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A COMPUTER SIMULATION ANALYSIS OF
THE USAF VEHICLE
ALLOWANCE/AUTHORIZATION PROCESS

THESIS

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Presented to the Faculty of the School of Systems and Logistics

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Preface

The purpose of this research was to determine whether the incorporation of Electronic Data Interchange (EDI) would improve the process of coordinating the AF Form 601, Equipment Action Request. This form, which is initiated by base level vehicle managers and coordinated through MAJCOMs and WR-ALC, is used to obtain authorizations and allowances for vehicles and other registered equipment. The process of mailing the 601 to each coordinating agency is both time-consuming and paperwork-intensive. The incorporation of EDI would allow the information on the form to be transmitted electronically, saving time and adding value to the process at all levels.

By defining the system as it exists and mimicking that flow in a computer simulation model, the effects of EDI on the process were evaluated. Indications are that the reduction in transmittal time alone will result in a modest decrease in cycle time, but that reductions in processing times hold even greater potential for process improvement.

Without the help of numerous people, this research would not have been possible. I'd like to thank my advisor, Lt Col Robert Trempe, whose enthusiasm and insight provided me with the motivation to go forth with this project. I'd also like to thank Mr. Charles Myers and Mr. Sonny Johnson at WR-ALC/LZE, who provided the framework for developing the model. Finally, I'd like to thank my wife Diane and my boys Andrew and Kyle for their patience and encouragement throughout this process.

Captain Charles T. Butler

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Abstract

This research examined the effects of the incorporation of Electronic Data Interchange (EDI) on the USAF vehicle allowance/authorization process. The study utilized a computer simulation model to mimic the flow of the AF form 601, Equipment Action Request, as it is submitted at base level and coordinated through the MAJCOM and WR-ALC. The hypothesis was that the allowance/authorization cycle time could be made shorter by transmitting the information contained on the form 601 electronically, rather than mailing the form to each coordinating agency.

In order to compare the process with and without the use of EDI, two computer simulation models were developed, one which reproduced the current system and another whose variables and parameters were modified to simulate the effects of EDI. The output from the models was compared by using a paired-t test to determine differences in average system residence time for the 601.

The incorporation of EDI was found to produce modest improvements in 601 residence times -- the time elapsed in the coordination process between 601 submittal and approval. Mean residence times were reduced by approximately nine days by transmitting the information electronically. Additionally, it was found that reductions in processing times hinted at even greater reductions in average 601 residence times.

A COMPUTER SIMULATION ANALYSIS OF THE USAF VEHICLE ALLOWANCE/AUTHORIZATION PROCESS

I. Introduction

General Issue

Air Force Systems Command and other MAJCOM vehicle managers devote an enormous amount of time to the administration and management of vehicle allowances and authorizations. Because they prescribe the number of vehicles that can be acquired or on hand at a given organizational level, vehicle allowance and authorization levels must be carefully managed to ensure the best use of limited vehicle assets.

Vehicle managers must also be able to respond quickly to the constantly-changing missions of the units they support. Changes in weapons system types or quantities, new mission taskings, or changes in unit organizational structure can all affect the number of vehicles required for successful mission support. The contribution that vehicles provide to mission support can be reflected in the investment that they represent. The Air Force currently has approximately 128,500 vehicles in its fleet, with a purchase value of almost $3.2 billion. Replacing each of those vehicles would cost approximately $4 billion (Wiggins, 1991). Vehicles are also a critical wartime asset. The Air Force prepositioned or shipped approximately 9000 vehicles to support operations in the recent Gulf war (Berle, 1991).

The ability to justify and acquire vehicles is a key measure of how well the vehicle manager performs his or her assigned duties;

however, a variety of factors combine to limit the manager's capability to quickly authorize, much less assign, assets to meet those needs. First, Congress has mandated ceilings which limit USAF's total inventory of certain varieties of vehicles, particularly general purpose vehicles. Additionally, limits have been placed on the number of new authorizations which can be approved. Although vehicle Tables of Allowances have been tailored to meet the needs of individual units, this "tight fit" of allowances to assets leaves little room to facilitate increases in vehicle levels stemming from mission change (Johnson, 1990).

Other administrative requirements place constraints on vehicle management flexibility, particularly the allowance/authorization process. Current allowance/authorization management primarily involves tracking current vehicle assignments, requesting approval for new allowances/authorizations, and requesting changes to existing ones. These approval requests are documented and routed on the Air Force (AF) Form 601, Equipment Action Request. All actions regarding changes to vehicle allowance/authorization levels must be submitted on the Form 601, which is subsequently routed from base fleet managers, through the MAJCOM, to AFLC, and often to Item Managers, the functional experts throughout AFLC. This process is time-consuming, affecting the fleet manager's ability to make timely decisions. Given the need for base level flexibility in reassigning and acquiring vehicle assets, vehicle managers at HQ/AFSC have posed the question, "What are the shortcomings in the vehicle allowance/authorization process and how can we manage it better from a user's perspective?"

Problem Statement

The USAF vehicle allowance/authorization process contains shortcomings which inhibit the ability of wing and major command-level managers to respond quickly to changes in vehicle fleet requirements.

Process Definition

Before the research can make any assumptions about the allowance/authorization process, the process must be defined and examined in its existing form. The system's boundaries -- for purposes of the study at hand -- were determined to include only the 601 approval and coordination process for vehicle allowances/authorizations. The process under study does not include other related or offshoot processes such as the Vehicle Priority Buy or other vehicle acquisition processes. The process begins at the point that the 601 was submitted by the base level user for consideration by the MAJCOM and ends when the unit has been notified that the request has been either approved or disapproved at one of the various decision points in the flow.

Formal guidance for the allowance/authorization process can be found in AFLC Regulation 67-14, Air Force Equipment Allowance Management Program. This regulation provides instructions for proper documentation, coordination, and processing of AF Forms 601. Although new vehicle allowance/authorization change requests are generated through numerous circumstances, such as support equipment acquisition for major weapons systems, the primary process focus for this research is change requests initiated at base or command level in response to minor mission changes.

Whenever base vehicle managers determine -- usually from user input -- that a unit requires additional vehicles to accomplish its mission, two particular constraints prohibit them from arbitrarily assigning vehicles to fill that perceived need. The first is a Table of Allowances (TA) which prescribes the number of items of a particular category of support equipment permissible for use by a unit. Allowable vehicle levels and types are governed by TA 012. Allowances are standardized by organization, function, facility, or individual specialist according to a basis of issue (BOI). BOIs further define allowable support equipment levels according to the specific needs of a given organizational type and level. Allowances are managed by AFLC via the USAF Equipment Management System (AFEMS) (HQ AFLC, 1984;5).

Another constraining factor governing permissible vehicle quantities is authorizations. Authorizations are command-defined levels governing the number of vehicles permitted in individual units. These levels are generally more restrictive than those prescribed by the TA. Commands list authorized vehicle levels by type in a vehicle authorization list (VAL). The TA is the overriding document -- a vehicle can be allowed and not authorized but not vice versa. Before a vehicle can be physically assigned, it must be both allowed and authorized (HQ USAF, 1987;36).

Changes to the TA and VAL are requested via the AF Form 601, Equipment Action Request. When vehicle managers wish to increase the number of vehicles assigned to a particular unit, they must first consult TA 012 to ensure that the vehicle is allowed. Additionally, they must consult the command VAL to determine the number and types of vehicles that may be assigned for that function. If both allowances and authorizations do not exist for that function, the base Vehicle Operations Branch initiates action to obtain them (HQ AFLC, 1989;5).

The first step in the process is to obtain approval of the Vehicle Authorization and Utilization Board (VAUB). This board, chaired by the base Deputy Commander for Resources, and consisting of personnel from key functional areas, validates the requirement against mission needs, alternative transportation sources, and other factors. If the request is approved by the VAUB, the Vehicle Operations Officer (VOO) prepares the Form 601. The 601 contains justification to include expected vehicle utilization, effect on mission requirements, number of vehicles currently authorized and assigned, and other data directed at determining mission criticality. The form is signed by the base Chief of Transportation and forwarded to the Registered Equipment Management System (REMS), a supply automated system for tracking equipment allocations. The REMS manager logs the date that the request was forwarded to higher headquarters and sets a suspense for follow up (HQ AFLC, 1989;5)

Once the request has been approved by all base agencies, it is forwarded to the MAJCOM for further review. The MAJCOM Command Equipment Management Office (CEMO) evaluates the request against current authorization and allowance levels and against mission requirements. Evaluations are carefully screened since authorization ceilings for some vehicle types may require that a lower-priority authorization is deleted for every new one approved (HQ AFLC, 1989;5).

