	14.587

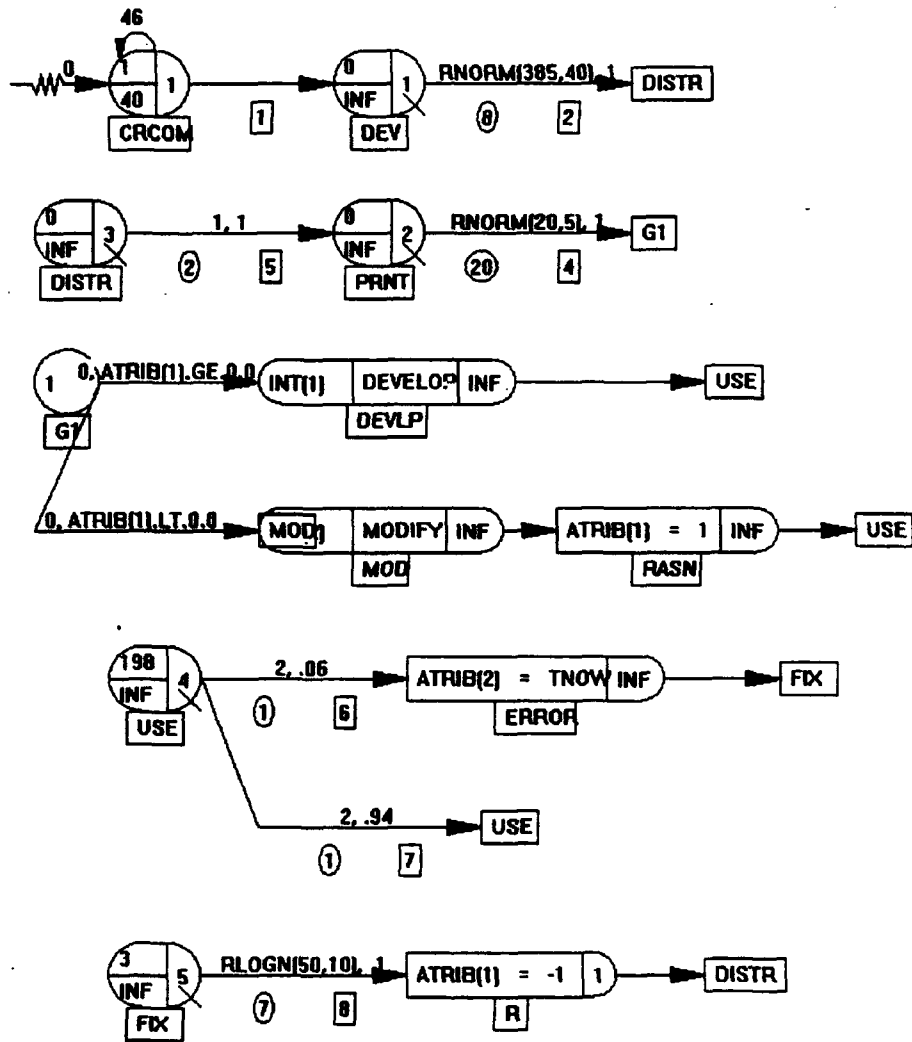
\*\*REGULAR ACTIVITY STATISTICS\*\*

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1	.0000	.0000	1	0	40

\*\*SERVICE ACTIVITY STATISTICS\*\*

ACT NUM	ACT START	LABEL OR NODE	SER CAP	AVERAGE UTIL	STD DEV	CUR UTIL	AVERAGE BLOCK	MAX IDL TME/SER	MAX BSY TME/SER	ENT CNT
2	DEV	QUEUE	8	7.289	1.74	8	.00	8.00	8.00	31
4	PRNT	QUEUE	20	9.898	2.92	9	.00	20.00	16.00	111
5	DIST	QUEUE	2	.891	.82	2	.00	2.00	2.00	109
6	USE	QUEUE	1	.088	.28	1	.00	116.00	4.00	80
7	USE	QUEUE	1	.912	.28	0	.00	4.00	116.00	832
8	FIX	QUEUE	7	2.375	1.71	1	.00	7.00	7.00	89

COMPUTERIZED MODEL:



COMPUTERIZED SUMMARY OUTPUT REPORT:

S L A M I I S U M M A R Y R E P O R T

SIMULATION PROJECT THESIS

BY PARSONS&BERGIN

DATE 6/ 1/1994

RUN NUMBER 1 OF 1

CURRENT TIME .1825E+04

STATISTICAL ARRAYS CLEARED AT TIME .0000E+00

\*\*STATISTICS FOR VARIABLES BASED ON OBSERVATION\*\*

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO.OF OBS
DEVELOP	.444E+03	.342E+02	.771E-01	.333E+03	.495E+03	30
MODIFY	.749E+02	.160E+02	.214E+00	.462E+02	.131E+03	69

\*\*FILE STATISTICS\*\*

FILE NUMBER	LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAIT TIME
1	DEV QUEUE	1.013	.837	3	1	46.223
2	PRNT QUEUE	.000	.000	0	0	.000
3	DIST QUEUE	.000	.000	0	0	.000
4	USE QUEUE	216.794	10.913	235	235	344.942
5	FIX QUEUE	.145	.712	6	0	4.067
6	CALENDAR	12.371	1.833	19	13	8.491