Requests that require allowance changes or additions are forwarded to WR-ALC/LZE for TA manager approval. Because many commands have closely-aligned allowance and authorization levels, simple vehicle rotations or reassignments may generate this type of action. In addition to ensuring that the request contains all of the appropriate data, the TA manager reviews each request carefully against the same mission criteria that was reviewed at lower echelons. Additionally, the TA manager may coordinate with the responsible AFLC Item Manager (IM) to further validate the requirement. This IM may be located at another base, adding days to the coordination process. Some of the Item Manager's duties in this regard are to determine whether suitable vehicles exist in the present inventory, or whether a completely new vehicle type is required. If a new vehicle type is required, the IM conducts further coordination with the USAF Cataloging and Standardization Center (CASC) at Battle Creek, Michigan. CASC assigns stock numbers to these new requirements (Johnson, 1990).

The TA manager has 15 calendar days in which to process 601s. In the event that coordination requirements are anticipated to exceed 15 days, the CEMO is notified. If written coordination is required from another staff agency, the TA manager is granted an additional 15 days to process the request. The CEMO will be advised of approved requests granting interim authority to change REMS data to reflect the new allowance/authorization. This will permit managers to immediately take action to fill a requirement (HQ AFLC, 1984;20-21).

Current Efforts to Automate the 601 Process

Air Force Vehicle managers have not overlooked the possibility of automating the 601 process. In fact, efforts are currently underway to develop an EDI-integrated program for equipment management Air Force-wide. EDI, or Electronic Data Interchange, is described by Emmelhainz as "the interorganizational exchange of business documentation in structured, machine-processable form." The Air Force Equipment Management System (AFEMS), currently under development by the Martin-Marietta Corporation, will provide vehicle managers with an on-line capability to exchange the information currently captured by the 601 in just that sort of format. Accessed from personal computers at base level, the system will connect users at all levels with a mainframe-driven database at HQ AFLC. AFEMS is scheduled for completion in September 1993, with a final operating capability cost of $78 million (Harding, 1991).

AFEMS will offer several features which, once implemented, will revolutionize the way Air Force (AF) equipment, including vehicles, are managed. Because the mainframe will serve as a host for information flowing among a network of users, information transfer will be virtually instantaneous. Once a user has executed one of the various functions (including 601 processing) available through the system, user-designated coordination authorities at each level will also have immediate access to that information (Harding, 1991).

Another significant feature of AFEMS is the ability to "build" a 601 by accessing a set of screen templates designed for that purpose. Not only does each of the nine templates have preformatted fields in which to type the necessary codes, figures, etc., but the database also contains the current information necessary to complete the template automatically. For instance, if a base vehicle manager wishes to submit a 601 requesting a new forklift, he or she may only need to complete a very cursory series of preparatory blocks such as organization, vehicle type, etc. The database contains equipment data pertaining to that unit

-- including the number currently allowed, authorized, and assigned -- and can extrapolate the remaining supply information necessary to "build" the request (Harding, 1991).

This ability to access all codes necessary to complete the request should be faster and more accurate than the current method, which can require research into several paper documents to obtain the proper information necessary for coordination. Once the appropriate blocks have been filled in, the request can be saved to the database, where it can be instantly accessed by coordination agencies at each level (Harding, 1991).

The system can also prompt the user when mistakes occur. For example, if an uncataloged national stock number or allowance identification code is entered, the system will inform the user. Additionally, the screen data fields will prohibit users from entering too many characters for a particular code (Harding, 1991).

Although this research does not attempt to evaluate or validate AFEMS, some of the features of AFEMS will be used in experimental models to validate or fail to validate the use of EDI as a means of improving the 601 process. For example, later models will incorporate the concept of instantaneous information transmittal as an assumption for experimentation.

Investigative Questions

Before making any firm conclusions about process improvements, the research must ultimately answer the question, "How can the allowance/authorization process be improved from the users' perspective?" Investigation will begin with an in-depth analysis of the system as it exists. "What are the current process flows?" "What are the major constraints within the process?" "Who owns the process?" "Who are the customers or beneficiaries of the process?" Once the process has been defined, research can concentrate on the mechanics of the process. Several questions must be answered, including, "To what extent do decisions affect the performance of the process?" "What factors contribute to process flow rate?" To answer these questions the research should contain some method of making these process flows visible and measurable. Probably the best way to achieve this degree of measurability is by using computer simulation to model the system and adjusting the inputs to reflect the dynamics of the process. Simulation should reveal the shortcomings in the process and provide some insights into ways that the process can be improved.

Guiding Hypothesis

The guiding hypothesis that has emerged from initial analysis of the system is that the integration of electronic data interchange into the 601 process will improve overall process performance and overcome the effects of varying input parameters. By transmitting the information contained in the form 601 electronically, rather than mailing the form between the various decision points, the overall processing time of the 601 will be reduced.

Methodology Overview

This research will utilize computer simulation to model the present allowance/authorization process as it is prescribed by regulation, and as it is perceived by the users and agencies who have inputs to the process. The scope of the process to be studied encompasses the flow of the AF Form 601, the primary document used to request approval for or changes to vehicle allowances and authorizations. Once each process step has been identified and modeled in its various forms, the model will be modified to incorporate hypothesized improvements so that their effects can be tested. The 601 is the entity which will provide visibility of system performance. The primary measure of merit will be the 601 residence time, or the amount of time between 601 submittal at base level and approval at WR-ALC.

<u>Summary</u>

Thus far, initial research has concluded that the AF form 601 process is a critical element in vehicle managers' ability to respond quickly to mission changes which affect vehicle requirements. The application of EDI holds some interesting potential for reducing the time necessary to coordinate allowance/authorization approval, thus improving the value of the process to managers at all levels. Before making conclusions about the degree of improvement which might be obtained through EDI, subsequent research must establish the basis for using EDI, as well as methods for assessing the effects of EDI. Chapter II, Literature Review, will further examine EDI as a method of improving processes, and will also look at computer simulation modeling as a method of evaluating processes.

II. Literature Search

Introduction

Before examining the specific methodology that the research will take, it is important to look at EDI as a concept, and to review some of the literature concerning systems and modeling. This review will provide some basis for the structure that later experimentation will take. First, the review will define the concept of EDI, as well as some of EDI's advantages and current applications. The review will also discuss the characteristics of systems such as the 601 process, and will look at simulation modeling as a method of capturing the flows inherent in systems. This review will lay the groundwork for the experimentation methodology, which will be discussed in Chapter III.

Options for Process Improvement

The 601 process involves an exchange of information between agencies at widely-separated locations. The distribution of this information -- both between points on the same base and between bases -- adds days to the 601 coordination process. The physical movement of the 601 form complicates decisionmaking and slows the process of meeting urgent mission requirements.

Reducing the amount of time necessary to process 601s could take several forms. First, the number of 601s submitted could be reduced, decreasing the workload on the managers who must process them. The amount of time necessary to process the information at each level could likewise be reduced. The number of processing activities could be decreased, speeding the flow of information through the system. Finally, the amount of time the information spends between processing points could be reduced.

Because AF vehicles represent an expensive and mission-critical group of equipment items, individual accountability is a must. The 601 helps to provide that accountability; therefore, reducing the number of 601s submitted to document management actions does not appear to be a viable option, at least in the near term. Similarly, command and logistics support coordination is necessary to ensure that vehicles are effectively allocated and assigned. Reduction in the number of processing points could negatively impact mission validation when considering the needs of requesting units. Finally, a reduction in processing time at each management level would require streamlining a complex supply accountability system that manages not only vehicles, but also registered equipment of all types.

EDI -- A Possible Solution

The remaining option, shortening the intransit time between information processing points, is technologically feasible through the application of Electronic Data Interchange (EDI). Defined by Emmelhainz as "the interorganizational exchange of business documentation in structured, machine-processable form," EDI has become an accepted method of transmitting business information for many applications. More than simply replacing paper documents with electronic documents, EDI is actually a way of replacing manual data with electronic data. Emmelhainz further points out that "the purpose of EDI is not to eliminate paper, but rather to eliminate processing delays and manual reentry" (Emmelhainz, 1990;4).

Traditional forms of information flow contains at least four inherent disadvantages. First, paper-based systems increase the time required to process information. One of the primary sources of delays is the time it takes to physically transfer the information between processors, whether handcarried, telephoned, or in the case of the 601, mailed. Paper-based systems also suffer from low accuracy, particularly systems which require a large amount of data entry. This disadvantage becomes further evident when that data must be rekeyed at multiple processing points. Manual reentry produces another undesirable side effect of paper-based systems, that of increased labor usage. Comparison of the manual entry with source documents further adds to the burden of ensuring the accuracy of each process. Finally, increased uncertainty results from variations in mail and distribution systems used to transmit information (Emmelhainz, 1990;4,9-10).

The 601 process suffers from each of these problems. Transmittal is by mail, increasing intransit time and uncertainty. The numerous codes and figures which must be entered on the 601 present numerous opportunities for mistakes at the source, and create additional reconciliation burdens downstream. Finally, additional communication is required to acknowledge receipt at each level and to coordinate correction of form discrepancies.

Replacing these paper-based systems with an electronic information flow offers possible solutions to these problems. Among the advantages cited by Emmelhainz are improved operations, increased customer responsiveness, improved channel management, and increased ability to compete internationally (Emmelhainz, 1990;25). The first two of these benefits, and to a lesser degree the third and fourth, are worthy goals for the 601 process as well as other internal and external DoD operations.

Usually EDI is implemented as a means of streamlining communications with external organizations; however, EDI can benefit internal operations within organizations as well. One by-product of the EDI-implementation process is a complete assessment of current operations. Before EDI can flow, current paperwork flows must be analyzed, and many organizations find that this analysis spots weaknesses in processes and policies. Thus, the EDI implementation process forces organizations to determine what the perceived and actual flows are and make corrections to them if needed (Emmelhainz, 1990;33-34).

EDI may improve internal stability by decreasing processing times and increasing the certainty associated with those processes. For instance, Emmelhainz describes how the Ford Motor Company has integrated its EDI system with its Just-In-Time (JIT) production system. The JIT system depends on the timely delivery of parts to maintain critical production schedules. Because EDI has been integrated into the purchasing process, the purchasing timeline has been reduced and production schedules experienced more stability (Emmelhainz, 1990;34-35). Vehicle managers at all levels would be the beneficiaries of this improved responsiveness if EDI proved as effective for the 601 process.

Another way in which EDI improves internal operations is through improved personnel productivity. EDI eliminates much of the administrative activity associated with preparing documents, thus freeing personnel for other duties. George Klima, former Director of Accounting Systems for Super Valu stores notes that buyers in that organization once viewed their roles as primarily administrative. Following the implementation of EDI, however, they view themselves as merchandisers. Because EDI eliminates many of the nuisance tasks associated with lost or incorrect orders, salespeople and buyers sense an increased measure of professionalism in their jobs (Emmelhainz, 1990;35-36). Boland echoes this finding, noting that without EDI, salespeople spend as much as 50 percent of their time on paperwork (Boland, 1989;140). Because the 601 process is primarily an administrative function that stems from other vehicle management activities, benefits resulting from EDI could have similar positive consequences for Air Force vehicle managers.

Perhaps the most important benefit of EDI in terms of its possible adaptation to the 601 process is that of improved customer service. By virtue of its ability to provide real-time status on information in the process pipeline, EDI adds value to managers who must respond quickly to such requests, as well as customers who need status information quickly (Emmelhainz, 1990;36-37). EDI's shorter process times could also reduce the residence time of 601s in the system -- the time spent between 601 submittal and final approval -- thereby improving the process' responsiveness to vehicle managers awaiting the outcome of request coordination.

Although the primary impetus for EDI in business has been increased competitiveness, the cost savings of EDI have not gone unnoticed. For example, the use of EDI in the automotive industry is widely credited with saving $200 per vehicle. These savings come from several sources including reductions in document processing costs, reductions in personnel levels, reductions in inventory, and reductions in freight and handling charges (Emmelhainz, 1990;28-31). The National Association of Purchasing Management estimates that EDI can cut the bottom-line cost of transactions by 20 to 60 percent. These reductions come from an estimated 50 percent reduction in work hours in the purchasing cycle (Boland, 1989;142) Reductions in document processing costs and personnel levels appear to hold the most potential for the 601 process.

Document processing cost savings vary from industry to industry; however, savings are tied to the costs of processing the document prior to the implementation of EDI. One study of U.S. managers revealed that EDI offers a 10-to-1 cost benefit in the processing of purchase orders. The study showed that a paper document that is typed, revised, and mailed costs upwards of $48, while a similar document that is prepared and transmitted electronically costs just $5. Hewlett-Packard claims a decrease of from $1.65 to $0.58 per purchase order. The Automotive Industry Action Group has noted a savings of $12 per document through the use of EDI (Emmelhainz, 1990;28-29).

Current EDI Applications

EDI is currently in use -- and is showing tremendous growth -- across a diverse range of industries. Emmelhainz notes that a 1988 survey showed that over 34 percent of Fortune 1000 companies, large universities, and government agencies were using EDI. Another 20 percent were in the process of planning or implementing EDI (Emmelhainz, 1990;41).

The transportation industry and government have both seen tremendous growth in the use of EDI. The transportation industry was among the first to develop EDI on an industry-wide basis, and in fact pioneered much of the architecture and standards used in EDI today. The rail industry is among the most advanced EDI users, applying the technology to manage waybills, locate railcars, and transmit purchase orders and freight bills. Shipper agent Interamerican Transport Systems has used EDI to shave 16 man-hours per day off of the time required to track rail cars manually. Conrail has experienced similar success in managing waybills, reducing the time required to transmit waybill information by facsimile from two hours to just one minute through the use of EDI (Emmelhainz, 1990;42-43).

The trucking industry is also heavily engaged in EDI, and many shippers now expect carriers to have EDI capability. The primary focus of EDI in trucking is the electronic transfer of freight bills. Yellow Freight Systems, Inc. uses electronic billing to audit, transfer, and execute billing of its customers.

This technology has become a part of a larger effort to nurture long-term, stable customer relationships. Procter and Gamble uses EDI primarily to manage its outbound freight bills in a manner which reduces administrative requirements and allows customer service representatives to spend more time performing customer service tasks (Emmelhainz, 1990; 44-45). The U.S. government has also become fertile ground for the growth of EDI. In addition to the DoD. the Federal Supply Service and the General Services Administration have begun using EDI. Major areas that have embraced the use of EDI are procurement, retailing, and transportation (Emmelhainz, 1990;57).

Emmelhainz quotes David F. Baker of the Office of Management and Budget as saying, "If there is any process in the government that is made for EDI, and cries out for EDI, it is procurement." Indeed, DoD recently announced that it was beginning an EDI program that would require vendors supplying goods to the DoD to have EDI capability. An example of this effort is the Defense General Supply Center's Paperless Ordering Purchasing System (POPS), which uses EDI to place orders with DuPont and other vendors (Emmelhainz, 1990;58).

Government resale activities such as the Army and Air Force Exchange Service (AAFES) have also benefitted from the user of EDI. AAFES is currently using EDI to transmit purchase orders to 14 vendors. The Marine Corps is testing EDI at its East Coast Commissary Complex and processes about 40 percent of its orders electronically. Military retail purchasers have experienced some of the same benefits as commercial retailers, including reduced order processing time, reduced inventory, and increased sales (Emmelhainz, 1990; 59).

Government transportation activities, like their commercial counterparts have increased their use of EDI as a way of streamlining activities. As the world's largest shipper, EDI offers the DoD many potential applications. One target for adaptation to electronic transfer is government bills of lading. In a recent test of twelve DoD activities, three motor carriers, and three finance offices, EDI was found to reduce both costs and paperwork associated with bills of lading (Emmelhainz, 1990;59-60).

Undoubtedly, EDI has proven to be an effective means of streamlining systems, improving responsiveness, and reducing costs. As Boland notes, EDI can also provide an opportunity for a company to reevaluate its internal system flow and identify new ways to coordinate information (Boland, 1989;142). The identification of those flows, processes, and activities inherent in an organization's system -- whether for EDI implementation or other improvement goals -- requires a systematic approach.