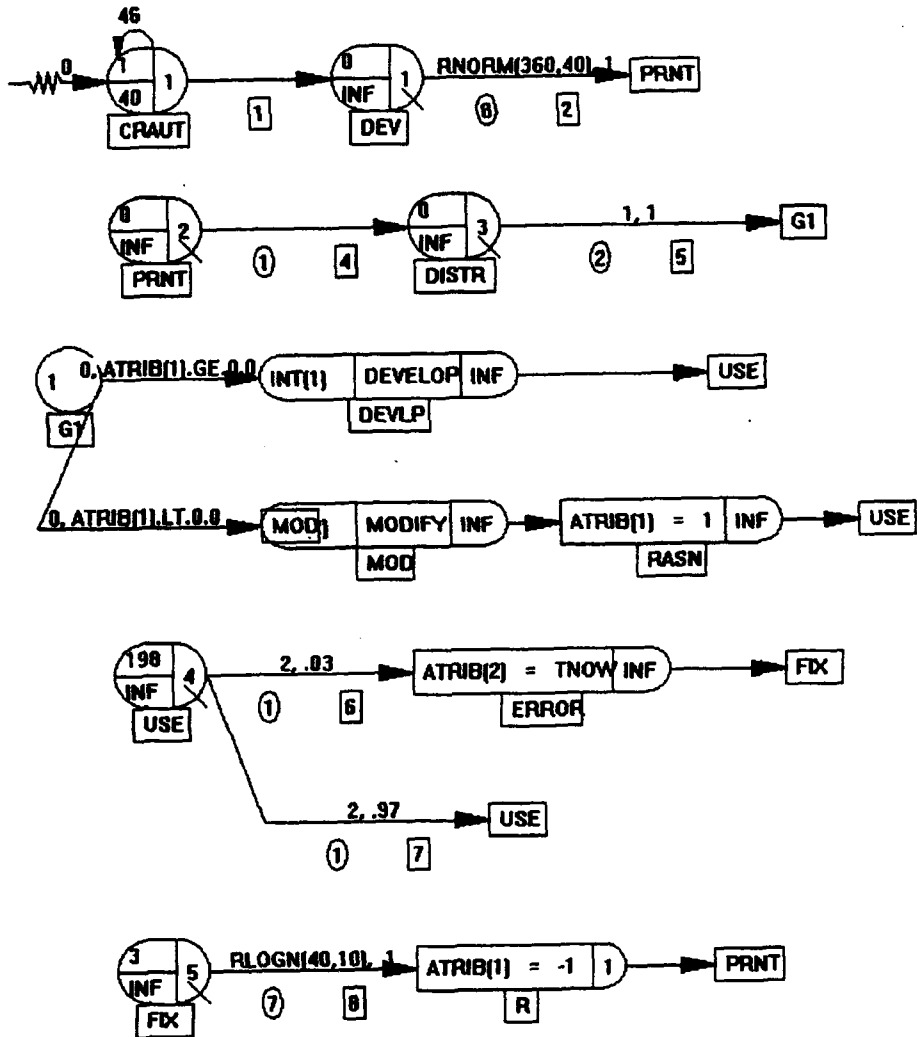
\*\*REGULAR ACTIVITY STATISTICS\*\*

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1	.0000	.0000	1	0	40

\*\*SERVICE ACTIVITY STATISTICS\*\*

ACT NUM	ACT START	LABEL OR NODE	SER CAP	AVERAGE UTIL	STD DEV	CUR UTIL	AVERAGE BLOCK	MAX TME/SER	IDL TME/SER	MAX BSY	ENT CNT
2	DEV	QUEUE	8	7.292	1.74	8	.00	8.00	8.00	31	
5	DIST	QUEUE	2	.056	.23	1	.00	2.00	2.00	101	
4	PRNT	QUEUE	20	1.118	1.19	2	.00	20.00	7.00	99	
6	USE	QUEUE	1	.068	.25	1	.00	118.00	4.00	62	
7	USE	QUEUE	1	.932	.25	0	.00	4.00	118.00	850	
8	FIX	QUEUE	7	1.922	1.70	1	.00	7.00	7.00	71	

AUTOMATED MODEL:





AUTOMATED SUMMARY OUTPUT REPORT:

S L A M I I S U M M A R Y R E P O R T

SIMULATION PROJECT THESIS

BY PARSONS&BERGIN

DATE 6/ 1/1994

RUN NUMBER 1 OF 1

CURRENT TIME .1825E+04

STATISTICAL ARRAYS CLEARED AT TIME .0000E+00

\*\*STATISTICS FOR VARIABLES BASED ON OBSERVATION\*\*

	MEAN VALUE	STANDARD DEVIATION	COEFF. OF VARIATION	MINIMUM VALUE	MAXIMUM VALUE	NO.OF OBS
DEVELOP	.356E+03	.469E+02	.132E+00	.251E+03	.450E+03	32
MODIFY	.456E+02	.122E+02	.267E+00	.259E+02	.809E+02	47

\*\*FILE STATISTICS\*\*

FILE NUMBER	LABEL/TYPE	AVERAGE LENGTH	STANDARD DEVIATION	MAXIMUM LENGTH	CURRENT LENGTH	AVERAGE WAIT TIME
1	DEV QUEUE	.086	.280	1	0	3.927
2	PRNT QUEUE	.000	.000	0	0	.000
3	DIST QUEUE	.000	.000	0	0	.000
4	USE QUEUE	220.049	11.055	240	240	348.603
5	FIX QUEUE	.058	.406	3	0	2.630
6	CALENDAR	10.130	1.503	15	9	7.536

\*\*REGULAR ACTIVITY STATISTICS\*\*

ACTIVITY INDEX/LABEL	AVERAGE UTILIZATION	STANDARD DEVIATION	MAXIMUM UTIL	CURRENT UTIL	ENTITY COUNT
1	.0000	.0000	1	0	40

\*\*SERVICE ACTIVITY STATISTICS\*\*

ACT NUM	ACT START	LABEL OR NODE	SER CAP	AVERAGE UTIL	STD DEV	CUR UTIL	AVERAGE BLOCK	MAX TME/SER	IDL MAX TME/SER	BSY MAX TME/SER	ENT CNT
2	DEV.	QUEUE	8	7.012	1.69	8	.00	8.00	8.00	8.00	32
4	PRNT	QUEUE	1	.000	.00	0	.00	137.71	.00	.00	79
5	DIST	QUEUE	2	.043	.21	0	.00	2.00	2.00	2.00	79
6	USE	QUEUE	1	.041	.20	1	.00	136.00	2.00	2.00	37
7	USE	QUEUE	1	.959	.20	0	.00	2.00	136.00	136.00	875
8	FIX	QUEUE	7	1.091	1.40	0	.00	7.00	7.00	7.00	47

## Appendix 7: SLAM II Assumptions

The simulation models contain rough order magnitude (ROM) estimates for all time distributions. Basically the paper model simulates the current paper (G022) system. Computerized and automated systems have very similar develop and review processes and the main differences between them and the paper model is the print process. The computerized model assumes the TOs are printed at the base level and the automated model assumes the TO is never printed.

Time distributions for develop, print, distribute, use, and fix TO processes were estimated by the research team, based on the literature review and interviews, and inputted into the model. The estimates are as follows:

### All Three Models Assume:

1. There are approximately 200,000 TOs in use in the USAF inventory and another 10,000 TOs at the ALC to be fixed.
2. Eight thousand TOs are created annually.
3. All models follow the same chronological processes: develop, print, distribute, use, and fix except the paper model includes a print process prior to distribution and the computerized requires printing after the distribution process. The automated model does not require the print process. If a current TO requires a change, it does not require the develop process because the develop process is for new TOs.

### The Paper Model Assumes:

1. Develop TO: follows a normal distribution with a mean of 385 days and standard deviation (SD) of 40 days and contractor's capacity is unlimited.
2. Print TO: follows a triangular distribution with a mean of 90 days, a low of ten and a high of 365 days. Capacity is 20,000 TOs.
3. Distribute TO: follows a normal distribution with a mean of 15 days, SD of 5 days and capacity of 2,000 TOs.
4. Use TO: Eight % of TOs require changes annually.
5. Fix TO: follows a log normal distribution with a mean of 50 days, SD of 10 days, and capacity of 7,000 TOs.

**The Computerized Model Assumes:**

1. Develop TO: follows a normal distribution with a mean of 385 days and standard deviation (SD) of 40 days and contractor's capacity is unlimited.
2. Print TO: follows a normal distribution with a mean of 20 days, SD of 5 days
3. Distribute TO: requires just one day and has no capacity limits for TO quantities.
4. Use TO: Six % of TOs require changes annually.
5. Fix TO: follows a log normal distribution with a mean of 50 days, SD of 10 days, and capacity of 7,000 TOs.

**The Automated Model Assumes:**

1. Develop TO: follows a normal distribution with a mean of 360 days and standard deviation (SD) of 40 days and contractor's capacity is unlimited.
2. Print TO: not required.
3. Distribute TO: requires just one day and has no capacity limits for TO quantities.
4. Use TO: Three % of TOs require changes annually.
5. Fix TO: follows a log normal distribution with a mean of 40 days, SD of 10 days, and capacity of 7,000 TOs.

**Appendix 8: Assumptions for Life Cycle Cost  
Analysis (LCCA) Formulation**

**KEY ASSUMPTIONS:** Cost estimates for paper and computer TO formats were obtained from the literature review and interview processes. Additionally, this analysis contains rough order magnitude (ROM) cost estimates developed by the research team when literature review and interview data did not provide the estimates.

Cost estimates for automated TO format was obtained from the Armstrong Laboratory cost benefit study conducted on the F-16 aircraft. This study converted the Armstrong Laboratory's ROM estimates into unit costs for one aircraft and TO page.

Costs are divided into two categories, non recurring and recurring, for this LCCA.

**NON RECURRING COSTS**

**CONSULT:** Consulting includes systems engineering and program management efforts required to develop a particular TO format.