Systems Design

Once the system has been mapped in its present form, research into its behavior must take a structured approach. Forrester has outlined a systematic approach to designing industrial and economic systems; however, his philosophies provide the framework for the design of smaller experimental projects as well. His study of industrial dynamics -- the study of information feedback characteristics of industrial activity -- captures many of the attributes of the 601 process. These studies attempt to explain how organizational structure, policy amplification, and time delays in decisions and actions interact to influence the success of the organization or system. His theories also treat the interactions between information flows, such as those represented in the 601 process (Forrester, 1961;1-13). Forrester's industrial dynamics approach to systems design progresses through several steps:

1. Identify a problem.

2. Isolate the factors that appear to interact to create the observed symptoms.

3. Trace the cause-and-effect information feedback loops that link decisions to action to resulting information and to new decisions.

4. Formulate acceptable formal decision policies that describe how decisions result from the available information streams.

5. Construct a mathematical model of the decision policies, information sources, and interactions of the system components.

6. Generate the behavior through time of the system as described by the model.

7. Compare results against all pertinent available knowledge about the actual system.

8. Revise the model until it is acceptable as a representation of the actual system.

9. Redesign, within the model, the organizational relationships and policies which can be altered in the actual system to find the changes which improve system behavior.

10. Alter the real system in the directions that model experimentation has shown will lead to improved performance.

This outline forms an effective framework for analysis of and experimentation with the 601 process (Forrester, 1961;13).

System Characteristics

As a complex system, the allocation/authorization process shares many of the same characteristics as other processes; that is, it is a group of interacting activities that form a system. As such, the process should be viewed from a systems perspective, recognizing that optimizing the performance of the various subsystems may not guarantee the optimization of the whole. Shannon notes that complex systems share characteristics that become obstacles to improving overall system performance. These are attributes that must be considered within Forrester's industrial design framework and include:

1. Change. Systems rarely remain static for long periods of time. Elements (entities) constantly enter and leave the system over time in a birth-and-death process. In the vehicle allowance/authorization process, AF Form 601s are the entities of interest.

2. Environment. The environment contains all the external variables that can affect the system's state. Additionally, each system has its own subsystems and is often a part of a larger system. The allowance/authorization process is no exception. It forms a subsystem of the larger vehicle acquisition/allocation process, and has subsystems of its own, such as the flow loop for assigning National Stock Numbers (NSN) to identify new vehicle types.

3. Counterintuitive Behavior. Systems often display behavior which is counter to that revealed by casual observation. Cause and effect relationships may not be readily apparent through time and space. By modeling the 601 flow, some of these anomalies may become evident in the allowance/authorization process.

4. Drift to Low Performance. Complex systems gradually deteriorate towards a condition of decreased performance over time. Remedies for this deterioration often do not consider the counterintuitive nature of the system, and are therefore ineffective or further detrimental to system performance.

5. Interdependency. Each event in a system is influenced by previous events and will affect subsequent events. The effect of system input rates and flows is of particular interest in this study. The rate and

flow of 601 inputs -- and the rate at which they are processed -- will affect the performance of each sequential activity in the system.

6. Organization. Almost all complex systems have a hierarchy of parts and subsystems which interact to execute the functions of that system. In the 601 process, command and functional hierarchies exist which must interact effectively to manage authorization/allocation approval (Shannon, 1975; 36-37)).

System Modeling

Given that the 601 process entails each of these characteristics of systems, any in-depth examination of the process must contain some means of explaining the behavior of this system. Several approaches are available to give some insight into the behavior of complex systems. One is direct experimentation. Direct experimentation involves interaction with the actual system in order to determine the effects of various inputs. This method has several disadvantages. First, it is extremely expensive in terms of manpower and resources. Second, the time required to observe the effects of these various inputs may be prohibitive. Direct experimentation may also preclude the necessary number of experiment replications needed to statistically validate the results of the experiment. Another approach for studying the effects of inputs on complex systems is mathematical modeling. This method also has drawbacks. For instance, most mathematical models cannot capture dynamic or transient events. Mathematical models are also limited in the types of distributions that they can sample from. Additionally, many systems are too complex to be effectively modeled mathematically (Pidd, 1984;8-9).

Computer simulation, then, must be regarded as the best alternative for capturing the behavior of a relatively complex system such as the 601 process. Although simulation models may require time and money to construct and run, these considerations are less important when compared against the cost of direct experimentation on the existing system. Simulations have the capability of duplicating months or even years of real system operation. Computer simulations can also be replicated numerous times in order to gain the necessary statistical significance to draw inferences about system behavior (Pidd, 1984;8-9).

What makes a good simulation model? Shannon notes seven qualities of good models:

1. It must be simple for the user to understand.

2. It must be goal or purpose directed.

3. It must be robust, in that it does not give extreme answers.

4. It must be easy for the user to control and manipulate, i.e. it should be easy to communicate with.

5. It should be complete on important issues.

6. It should be adaptable, with an easy procedure for model modification or updating.

7. It should be evolutionary, in that it should start simply and become more complex, in conjunction with the user. These steps emphasize the care that must go into developing an effective computer simulation model (10,22).

In order to meet these criteria, the modeler must follow a structured approach in developing a model that will be used to simulate a real system. Shannon distinguishes eleven stages of model development. They include:

1. System Definition. Determining the boundaries, restrictions, and measure of effectiveness to be used in defining the system to be studied.

2. Model Formulation. Reduction or abstraction of the real system to a logic flow diagram.

3. Data Preparation. Identification of the data needed by the model, and their reduction to an appropriate form.

4. Model Description. Description of the model in a language acceptable to the computer to be used.

5. Validation. Increasing to an acceptable level the confidence that an inference drawn from the model about the real system will be correct.

6. Strategic Planning. Design of an experiment that will yield the desired information.

7. Tactical Planning. Determination of how each of the test runs specified in the experimental design is to be executed.

8. Experimentation. Execution of the simulation to generate the desired data and to perform sensitivity analysis.

9. Interpretation. Drawing inferences from the data generated by the simulation.

10. Implementation. Putting the model and/or results to use.

11. Documentation. Recording the project activities and results as well as documenting the model and its use (Shannon, 1975:23).

System definition and model formulation can be achieved in several ways. Forrester suggests that the model come first; that is, the researcher normally has enough information to construct a useful model. He asserts that the model will define the data that will be collected (Forrester, 1961;57).

Emshoff and Sisson suggest a flow approach to grasp a situation. This entails breaking the system down into a flow which alternates between processing and movement. Once these elements are identified, further definition comes through observation and questioning (Emshoff and Sisson, 1970;65). Shannon advocates that the modeler specify the goals of the system and the boundaries between the system and the environment in order to define the system. He also suggests the use of a static model such as a flow diagram, but cautions that the diagram should include only those elements that are relevant to the study objectives (Shannon, 1975;26).

Another consideration in model formulation is that the model captures specific phenomena or behavior that characterizes the system. This structure is important in determining any cause-and-effect relationships in the model. Elements of this structure include levels, flow rates, decision functions, and information channels. These building blocks to model behavior may be applied to models of any magnitude (Forrester, 1961;68-70).

These three elements are also present in the 601 process. Levels are accumulations within the system. They may be customers in a queue, goods in transit, or information waiting to be processed. For the 601 process levels may be represented by the number of 601s in the system or waiting to be processed at some organizational level (Forrester, 1961;68-70).

Flow rates define the present, instantaneous flows between the levels in the system. Flow rates are often not easily distinguishable from levels, particularly when applied to intangible rates and levels such as information. Rates correspond to activity, while levels measure the resulting state to which the system has been brought as a result of flow rates. Flow rates in the 601 process would be represented by the number of 601s introduced into the system, or the number released by some processing function during a given time period (Forrester, 1961; 68-70).

Decision functions represent policy that determines how information about flow rates leads to decisions. Decision functions are responses to the state of the system that lead to action in some form, such as hiring employees or opening another teller line in a bank (Forrester, 1961; 68-70).

Information is an important ingredient in determining flow rates and levels. Because decision functions are dependent on information to provide a feedback of present rates and levels, information serves as a moderator or expeditor in complex systems. Time relationships and amplification phenomena complicate these feedback loops. Information lag times and a tendency for some systems to exaggerate information inputs create surpluses and deficits in levels and flows that must be accounted for (Forrester, 1961;68-70).

Data Preparation

Data preparation involves determining whether data are available to estimate the values of parameters and constants. This includes evaluating the starting values of all variables and providing data with which simulation outputs can be compared for validation. Variables represent system attributes which can take on different values and in some way affect the performance of the system. A parameter, on the other hand, represents an attribute that remains constant over all foreseeable ranges of system operation (Shannon, 1975;15). Emshoff and Sisson note that variables or parameters that affect, but are unaffected by, the system are called exogenous factors. Variables or parameters whose values are determined by other system variables are called endogenous factors (Emshoff and Sisson, 1970;52).

Exogenous and endogenous variables and parameters are further defined as controllable or uncontrollable, and static or dynamic. Exogenous uncontrollable variables must be input to the model to represent the relevant parts of the world that are external to the system. These include such data as frequency distributions for starting times. Dynamic exogenous variables might represent policies which determine the values of other variables, and can be drawn from historic or statistical data. Dynamic endogenous variables are those that are to be predicted by the model, and include performance measures. These may have to be estimated to provide starting data for the model (Emshoff and Sisson, 1970;52-53).

Validity and Verification

Perhaps the most important issue in modeling is that of validity and verification. Cook and Russell describe a five-stage process for establishing model validity. The first is program testing. This involves examination of the code used to program the model to ensure that it works as intended. This function is also known as verification. Variable generation tests apply goodness-of-fit and other parametric and nonparametric tests to both input and output data (exogenous and endogenous variables) to ensure that variables for both the model and the real system are similarly, if not exactly, distributed. Another step in model validation is subjective validation. This involves review of the model's design and output by persons familiar with the real world system, but not involved in the simulation study. This step judges whether the model is a reasonable representation of the real system (Cook and Russell, 1989;606-607). Balci refers to this practice as "face validity" (Balci, 1989;68). The final step, according to Cook and Russell, is historical validity. This step compares system input and output variables with documented performance variables of the real system to further ensure model realism (Cook and Russell, 1989;607).

Balci further defines the validation process by breaking validation down into two areas -- data validation and model validation. Data validation determines whether model parameters and variables are identified, measured, or estimated with sufficient accuracy. It also ensures that data transformations are performed correctly to ensure that the model and real system are using the same measurement units. Model validation differs from data validation in that model validation is concerned with the accuracy of model logic and behavior, rather than specific variable or parameter values (Balci, 1989;67).

Pidd discusses two types of validity: "black box" validity and "white box" validity. Black box validity asks the question, "does the model accurately reflect the real system?" Would someone involved with the real system accept the simulation as a viable representation of the real system? Black box validity may be complicated by the fact that the system being modeled has inherent flaws -- hence the reason for modeling to begin with. In contrast, white box validity concerns the accuracy of the parameters used to simulate system events. White box validity asks the question, "do the components of the model represent known behavior and/or valid theory which exists?" (Pidd, 1984;9-10).

These principles will be used in the later development of models designed to experiment with the 601 process as it exists, and to compare it with hypothesized improvements to the process. These principles should lead to a more accurate, effective model for testing the proposed hypotheses.

Summary

This chapter has examined how EDI can be an effective method of improving processes such as the allowance/authorization process. It has discussed how EDI, by reducing the time and variability inherent in paperwork and multiple data entry processes, can reduce costs and improve operational effectiveness. The search has also evaluated some of the characteristics of systems such as the 601 process, and established an approach for modeling systems to capture some of those characteristics. The next chapter, Methodology, will outline the approach taken to model the 601 process and the experimentation methods used to evaluate the effects of EDI on the 601 process.

III. Methodology

Introduction

The methodology used to study the allowance/authorization process will be based on Forrester's industrial dynamics approach to systems design, as well as Shannon's eleven stages of the simulation process. This will include defining the system and identifying key interactions that result in system problems. It will also reduce the system to a logic flow that can be effectively modeled using computer simulation. The methodology will progress to identification, collection and preparation of data used to formulate system variables and parameters. The next step will be to validate the input data to ensure that it is representative of actual system parameters.

The research will then focus on the development of a model that will validate, or fail to validate, the hypothesis introduced in the introductory chapter. Another validation stage will result from completion of the basic model, this one focusing on validating the model as a representation of the actual system. The model's success will also depend largely on the ability to design experiments that will yield the desired results. Once the model has been altered to facilitate experimentation, it will be executed in order to draw inferences concerning system performance. These experiments will prove or disprove the validity of the guiding hypothesis and will provide some information for improving system performance.

Guiding Hypotheses

As mentioned in the introductory chapter, the hypothesis guiding the research is that the integration of electronic data interchange (EDI) into the 601 process will improve overall process performance and overcome the effects of varying input parameters by decreasing intransit times for those 601s that are between activities. The measure of merit in determining system performance will be overall 601 residence times within the system. Residence times are defined as being the time between 601 submittal at the base level and approval at WR-ALC.

Rejecting or failing to reject the hypothesis will be determined by the differences in mean processing times for the model of the current system versus the mean processing times for the model with EDI integrated as a method of transferring the information captured by the 601. Criteria for hypothesis acceptance will be that a confidence interval containing the mean processing time difference will reflect, with a 95 percent probability, a reduction in processing time for the model with EDI incorporated.

System Definition

The first step in the methodology is to identify the process as it exists. In addition to the review of governing regulations framework as it is prescribed to users at all levels, the next step will be to interview individuals at each step in the process, from base level to final approval authority, in order to get a consensus on the structure and behavior of the process or processes as they are perceived.

Once the key players, flows, coordination loops, and decision points in the process are identified, the process will be recreated in a flow diagram. This flow diagram will provide the framework around which simulation code -- as well as system variables and parameters -- will be adapted.

Model Formulation

Model formulation will involve translating the steps involved in the flow diagram into computer language in order to mimic system behavior. GPSS/H is the simulation language which will be used to accomplish this task. The GPSS/H language was chosen because its structure permits it to be learned in a relatively short time. Additionally, it can handle fairly sophisticated models on a personal computer. This feature eliminates one of the considerations of running simulation models on large mainframe computers -- the cost of computer time.

The model will be formulated to represent the current system; however, it may trivialize or bypass altogether steps which are determined to be irrelevant to system performance. Instead, those areas that are deemed as critical bottlenecks, critical processes, or potential governors of flow rates and levels will be more detailed.

One assumption that will be made in this regard is that the model does not necessarily have to reflect the flow of 601s from every USAF base and MAJCOM in order to be effective. Representing each 601 source in the model would drastically complicate model coding and complexity, as well as drastically increase the amount of data that would have to be collected to develop effective model parameters and variables. Additionally, a global orientation may not prove useful for examining flows between individual users at levels below WR-ALC, the convergence point in the process for all USAF 601s. This is an important point since base-level and MAJCOM vehicle managers are the primary beneficiaries of system success or failure.

A simpler, and possibly more effective strategy will be to model the flow from the perspective of a single base-level user submitting 601s to a single MAJCOM, who in turn forwards those requests to WR-ALC and beyond. Model development and data preparation will be accomplished according to this assumption.

The model will also be designed to facilitate measurement of those key variables which characterize system performance. This will include steps to identify the independence of activities and reduce the effects of autocorrelation on sequential activities. It will also include steps to isolate those variables deemed most indicative of system problems.

With these assumptions in mind, simulation code will be adapted to the flow diagram to simulate the processes taking place in the diagram. While model parameters and variables will not yet be defined, the presence of the basic code will dictate the types of questions which need to be asked in order to obtain data to apply to the code.

Data Preparation

In order to establish the range of operation for the computer code, data must be collected from several sources to get realistic representations of system variables and parameters. These include interarrival times, processing times at each activity center, intransit times, feedback loops and other characteristics of system behavior. These system variables and parameters will animate the model in a fashion which will represent system activity.

Data preparation will require interaction with system users at all levels, not only to ensure that the needed data is identified, but also to make sure that the data is valid as it is applied to the model itself. With the single base/MAJCOM/WR-ALC flow assumption in mind, data gathering will involve interviews with system users to obtain either historical or estimated data on which to base model parameters. Some of this data may be obtained in the process of defining the system, but most will follow the establishment of the model's basic code. The type of data used will depend on the degree of accurate historical data that is available. Some data may be based on historical data, while other variables and parameters will be based on estimates from managers at using activities.

A convenience sample of four major commands -- MAC, SAC, TAC, and AFSC -- will be interviewed to get a broad sample of perspectives on system variables and parameters. These commands were selected based on the wide range of missions that they represent, as well as their large and relatively stable fleet sizes. Additionally, CONUS bases were chosen to simplify data gathering, as well as to avoid large fluctuations in 601 mailing times that might be experienced between overseas commands, their subordinate units, and WR-ALC. Interviews will be directed at MAJCOM CEMOs, the persons who actually process and distribute the 601s at the MAJCOM level.