**FORMAT**

**ASSUMPTIONS / RATIONALE**

**PAPER:** Paper format already developed: \$0 cost.

**COMPUTERIZED:** ROM estimate \$5 / page (pg.).

**AUTOMATED:** \$12.8 Million M)/575,000 pgs = \$22.3/pg  
(29:32).

**DATA:** The technical order final product to be delivered to the end user.

**FORMAT**

**ASSUMPTIONS / RATIONALE**

**PAPER:** Based on interviews \$1,000 / pg.

**COMPUTERIZED:** ROM estimate \$1200 / pg.

**AUTOMATED:** ROM \$400 / pg due to increased efficiency from Air Force Authoring System.

**HARDWARE:** Hardware required to support the alternative TO.

**FORMAT**                    **ASSUMPTIONS / RATIONALE**

**PAPER:**                    Basecase assumed \$0 to support paper format  
other format costs are relative to paper.

**COMPUTERIZED:** ROM estimate \$25,000 / aircraft (acft).

**AUTOMATED:**                \$97.7 M / 1700 aircraft = \$57,471/acft  
(29:32).

**SOFTWARE:** Software required to support TO format..

**FORMAT**                    **ASSUMPTIONS / RATIONALE**

**PAPER:**                    Basecase assumes \$0 to support paper.

**COMPUTERIZED:** ROM estimate \$2 / pg.

**AUTOMATED:**                \$6.7 M / 575,000 pages = \$11.7 / pg  
(29:32).

**TELECOMMUNICATIONS:** Telecommunications will be implemented  
regardless of which format is chosen so this is not a  
relevant cost for this life cycle analysis.

**TRAINING:** Initial training required to support TO  
format.

**FORMAT**                    **ASSUMPTIONS / RATIONALE**

**PAPER:**                    Basecase assumes \$0 to support paper.

**COMPUTERIZED:** ROM estimate 1/4 of automated training costs.

**AUTOMATED:**                \$2.5 M / 1700 acft = \$1470 / acft (29:32).

**DATA CONVERSION:** Cost to convert data from paper into  
another format.

**FORMAT**                    **ASSUMPTIONS / RATIONALE**

**PAPER:**                    Basecase assumes \$0 to support paper (no  
conversion necessary).

**COMPUTERIZED:** \$15 / pg estimate from interview (32)

**AUTOMATED:**                \$54.6 M / 575,000 pgs or \$95 / pg (29:32).

## RECURRING / ANNUAL COSTS

**TO USAGE:** Costs due to manual posting of TO changes, TO research time, weight required for deployment, and effort required to submit AFTO 22 change requests.

### FORMAT                      ASSUMPTIONS / RATIONALE

**PAPER:**                      \$73.4 M / 1700 acft = \$43,177 / acft  
(29:33).

**COMPUTERIZED:** Same as paper format or \$43,177 / acft.

**AUTOMATED:**                \$8.4 M / 1700 acft = \$4,941 / acft  
(29:33).

**TRAINING:** Recurring training required to support TO format.

### FORMAT                      ASSUMPTIONS / RATIONALE

**PAPER:**                      Basecase assumes \$0.

**COMPUTERIZED:** Additional follow on computer training negligible and to be accomplished on the job.

**AUTOMATED:**                Additional follow on computer training negligible and to be accomplished on the job.

**TO CHANGES:** Cost to correct deficiencies within TOs.

### FORMAT                      ASSUMPTIONS / RATIONALE

**PAPER:**                      Eight percent of TOs require annual changes at \$500 / pg (1:vii).

**COMPUTERIZED:** ROM estimate 6 percent of TOs require annual changes at \$300 / pg.

**AUTOMATED:**                ROM estimate 3 percent of TOs require annual changes at \$300 / pg.

**DIAGNOSTICS:** Costs due to maintenance troubleshooting time, retest OKs, repair time.

**FORMAT**                    **ASSUMPTIONS / RATIONALE**

**PAPER:**                    \$146.7 M / 1700 acft = \$86,309 / acft.

**COMPUTERIZED:** Same as paper format.

**AUTOMATED:**                \$100 M / 1700 acft = \$58,824 / acft.

**COMMUNICATION:** Costs due to information system interactions and part ordering.

**FORMAT**                    **ASSUMPTIONS / RATIONALE**

**PAPER:**                    \$8.9 M / 1700 acft = \$5,250 / acft  
(29:33).

**COMPUTERIZED:** Same as paper format.

**AUTOMATED:**                \$3.9 M / 1700 acft = \$2,294 / acft  
(29:33).

**HARDWARE MAINTENANCE:** Cost to maintain hardware.

**FORMAT**                    **ASSUMPTIONS / RATIONALE**

**PAPER:**                    Basecase cost = \$0.

**COMPUTERIZED:** ROM estimate \$200 / acft.

**AUTOMATED:**                \$5.4 M / 1700 acft = \$3,177 / acft  
(29:33).

**SOFTWARE MAINTENANCE:** Cost to maintain software.

**FORMAT**                    **ASSUMPTIONS / RATIONALE**

**PAPER:**                    Basecase cost = \$0.

**COMPUTERIZED:** ROM estimate is \$200 / acft.

**AUTOMATED:**                \$8.5 M / 1700 acft = \$5,000 / acft.

**MISHAPS:** Costs incurred from class I mishaps that indicated TOs as contributing factor.

FORMAT                    ASSUMPTIONS / RATIONALE

PAPER:                    \$8.5 M / 15,000 total acft in AF inventory =  
\$567 / acft (1:1-6).

COMPUTERIZED:        Same as paper format.

AUTOMATED:            ROM estimate 90 percent reduction in  
mishaps due to TO errors or \$57 / acft.

**MAIL:** Costs due to mailing changes.

FORMAT                    ASSUMPTIONS / RATIONALE

PAPER:                    Eight percent of TOs change annually at \$10  
/ pg ROM mailing costs.

COMPUTERIZED:        No mailing costs for computerized format.

AUTOMATED:            No mailing costs for automated format.

**TELECOMMUNICATIONS:** Costs for sending TO changes in  
electronic format.

FORMAT                    ASSUMPTIONS / RATIONALE

PAPER:                    No costs for paper format.

COMPUTERIZED:        Six percent of TOs require changes and ROM  
cost \$3 / pg to transmit.

AUTOMATED:            Three percent of TOs require changes and  
ROM cost \$3 / pg.

**AF MANPOWER:** Overhead costs for management structure.

FORMAT                    ASSUMPTIONS / RATIONALE

PAPER:                    ROM estimate \$500 / pg.

COMPUTERIZED:        ROM estimate \$250 / pg.

AUTOMATED:            ROM estimate \$75 / pg.



**Appendix 9: Life Cycle Cost Analysis Formulas**

TO LIFE CYCLE COST ANALYSIS FORMULAS		
ORGANIZATION:	F-16 SPO	
ACFT (QTY)	LIFE CYC (# YRS)	TO (#PGS)
1,700	10	575,000
NON RECURRING COSTS		
	CONSULT	DATA
PAPER	0	1000*\$C\$7
COMPUT	5*C7	1200*\$C\$7
AUTO	22.3*C7	400*\$C\$7
RECURRING COSTS		
	TO USAGE	TRNG
PAPER	43177*A7	0
COMPUT	43177*A7	0
AUTO	4941*A7	0
RECURRING COSTS		
	MISHAPS	MAIL
PAPER	567*A7	0.08*C7*10
COMPUT	567*A7	0
AUTO	57*A7	0

NONRECURRING	COSTS			
HDWRE	SOFTWR	TELECOM	TRNG	DATA C
1000*A7	0.5*C7	0	0	0
25000*A7	2*C7	0	350*A7	15*C7
57471*A7	12*C7	0	1470*A7	95*C7
RECURRING		ANNUAL	COSTS	
TO CHGS	TRBL SHT	COMMUN	HDWMX	SFW MX
0.08*C7*500	86309*A7	5250*A7	0	0
0.06*C7*300	86309*A7	5250*A7	200*A7	0
0.03*C7*300	58824*A7	2294*A7	3177*A7	5000*A7
RECURRING (CONT.)				
TELECOM,	AF MANPOWER			
0	500*C7			
0.06*C7*3	250*C7			
0.03*C7*3	75*C7			