Interviews will also include a sample of at least two bases per MAJCOM interviewed. These will be chosen to again get a broad perspective of mission types and fleet sizes within the command, i.e. a bomber and a missile base, a large and a small base, etc. Interviews there will focus on the Fleet Management Sections of base Vehicle

Operations Branches. They are the individuals who coordinate and submit 601s at the base level.

Finally, additional data will be gathered from the Support Equipment Division at Warner Robins Air Logistics Center (WR-ALC), the approval authority for vehicle allowance/authorization. In addition to providing quantitative data on system parameters, these interviews will explore other aspects of system behavior and performance such as:

1. Process ownership. What agency has overall responsibility for the implementation and effectiveness of the process?

2. Process inputs. What agencies have inputs to the process?

3. Process flows. What are the paths and loops followed by entities within the process?

4. Process visibility. To what extent do system users have access to entity status?

5. Process constraints. What resources or conditions constrain the capacity of the process?

6. Measures of merit. By what standard or standards should process effectiveness be measured? What constitutes "good" system performance?

7. Costs and benefits. What are the costs or benefits of good or bad system performance?

These elements will help to finalize model formulation and will complement the quantitative data used to define model parameters.

An important note to be made at this point is that the nature of the sampling used will not permit the research to make scientific conclusions about the effectiveness of EDI on the 601 process at every management level. The experimentation will instead provide some insight into the results that might be expected given an EDI-integrated 601 flow with the parameters that were used. In order to draw scientific conclusions, the parameter and variable data populations would have to be compared with the overall USAF populations using Chi-Square or other goodness-of-fit tests to determine if the data do indeed come from the same populations. Such an exercise would be extremely complex and time-consuming, and may not be necessary to make useful inferences about the effects of EDI on the 601 process.

Validation

Model validation will be patterned after Pidd's white and black box validation stages. White box validity will concern the accuracy of the model's coding to ensure that it carries out the desired model logic. Black box validity will concern making sure that the model logic reflects actual system performance. Flow chart comparison and further user interrogation will accomplish this task. White box validity will involve extensive use of model debugging and visual checks to ensure that the coding is correct. Black box validity will entail the "face validity" described by Emshoff and Sisson in which the system users give inputs concerning the accuracy of the model. It will also involve comparing the model's output data against any existing system historical data to further validate the model.

Strategic Planning

Strategic planning, as defined by Shannon, involves designing the experiment to facilitate measurement. In order to test the effects of EDI on the system, the model will be structured so that measurements can be taken at key delay points to determine delay duration. Additionally, total system time will be measured to test the effects of EDI on 601 total process times. The objective in this portion of the experiment will be to determine if EDI reduces system response time by reducing intransit times between activities.

First, a GPSS/H model will be constructed which imitates the processes inherent in the current system. Another model will then be constructed to reflect a proposed system which incorporates EDI as a means of transmitting the information normally carried on the form 601. An important note here is that faster transmittal times inherent in EDI will be the primary focus of later experimentation. Other features such as improved accuracy and faster processing may be mentioned, but will not be used to support the . .search hypothesis. These faster transmittal times can be easily simulated within the second model by changing the variables that represent entity advance times from one activity to another.

Tactical Planning and Experimentation

Test runs in the model will be replicated enough times to get a statistically significant number of output samples with which to make comparisons with the actual system and base model. For each of the runs, random number streams will be changed for processes that generate random numbers to ensure independence of each replication, and to facilitate synchronization of the two models. This step is important to ensure that differences in system residence times reflect the reduced intransit times, and not variations in other system activities. Additionally, runs will include an initialization period sufficient to overcome the effects of initialization bias in order to observe the system in its normal, steady-state behavior.

Interpretation

Once the model has been modified and executed to simulate the effects of EDI, sufficient output data will exist to draw inferences about system performance. Schriber suggests the use of a correlated paired-t test to compare the performance of alternative systems. This test, along with the use of assigned random number streams throughout the model, uses matched pairs of numbers to block out the effects of uncontrollable variables such as process times and transaction routing. By matching pairs of data from the two models, each can be compared based on the effects of intransit times alone, with all other factors being equal (Schriber, 1991: 339-340).

Computing the paired differences of the data will cancel out the effects of the uncontrollable factors. By working with matched pairs, a positive correlation is established between the members of each matched pair in order to reduce the variability in paired differences and sharpen the contrast between the alternative systems. This method will be used to determine the differences in residence times between the two models (Schriber, 1991: 339-340).

To execute the paired-t test, average residence times from each run of the base (without EDI) model will be paired with the corresponding average residence times of the experimental (with EDI) model. The differences in these times will be averaged for all of the runs, and paired difference confidence intervals obtained to estimate the true mean of that difference. The formula for obtaining the confidence interval is:

$$\bar{x}_D \pm t_{\alpha/2} \frac{s_D}{\sqrt{n_D}} \qquad (1)$$

where

$\bar{x}_D$ = *mean difference*
$t_{\alpha/2}$ = 1.833 *for a 95% confidence interval*
s_D = *sample standard deviation*
n = *sample size*

The confidence interval will contain a pair of numbers, one representing the lower limit and the other representing the upper limit of the range in which the true mean should lie given the alpha (probability) used. If the confidence interval of the difference in mean residence times between the two models does not span zero, it can be concluded that the inclusion of EDI into the process improves process times for this experiment.

If time savings are deemed to be small or nonexistent, further experimentation may be conducted to see how flow rates, queue sizes, and other factors have been affected by the inclusion of EDI. This may identify shortcomings or bottlenecks that may not be improved by EDI.

Conclusion

The results of this study will support or refute the effectiveness of EDI as a means of improving system performance and will provide some measure of the effects of management decisions on the flow of 601s through the system. This information will serve as a starting point for process modifications which will improve its responsiveness to users at all levels.

The next chapter, Model Development will provide an overview of the GPSS/H simulation language, and will describe the code that is used to represent the various activities occurring in the allowance/authorization process. It will also discuss the considerations which went into the development of each model, and will address the application of the variables and parameters that were derived from interviews with process users.

IV. Model Development

Introduction

As mentioned in chapter III, the simulation model was developed with Forrester's industrial dynamics approach and Shannon's eleven stages of model development in mind. The steps included defining the system, capturing the critical system processes into a flow diagram, and interpreting the flow diagram into computer language which could facilitate simulation of the actual and experimental systems. They also involved obtaining data to replicate the variables and parameters in the actual system, validating both the flow diagram ("black box" validity) and the computer code used to mimic the system ("white box" validity), and developing an output format which would enable statistical comparison of model alternatives.

Additional considerations in developing the model included simplicity of design, ease of modification, construction which would facilitate measuring statistics of interest with respect to system performance, and synchronization of steps in competing models to eliminate the effects of controllable variables. Simplicity of design was necessary, both to accommodate effective troubleshooting and to allow validation by users who may not be familiar with simulation language. Ease of modification was a prerequisite to permit adjustments for the various experiments to be performed using the same basic model framework. Finally, the model had to be constructed so that statistics on system residence times, queue sizes, and flow rates could be effectively measured.

Capturing the Flow

After the boundaries of the process were identified, the flow of the 601 process had to be defined. This included determining the 601 input source, intransit channels, decision and processing points, coordination loops, and output points. Following interviews with vehicle managers at base level and MAJCOMs, and equipment managers at WR-ALC, a flow diagram was developed which would permit visualization of key model processes (see Appendix A). This flow diagram became the direct source from which computer code could be adapted for later simulation models.

The flow chart uses standard flow symbols to denote input points, activity points, decision points, document initiation, and process routing. The chart actually begins with activities which lead up to the initiation of the 601. Although these activities are not part of the process to be modeled, their inclusion in the flow chart helps to provide a broader picture of the boundaries of the process and the events which generate process inputs.

The first segment of the chart describes base level activities which generate a 601 submission. The parallelogram represents the users' identification of the need for vehicle support. This symbol denotes an input into the system. From there, those users must coordinate the requirement with the vehicle operations branch, an activity point represented here, and henceforth in the chart, by a square or rectangle. Vehicle operations branch personnel determine if a new authorization/allowance is needed to support the requirement. This determination is a decision point represented by a diamond. If the request does require a new authorization/allowance, the process continues with preparation of an AF form 601. If an open authorization/allowance already exists, branch personnel may take action to obtain a vehicle asset to fill the slot without initiating a new 601 (Johnson, 1990).

The second group of symbols includes those which describe activities that take place once the request has been approved at base level and a 601 has been prepared and submitted to the MAJCOM vehicle manager (CEMO). Once the CEMO receives and evaluates the document, the first decision point determines whether the form is properly documented with the appropriate codes and request justification. If the form does not contain the proper administrative requirements, the CEMO coordinates with the submitting unit to correct the deficiencies. If all administrative requirements have been met, the request is evaluated against the current command vehicle authorization listing (VAL), and against mission urgency to determine if the need for the vehicle warrants a new authorization/allowance in light of command vehicle ceilings. If the need is properly justified and the command ceiling will not be exceeded, the CEMO may approve the new authorization at his or her level. If the command ceiling would be exceeded by the new authorization, the CEMO must decide if he or she wishes to delete an authorization elsewhere in order to accommodate the new authorization. Each of these decisions are represented in the chart by diamonds, and the outcomes are once again represented by rectangles (Johnson, 1990).

The CEMO must also determine if a new allowance is required by reviewing the appropriate Table of Allowances for the requesting activity. The outcome of this evaluation determines whether the 601 requires further coordination. If no new allowance is required, the

CEMO can approve or disapprove the authorization and no further action is required. If a new allowance is required, the CEMO must forward the 601 to WR-ALC/LZE, Air Force Support Equipment Division, for further evaluation (Johnson, 1990).

A third group of symbols describes activities which take place at WR-ALC, if the 601 requires action at this level. First, the Support Equipment Division must determine if the request requires further coordination based on specialized needs which must be assessed by the appropriate ALC Item Manager. If not, the Support Equipment Division can approve or disapprove the 601 according to the strength of the justification or other factors. Otherwise, a copy of the 601 is mailed to the Item Manager who is familiar with the mission and requirements of the requesting activity. The Item Manager makes an input to the support equipment division, who approves or disapproves the request based on that input (Johnson, 1990).

A final loop describes the possibility that the request will represent a new equipment requirement that does not have a previously-assigned national stock number. Once this loop has been accomplished or bypassed, the Support Equipment Division must decide if the new allowance would exceed ceilings for the requesting activity. Again, an existing allowance must be deleted if the new allowance would exceed the ceilings. If the Support Equipment Division agrees that the new allowance should be added, the 601 will be approved and the requesting command notified so that they can take action -- either through the vehicle priority buy or in-command rotation -- to fill the new authorization/allowance. This action completes the 601 process as it pertains to authorization/allowance requests, and defines the end of the flow diagram (Johnson, 1990).

The diagram was mailed to WR-ALC/LZE for examination, a step which constitutes black box validity of the model. AFSED personnel agreed with the flow diagram as a functional interpretation of the process, thus setting the stage for adapting computer code to facilitate simulation of the process (Johnson, 1991).

Development of Computer Code

Using the flowchart as a template, computer code was adapted to mimic the activities occurring in the 601 process. GPSS/H, a computer simulation language, was selected to facilitate experimentation with the 601 process and to collect information on process performance.

The GPSS/H Simulation Language. The GPSS/H simulation language is an effective method of mimicking the behavior of discrete systems. It allows the researcher to simulate dynamic processes and to measure key indicators of system performance such as resource utilization rates, queue sizes, residence times, and a host of other statistics of interest. The GPSS/H modeler views the system being modeled from the perspective of entities moving through the system. These entities, called *transactions* (abbreviated XACTs), are envisioned as moving through the system from block to block, with each block representing an action or process being performed on the entities. Once the program compiles the code, a START statement begins the flow of transactions into the system (Banks and others, 1989:7-13).

The portion of a GPSS/H model which represents the activity flow is made up of block statements. These consist of a GPSS/H command followed by a series of alphanumeric characters known as operands. The function of each operand varies with the command, but in general serves as a variable or parameter which defines the duration, frequency, routing, or distribution of the activity being performed upon each transaction (Banks and others, 1989:23-24).

For the model being studied, each transaction is representative of a 601 somewhere in the process. A GENERATE block represents the submission of a 601 at base level. For example, the GPSS/H block

```
GENERATE  RVEXPO(2,12)
```

represents 601s being submitted according to an exponential distribution with a mean of twelve, with the deviation from that mean determined by a current random number from random number stream two (more will be discussed about random number streams at a later point) (Banks and others, 1989:25,249).

GENERATE blocks can also specify the duration of a particular model run. The model can be run until a specified number of transactions are TERMINATEd, or, as in this model, until a specified amount of time units has elapsed. In this model, the block

```
GENERATE 730
```

is placed at the end of the block statements to tell the computer to run the model for 730 days (two years) (Banks and others, 1989:25).

GPSS/H also has blocks that can represent the time delay of an activity being performed. The ADVANCE blocks in this model represent processing times by MAJCOM, WR-ALC, Item Manager, and CASC activities, as well as the intransit times in between each of these activities. For example, the block

```
ADVANCE  7
```

would represent a process requiring seven days (time segments are recorded as days for this model, although minutes, hours, or other time measurements may be used) to complete. Because 601s represent temporary entities in the request process, they are TERMINATEd at the end of the process as they are either approved or disapproved (Banks and others,1989:26-28).

Other blocks within GPSS/H represent resources with limited capacity. The model was developed with blocks labeled CEMO, ROBINS, ITEMMGR, and CASC to represent these *facilities*, as they are termed in GPSS/H simulation language. SEIZE and RELEASE blocks represent transactions entering and leaving facilities. Before a transaction can enter a facility, it must SEIZE it. Once the facility is finished processing a transaction, it RELEASEs it, indicating that the required processing time has elapsed for that transaction. For this model, only one transaction can occupy any facility at one time; therefore, a transaction cannot SEIZE a facility until the previous transaction has been processed and RELEASEd. For example, the combination

```
SEIZE    CEMO
ADVANCE  7
RELEASE  CEMO
```

would represent a 601 being received by the MAJCOM Command Equipment Management Office, requiring seven days to process for approval/disapproval, and then being released for further coordination or returned to the submitting organization (Banks and others, 1989:28-30).

Complements to the SEIZE block are the QUEUE and DEPART blocks. These are bracketed around the SEIZE blocks and provide a holding place for transactions waiting to be SEIZEd by a facility. They also facilitate important measurements of flow rates such as queue sizes. By using the combination

```
QUEUE   MAJOR
SEIZE   CEMO
DEPART  MAJOR
```

measurements can be taken on the current, average, or maximum number of transactions waiting to SEIZE the facility named CEMO (Banks and others, 1989:91-93).

Other blocks are also used to facilitate the simulation of 601s moving through the system. The FUNCTION block specifies the probability that a particular transaction will be assigned a value which is used later for routing to non-sequential blocks or other deterministic activities. The FUNCTION blocks

```
MAJCO FUNCTION  RN2,D2
      0.05,1/1.0,2
```

determine that five percent of the transactions entering the block will be assigned a value of 1, and the rest will be assigned a value of 2. In this case the assignment is based on a random number from random number stream two, and is a discrete function with the distribution divided among two ranges (0-.05, and .05-1.0) (Banks and others, 1989:246-248).

Once the FUNCTION block has assigned a value to a particular transaction, a TEST block can be used to determine the value or status of that transaction and route the transaction accordingly. For example, the block

```
TEST E    FN(MAJCO),2,OUT
```

determines the status of the transaction which has been assigned a value by the function labeled MAJCO. If the transaction has been assigned a value equal to 2, it will proceed to the next sequential block, otherwise, it will be routed to the block labeled OUT. In this model, the combination

```
MAJCO FUNCTION  RN2,D2
     0.05,1/1.0,2
      TEST E      FN(MAJCO),2,OUT
```

simulates the event that five percent of the 601s received by the MAJCOM CEMO are disapproved (and routed out of the system), and the remaining 95 percent proceed for further evaluation (Banks and others, 1989:136-137).

Still other GPSS/H blocks permit effective statistical evaluation of the model's output. The RMULT block is a control statement that specifies a new offset into the designated random number stream for each model replication. This allows variation in generation frequencies, advance times, and other stochastic activities for each replication in the model. Another command, the RESET block, sets all transaction statistics to zero following an initialization run, but does not remove current transactions from the model. This permits the experimentation to begin at a point at which the process is already operating at steady state, rather than starting with empty facilities and waiting for them to become active. Beginning the simulation at other than steady state could affect the statistical accuracy of the model (Banks and others, 1989:211-217, 244-245).