YEAR	PAPER COST FORMULAS	
1	B12+C12+D12+E12+F12+G12+B19+C19+D19+E19+F19 +G19+H19+B26+C26+D26+E26	
2	\$B\$19+\$C\$19+\$D\$19+\$E\$19+\$F\$19+\$G\$19+\$H\$19+\$ B\$26+\$C\$26+\$D\$26+\$E\$26	
3	\$B\$19+\$C\$19+\$D\$19+\$E\$19+\$F\$19+\$G\$19+\$H\$19+\$ B\$26+\$C\$26+\$D\$26+\$E\$26	
4	\$B\$19+\$C\$19+\$D\$19+\$E\$19+\$F\$19+\$G\$19+\$H\$19+\$ B\$26+\$C\$26+\$D\$26+\$E\$26	
5	\$B\$19+\$C\$19+\$D\$19+\$E\$19+\$F\$19+\$G\$19+\$H\$19+\$ B\$26+\$C\$26+\$D\$26+\$E\$26	
6	\$B\$19+\$C\$19+\$D\$19+\$E\$19+\$F\$19+\$G\$19+\$H\$19+\$ B\$26+\$C\$26+\$D\$26+\$E\$26	
7	\$B\$19+\$C\$19+\$D\$19+\$E\$19+\$F\$19+\$G\$19+\$H\$19+\$ B\$26+\$C\$26+\$D\$26+\$E\$26	
8	\$B\$19+\$C\$19+\$D\$19+\$E\$19+\$F\$19+\$G\$19+\$H\$19+\$ B\$26+\$C\$26+\$D\$26+\$E\$26	
9	\$B\$19+\$C\$19+\$D\$19+\$E\$19+\$F\$19+\$G\$19+\$H\$19+\$ B\$26+\$C\$26+\$D\$26+\$E\$26	
10	\$B\$19+\$C\$19+\$D\$19+\$E\$19+\$F\$19+\$G\$19+\$H\$19+\$ B\$26+\$C\$26+\$D\$26+\$E\$26	
TOTAL (NO TIME VALUE OF \$)	SUM(B39:B48)	
TOTAL (NPV @.07)	NPV(0.07,B39:B48)	

YEAR	COMPUTERIZED COST FORMULAS	
1	B13+C13+D13+E13+F13+G13+B20+C20+D20+E20+F20 +G20+H20+B27+C27+D27+E27	
2	\$B\$20+\$C\$20+\$D\$20+\$E\$20+\$F\$20+\$G\$20+\$H\$20+\$ B\$27+\$C\$27+\$D\$27+\$E\$27	
3	\$B\$20+\$C\$20+\$D\$20+\$E\$20+\$F\$20+\$G\$20+\$H\$20+\$ B\$27+\$C\$27+\$D\$27+\$E\$27	
4	\$B\$20+\$C\$20+\$D\$20+\$E\$20+\$F\$20+\$G\$20+\$H\$20+\$ B\$27+\$C\$27+\$D\$27+\$E\$27	
5	\$B\$20+\$C\$20+\$D\$20+\$E\$20+\$F\$20+\$G\$20+\$H\$20+\$ B\$27+\$C\$27+\$D\$27+\$E\$27	
6	\$B\$20+\$C\$20+\$D\$20+\$E\$20+\$F\$20+\$G\$20+\$H\$20+\$ B\$27+\$C\$27+\$D\$27+\$E\$27	
7	\$B\$20+\$C\$20+\$D\$20+\$E\$20+\$F\$20+\$G\$20+\$H\$20+\$ B\$27+\$C\$27+\$D\$27+\$E\$27	
8	\$B\$20+\$C\$20+\$D\$20+\$E\$20+\$F\$20+\$G\$20+\$H\$20+\$ B\$27+\$C\$27+\$D\$27+\$E\$27	
9	\$B\$20+\$C\$20+\$D\$20+\$E\$20+\$F\$20+\$G\$20+\$H\$20+\$ B\$27+\$C\$27+\$D\$27+\$E\$27	
10	\$B\$20+\$C\$20+\$D\$20+\$E\$20+\$F\$20+\$G\$20+\$H\$20+\$ B\$27+\$C\$27+\$D\$27+\$E\$27	
TOTAL (NO TIME VALUE OF \$)	SUM(C39:C48)	
TOTAL (NPV @.07)	NPV(0.07, C39:C48)	

YEAR	AUTOMATED COST FORMULAS	
1	B14+C14+D14+E14+F14+G14+B21+C21+D21+E21+F21 +G21+H21+B28+C28+D28+E28	
2	\$B\$21+\$C\$21+\$D\$21+\$E\$21+\$F\$21+\$G\$21+\$H\$21+\$ B\$28+\$C\$28+\$D\$28+\$E\$28	
3	\$B\$21+\$C\$21+\$D\$21+\$E\$21+\$F\$21+\$G\$21+\$H\$21+\$ B\$28+\$C\$29+\$D\$28+\$E\$28	
4	\$B\$21+\$C\$21+\$D\$21+\$E\$21+\$F\$21+\$G\$21+\$H\$21+\$ B\$28+\$C\$30+\$D\$28+\$E\$28	
5	\$B\$21+\$C\$21+\$D\$21+\$E\$21+\$F\$21+\$G\$21+\$H\$21+\$ B\$28+\$C\$30+\$D\$28+\$E\$28	
6	\$B\$21+\$C\$21+\$D\$21+\$E\$21+\$F\$21+\$G\$21+\$H\$21+\$ B\$28+\$C\$32+\$D\$28+\$E\$28	
7	\$B\$21+\$C\$21+\$D\$21+\$E\$21+\$F\$21+\$G\$21+\$H\$21+\$ B\$28+\$C\$33+\$D\$28+\$E\$28	
8	\$B\$21+\$C\$21+\$D\$21+\$E\$21+\$F\$21+\$G\$21+\$H\$21+\$ B\$28+\$C\$34+\$D\$28+\$E\$28	
9	\$B\$21+\$C\$21+\$D\$21+\$E\$21+\$F\$21+\$G\$21+\$H\$21+\$ B\$28+\$C\$35+\$D\$28+\$E\$28	
10	\$B\$21+\$C\$21+\$D\$21+\$E\$21+\$F\$21+\$G\$21+\$H\$21+\$ B\$28+\$C\$36+\$D\$28+\$E\$28	
TOTAL (NO TIME VALUE OF \$)	SUM(D39:D48)	
TOTAL (NPV @.07)	NPV(0.07,D39:D48)	

**Appendix 10: Life Cycle Cost Analysis Output**

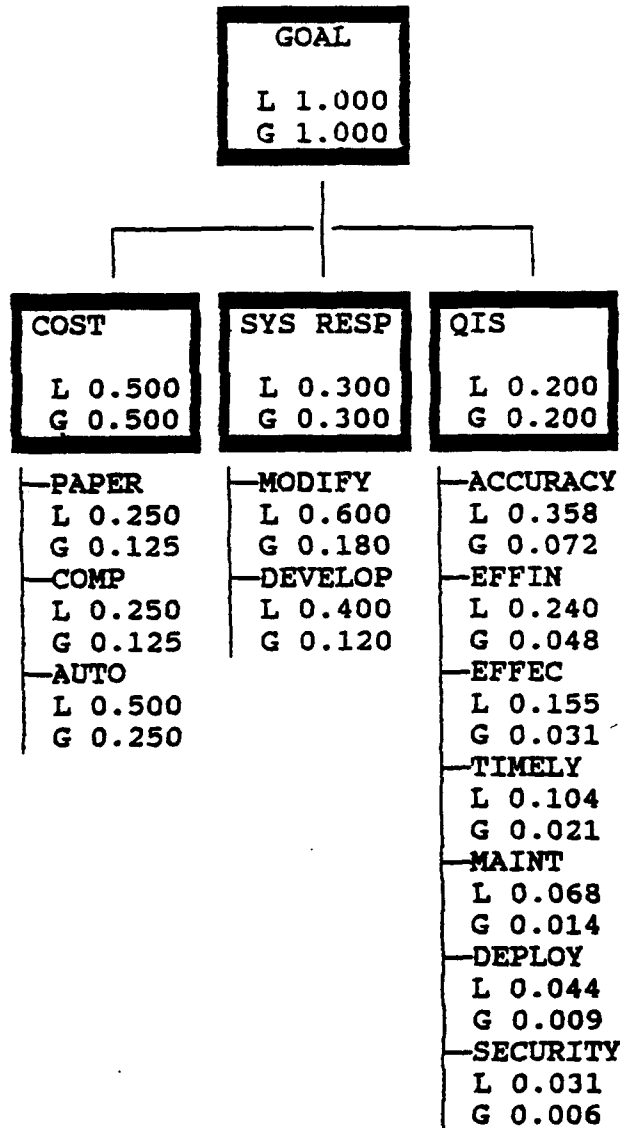
			TO LIFE CYCLE COST ANALY
ORG:	F-16 SPO		
ACFT	LIFE CYC	TO	
(QTY)	(# YRS)	(#PGS)	
1,700	10	575,000	
			NONRECURRING COSTS
	CONSULT	DATA	HDWRE
PAPER	0	575,000,000	1,700,000
COMPUT	2,875,000	690,000,000	42,500,000
AUTO	12,822,500	230,000,000	97,700,700
			RECURRING / ANNUAL COSTS
	TO USAGE	TRNG	TO CHGS
PAPER	73,400,900	0	23,000,000
COMPUT	73,400,900	0	10,350,000
AUTO	8,399,700	0	5,175,000
			RECURRING (COST/ACFT YR)
	MISHAPS	MAIL	TELECOM,
PAPER	963,900	460,000	0
COMPUT	963,900	0	103,500
AUTO	96,900	0	51,750

	(COST/ACFT)		
SOFTWR	TELECOM	TRNG	DATA C
287,500	0	0	0
1,150,000	0	595,000	8,625,000
6,900,000	0	2,499,000	16,100,000
(COST/ACFT YR)			
TRBL SHT	COMMUN	HDWMX	SFW MX
146,725,300	8,925,000	0	0
146,725,300	8,925,000	340,000	0
100,000,800	3,899,800	5,400,900	8,500,000
AF MANPOWER			
287,500,000			
143,750,000			
43,125,000			

YEAR	PAPER
1	1,117,962,600
2	540,975,100
3	540,975,100
4	540,975,100
5	540,975,100
6	540,975,100
7	540,975,100
8	540,975,100
9	540,975,100
10	540,975,100
TOTAL (NO TIME VALUE OF \$)	
TOTAL (NPV @.07)	
YEAR	COMPUTERIZED
1	1,121,678,600
2	384,558,600
3	384,558,600
4	384,558,600
5	384,558,600
6	384,558,600
7	384,558,600
8	384,558,600
9	384,558,600
10	384,558,600
TOTAL (NO TIME VALUE OF \$)	
TOTAL (NPV @.07)	
YEAR	AUTOMATED
1	524,572,050
2	174,649,850
3	174,649,850
4	174,649,850
5	174,649,850
6	174,649,850
7	174,649,850
8	174,649,850
9	174,649,850
10	174,649,850
TOTAL (NO TIME VALUE OF \$)	
TOTAL (NPV @.07)	

**Appendix 11: Analytical Hierarchy Formulation  
Charts and Performance Report**

Dr. David S. Christensen - Evaluation copy

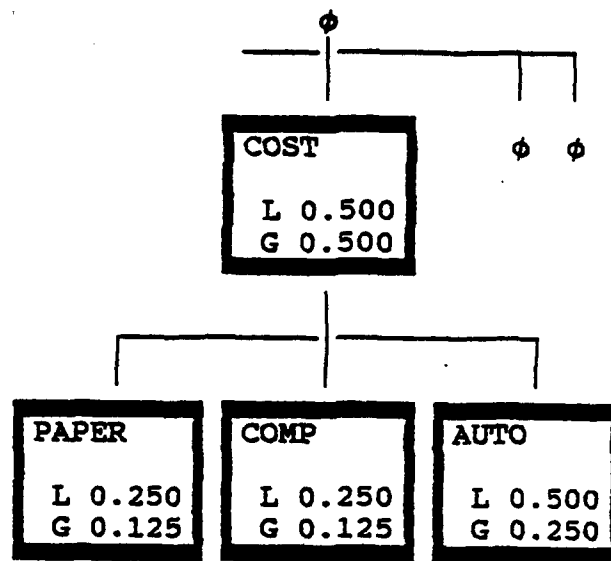


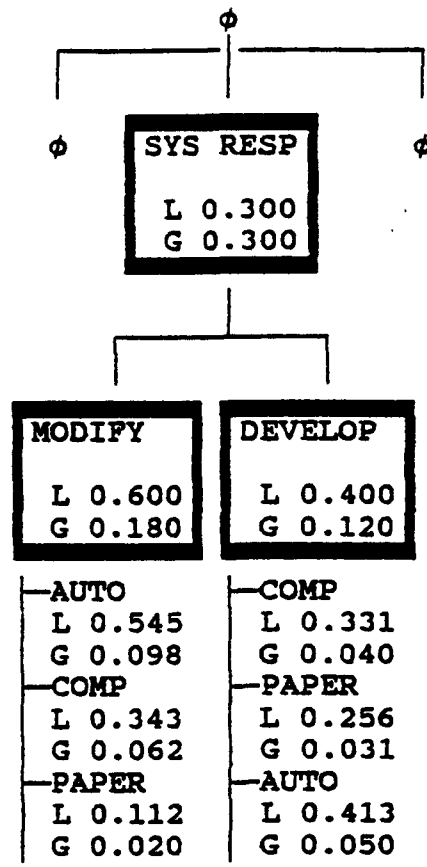


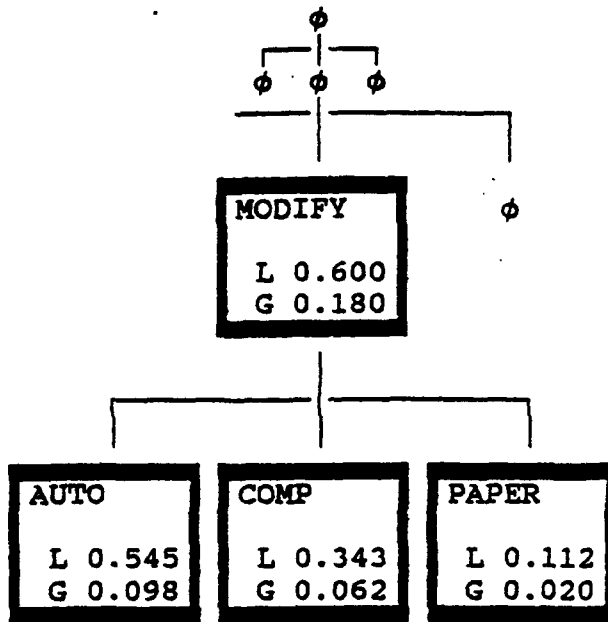
Glossary of Terms Used in Model

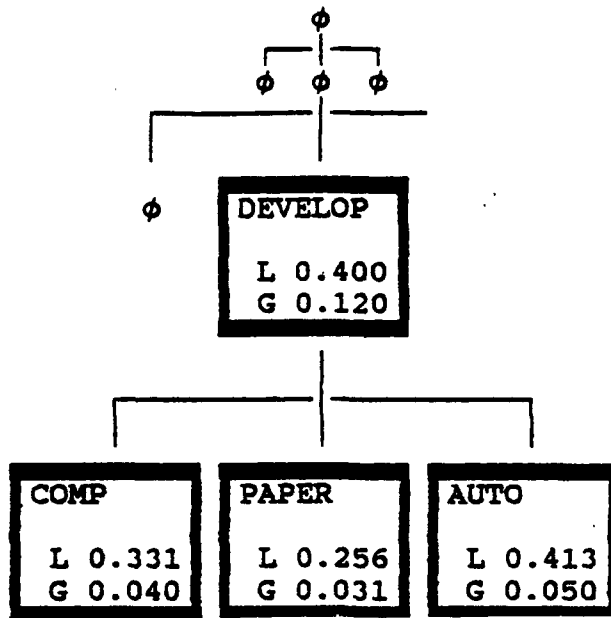
GOAL:

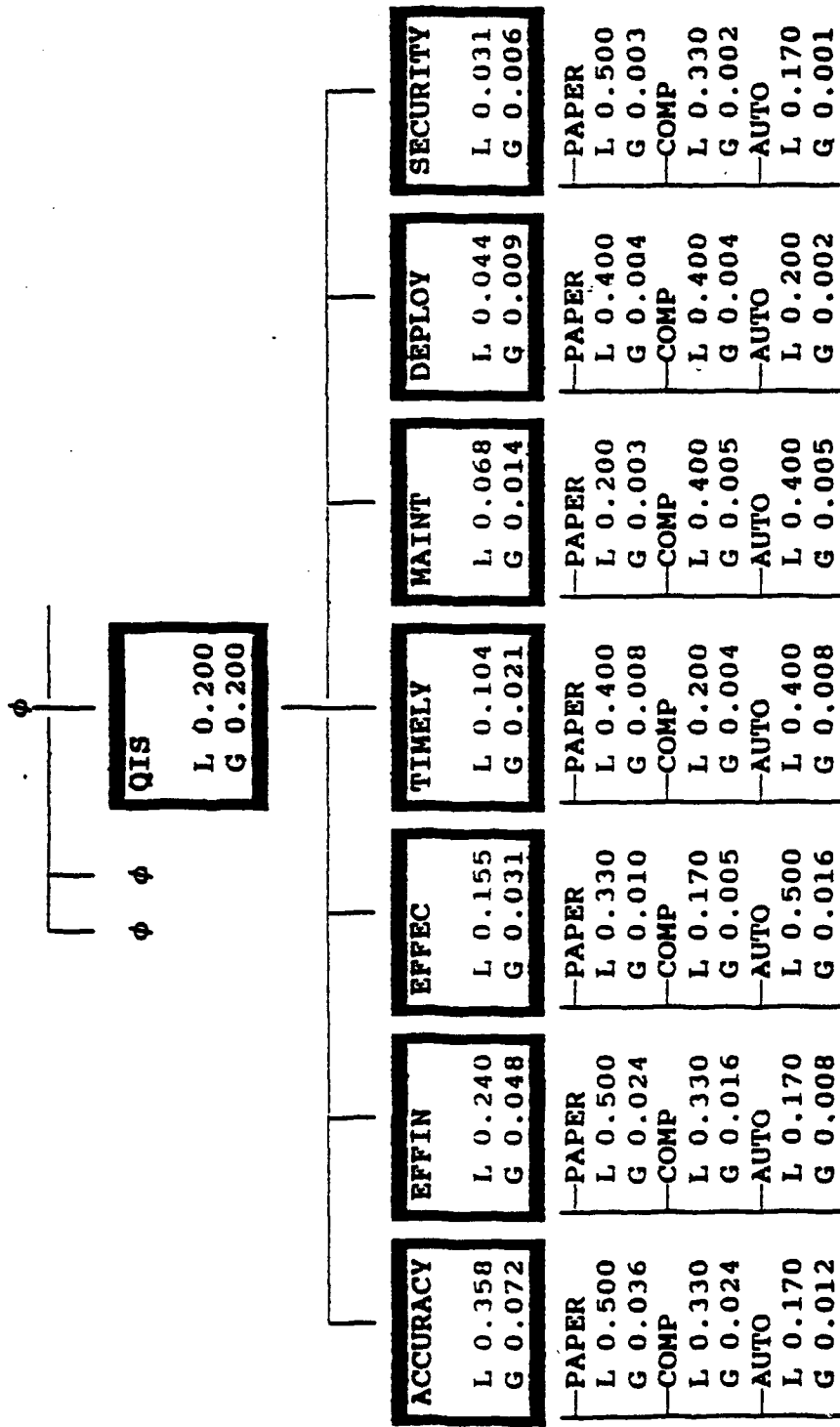
ACCURACY	---	ACCURACY OF TO
AUTO	---	AUTOMATED FORMAT
AUTOM	---	AUTOMATED FORMAT FOR TOS.
COMP	---	COPUTERIZED FROMAT
COMPUTER	---	COMPUTERIZED FORMAT FOR TOS
COST	---	AMOUNT OF \$ REQUIRED TO PURCHASE AND MAINTAIN TOS
DAMC	---	TIME REQUIRED TO DEVELOP, MODIFY, AND APPROVE TOS.
DEPLOY	---	DEPLOABILITY OF TO
DEVELOP	---	DEVELOPMENT TIME REQUIRED
EFFEC	---	EFFECTIVENESS OF TO
EFFIN	---	EFFIENCY OF TO
MAINT	---	MAINTAINABILITY OF TOS
MODIFY	---	MODIFICATION TIME REQUIRED
PAPER	---	PAPER FORMAT OF TO
QIS	---	QUALITATIVE CRITERIA IDENTIFIED BY FUNCTIONAL EXPERTS.
SECURITY	---	SECURITY FOR FORM OF TO
SYS RESP	---	TIME REQUIRED TO DEVELOP, MODIFY, AND APPROVE TOS.
TIMELY	---	TIMELINESS OF DELIVERY OF TOS



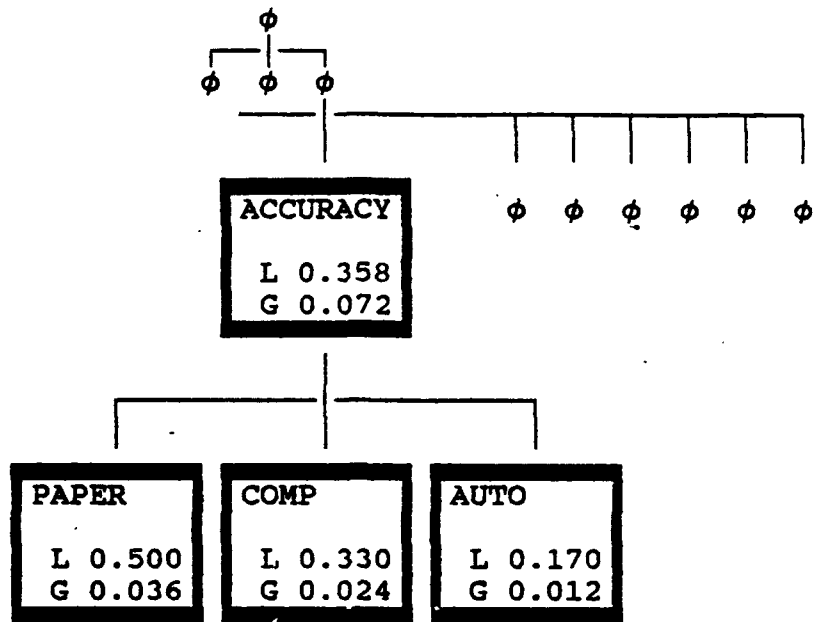


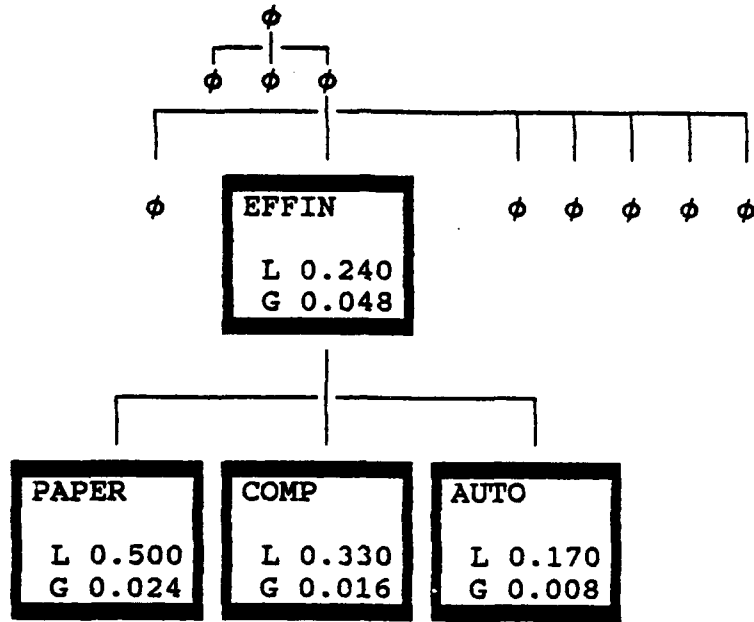




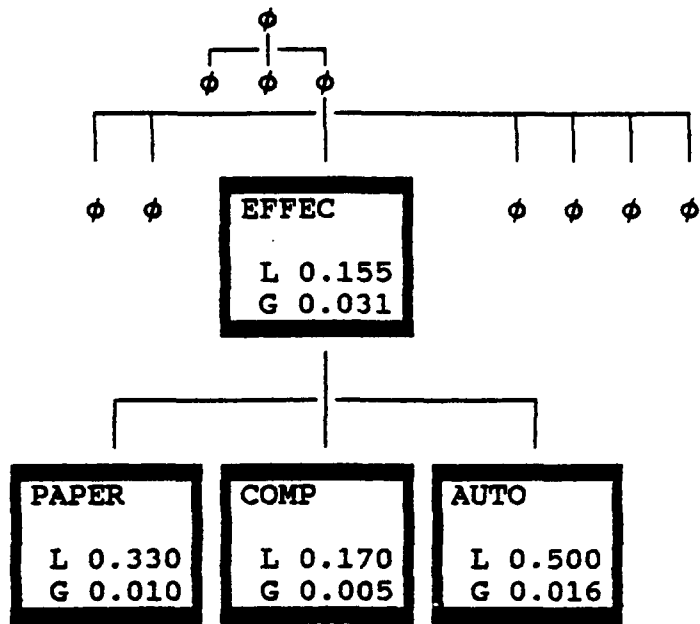


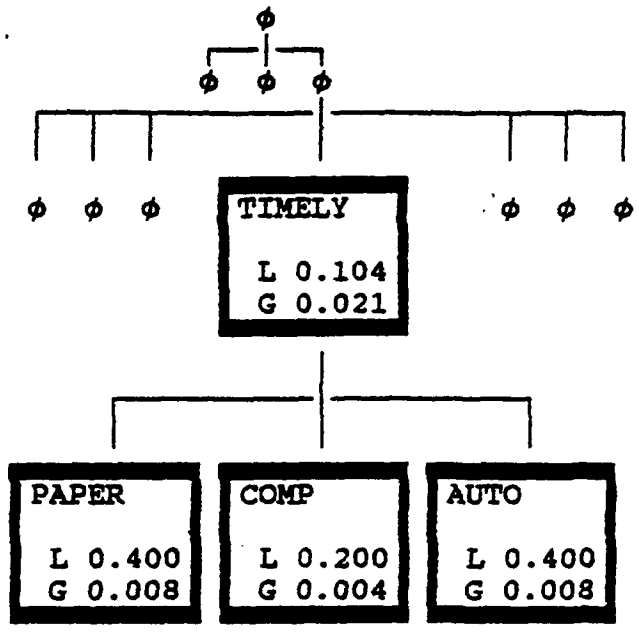
ACCURACY --- ACCURACY OF TO  
 AUTO --- AUTOMATED FORMAT  
 COMP --- COMPUTERIZED FROMAT  
 DEPLOY --- DEPLOABILITY OF TO  
 EFFEC --- EFFECTIVENESS OF TO  
 EFFIN --- EFFICIENCY OF TO  
 MAINT --- MAINTAINABILITY OF TOS  
 PAPER --- PAPER FORMAT OF TO  
 QIS --- QUALITATIVE CRITERIA IDENTIFIED BY FUNCTIONAL EXPERTS.  
 SECURITY --- SECURITY FOR FORM OF TO  
 TIMELY --- TIMELINESS OF DELIVERY OF TOS  
  
 L --- LOCAL PRIORITY: PRIORITY RELATIVE TO PARENT  
 G --- GLOBAL PRIORITY: PRIORITY RELATIVE TO GOAL

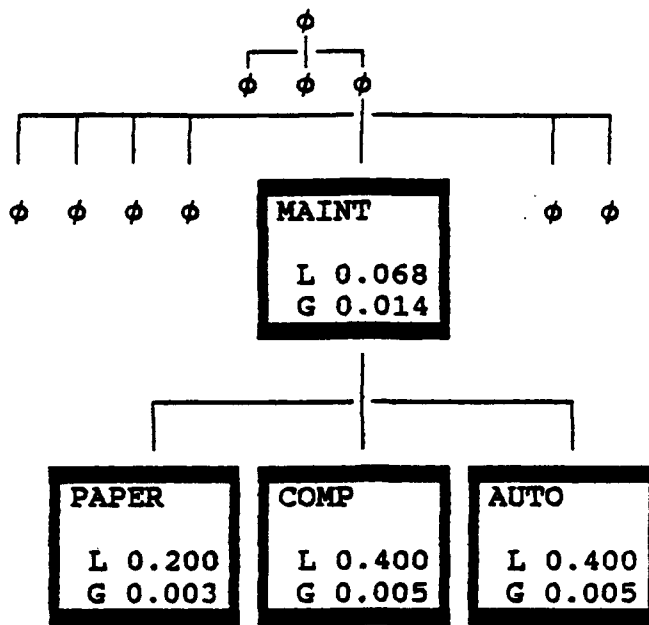


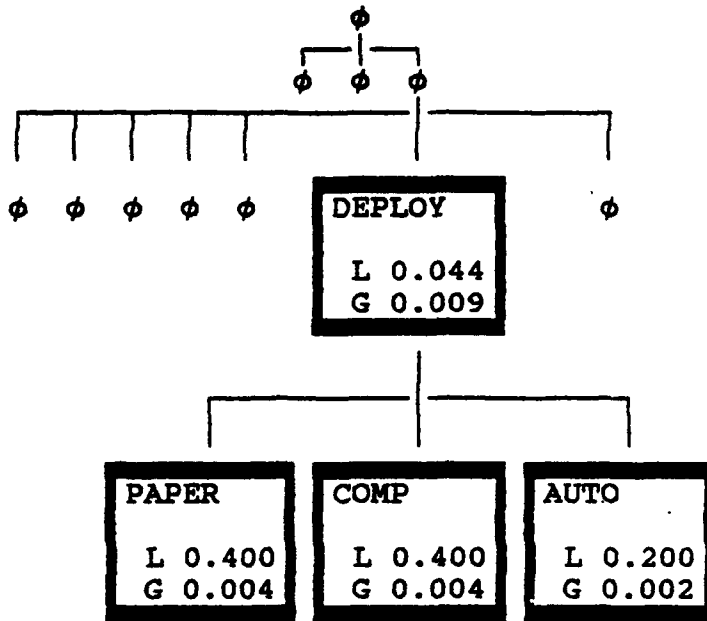


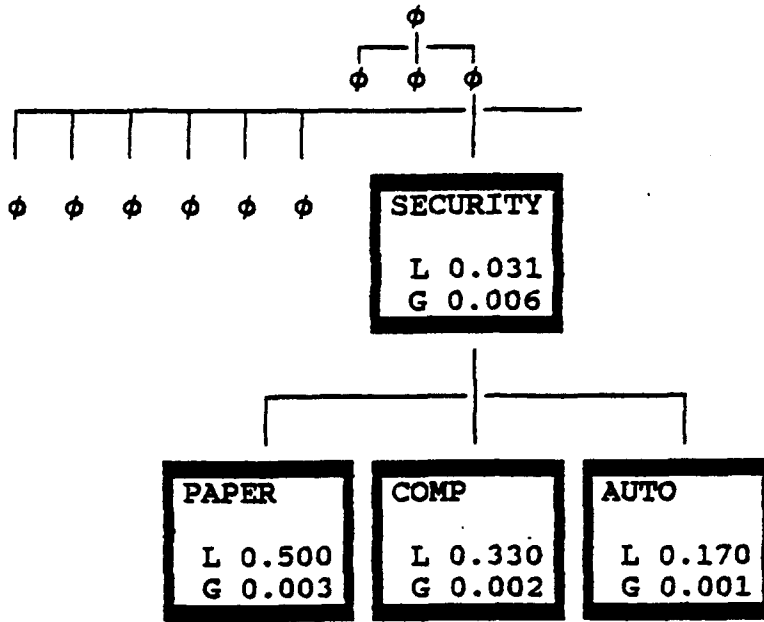






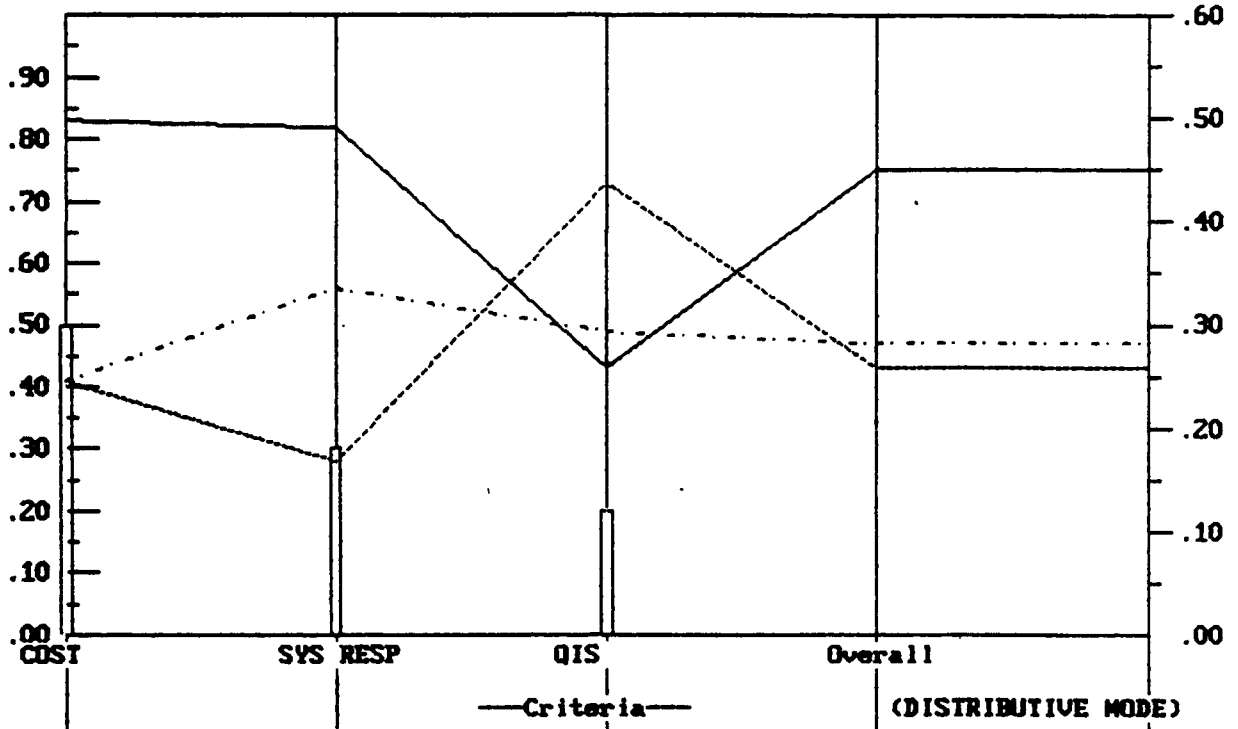








Critx PERFORMANCE WITH RESPECT TO GOAL FOR NODES BELOW: Aitx

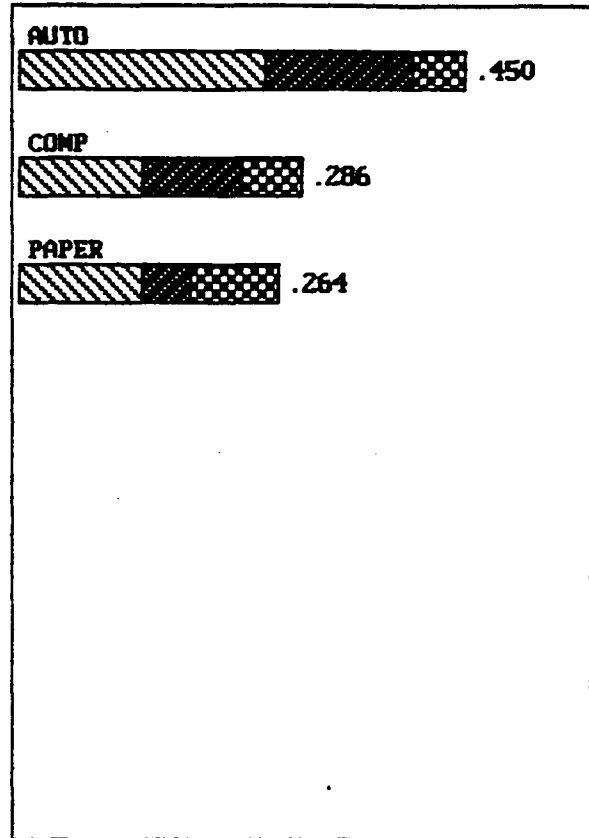
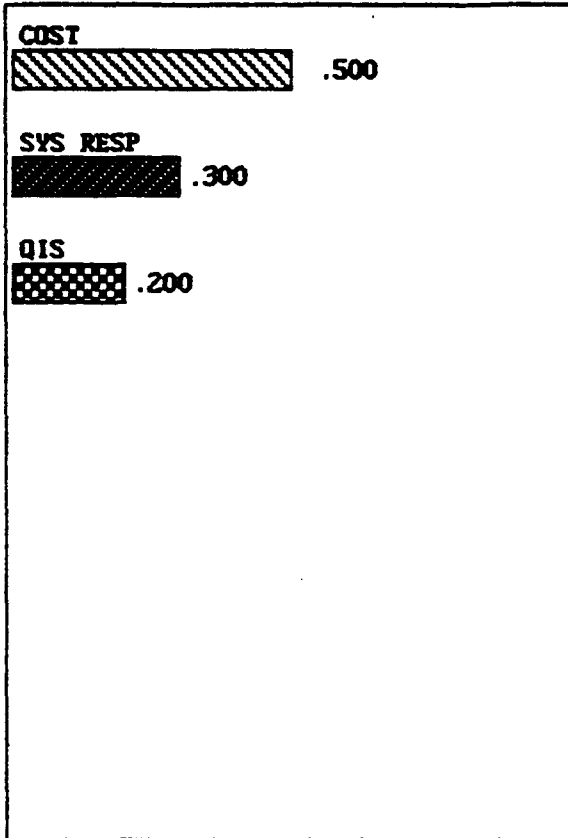


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## Vita

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<b>6. AUTHOR(S)</b> Susan J. Bergin, Lieutenant, USAF Terry A. Parsons, Captain, USAF				
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<b>13. ABSTRACT (Maximum 200 words)</b>  This research focused on developing a Cost Benefit Analysis process for Program Managers to implement when deciding what technical order format--paper, computerized or automated--to purchase. Factors which determined the outcome are costs (life cycle cost considering technical order format); qualitative issues (characteristics which are benefits of a technical order format); and system responsiveness (time required to develop or modify a technical order in each format). A literature review revealed problems with the paper technical order format, management infrastructure, quantitative cost estimates for different formats, and different techniques which could be used for a cost benefit analysis. Structured interviews were used to gather, from functional experts, subjective data and historical data about technical orders. The data collected was then used in one of three measurement techniques: 1) a simulation model to estimate the amount of time required to develop and modify each technical order format; 2) a life cycle cost analysis spreadsheet to evaluate the cost of each format; or 3) an analytical hierarchy to determine which technical order format is the best. On the basis of the estimations and assumptions made for this analysis, the research determined that the automated technical order format is the best format.				
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