Another set of control statements facilitates multiple model runs. The DO and ENDDO statements are run-control statements that form a loop which executes the model repeatedly for a number of replications specified by an index variable in the DO statement. Once the specified number of executions has been accomplished, the ENDDO statement discontinues the loop and the model stops running. For example, the combination

```
DO     &I=1,10,1
START  1
RESET
START  1
ENDDO
END
```

performs a series of 10 replications of the model, each consisting of an initialization period, followed by a second run for effect in which the RESET statement has removed all statistics from the model, but not the transactions. The DO loop variables consist of an integer ampervariable, &I, which can take on a number of values. It is incremented each time the model is executed. When its value equals that of the second operand, the ENDDO statement is executed, and the model stops (Banks and others, 1989:227-228).

Finally, PUTPIC statements can be used to print output statistics of interest into a specified output file. This permits the modeler to obtain customized reports using GPSS/H Standard Numerical Attributes (SNA's), codes which specify particular statistics about transactions, facilities, or queues. The SNA M1, for example, when included in a PUTPIC statement, would collect the system residence times of each transaction and print it into a file (Banks and others, 1989:171-173).

In summary, GPSS/H simulates entities moving through a system, each competing for scarce resources. Once the code is compiled, a START statement initiates the model, and a GENERATE statement introduces transactions into the model at specified intervals. Each transaction ADVANCEs through the model, SEIZEs facilities representing scarce resources, is routed using FUNCTIONs and TEST statements, and TERMINATEs when it has completed its assigned route. DO and ENDDO statements form control loops that permit multiple replications, and PUTPIC statements print specified information to files. Additionally, GPSS/H features SNAs which collect measurements of interest concerning the behavior of the system. Although some of these commands -- and numerous other GPSS/H commands which have not been mentioned -- have other uses within GPSS/H, the commands mentioned will be used to simulate the flows and loops inherent in the 601 process.

Development of Model Variables and Parameters. Although GPSS/H code provides a static framework around which the model is formulated, the adaptation of data to that code animates the model in a fashion which converts the code to a series of variables and parameters. Activities which remain constant over the foreseeable range of system operation are parameters, while those that take on different values during the process are variables. These variables and parameters define the simulation operation and give life to the model.

In order to define those variables and parameters, each block of GPSS/H code is followed by one or more operands which specify the stochastic distributions, frequencies, ranges, and durations of those activities. While the GPSS/H statements alone can reflect those activities being carried out by the flow diagram, the operands animate the code to reflect the time and interval realities within the system.

In order to develop operands which would accurately define system variables and parameters, some questions had to be answered. These questions included:

1. How often are 601s submitted?
2. What is the distribution of interarrival times?

3. What is the intransit time between each processing point?

4. How long does each process take?

5. What is the percentage of 601s that are approved/disapproved at each processing point?

6. What percentage require coordination outside the normal flow loop?

Interrogation began at the base level. Two bases were chosen from each of the following commands: SAC, MAC, TAC, and AFSC. Each base was interviewed to determine 1) the average number of 601s submitted in a year, and 2) the estimated intransit mailing time between the base and its serving MAJCOM. The first question was intended to provide the source variable for transactions entering the model. Although some of the bases had historical data pertaining to the number of 601s generated, some were estimates. Because the interarrival times (time between submissions) was assumed to be exponential in nature (see explanation on page 4-14, 4-15), a mean interval was determined from the data provided from the eight bases. This value was used as an operand for the initial GENERATE statement, and thus established the flow rate for the model. All of the intransit times to the serving MAJCOMs were estimates provided by the users. They were averaged to obtain an operand for the ADVANCE block between the base level and MAJCOM processing points.

As mentioned, four MAJCOMs were interviewed to determine parameter and variable values for model code corresponding to MAJCOM activities. Questions concerned 1) percentage of 601s disapproved at the MAJCOM level, 2) average MAJCOM 601 processing time, and 3) average intransit mail time to WR-ALC. The percentage disapproved at the MAJCOM level was used to determine the FUNCTION ranges at MAJCOM decision points. The average 601 processing time provided the operand for the ADVANCE statement used to represent MAJCOM 601 processing times. Finally, the average intransit mail time was needed to determine the operand value for the ADVANCE statement representing mail time between MAJCOM and WR-ALC decision points.

WR-ALC was the highest level at which parameter and variable figures were garnered. Similar to the questions posed to the MAJCOM were questions determining 1) the average length of time required to process each 601, as well as process times from Item Managers (IM) and CASC, 2) the percentage of 601s that must be coordinated with IMs and CASC, 3) the percentage of 601s that are disapproved by WR-ALC and IMs, and 4) the intransit mail time between WR-ALC and IM and CASC coordination points.

Appendix B contains a summary table of figures obtained from each agency in response to interview questions asked. The values for each base were averaged to obtain variable and parameter figures for a simulated base submitting 601s. Similarly, values obtained from the four MAJCOMs interviewed were averaged to derive variables and parameters for MAJCOM activities in the model. Because WR-ALC is the single point into which all 601s flow in both the actual system and in the model, the figures obtained for that agency were not modified. The figures obtained from each level were plugged into the appropriate operands of the corresponding GPSS/H block statements representing that activity.

For system processing times, an exponential distribution is assumed. Not only is this distribution commonly used in simulation models to reproduce activity times, but is preferred in this case over a normal distribution because of the possibility that a normal distribution can return negative numbers unless the standard deviation of the mean is at least 5. This phenomenon of GPSS/H models made use of the normal distribution undesirable for this model. Use of the exponential distribution is further substantiated by McClave and Benson, who note that the interarrival times to many real queues can be reasonably approximated by an exponential probability distribution. They also note that the exponential distribution has proved to be an adequate approximation to the time required to service a customer. Thus, the exponential distribution can be used to describe both the input source and the service mechanism (McClave and Benson, 1988:287). The 601 process is closely analagous to a servicing process, because of the queues, flows, and processing activities involved.

Model and Experiment Planning. The addition of interview data into the block statement operands completed the flow logic portion of the model; however, additional control statements and other considerations were necessary to facilitate the use of the model as a tool for comparing system alternatives. Three primary considerations were involved in model planning -- model synchronization, statistical effectiveness, and data output.

Because the experiment actually consisted of two separate GPSS/H models -- one representing the actual system and one modified to reflect the reduced intransit times resulting from the introduction of EDI -- it was necessary to ensure that the differences in 601 system residence times actually resulted from the reduced intransit times and not from stochastic variations in other process activities. This was accomplished by specifying the random number streams in each stochastically-controlled statement in order to synchronize the steps in the competing models.

GPSS/H simulations are stochastic in nature. They use random variables to simulate variations in the interarrival times of GENERATE blocks, the service, intransit, or processing times in ADVANCE blocks, and to assign transactions to frequency distributions in FUNCTION blocks. To generate these random variables, GPSS/H uses streams of random numbers extracted from a built-in random number generator. These random numbers are used to compute the variables and parameters defined by the operands following GPSS/H block statements (Banks and others, 1989:242-244).

Unless the modeler specifies the random number stream being used by each stochastic activity, GPSS/H uses random number stream (RNS) 1 as the default RNS. By specifying the random number streams to be used, or the point at which the generator selects the random number in the stream, the modeler can control the variability between two runs or two models. For example, two runs of an identical GPSS/H model will produce identical results in terms of number of transactions generated, the interval between transactions, queue sizes formed, etc. This occurs because GPSS/H draws random numbers from the same stream at the same point for corresponding transactions generated by each run. Variability between successive runs must be accomplished either by changing the RNS for at least one stochastic activity or changing the point in the RNS from which the activity draws random numbers (Schriber, 1991:344-345).

Changing the random number streams of stochastic activities (blocks) from one run to the next will produce different results. When the "A" (first) operand of one of these activities specifies the type of distribution being used, the random number stream being used is also specified. For example, the GENERATE block followed by the operand RVEXPO(2,10) introduces transactions according to an exponential distribution with a mean of 10. RNS 2 is specified by the first number within parentheses. By changing this number within the operand, the random number stream used by the GENERATE block to compute the exponential deviation from the mean 10 is also changed. Therefore, the interval between transactions will be changed as well (Banks and others, 1989:249).

Another means of facilitating variation between successive runs of a single model is by changing the starting point for the RNS. Ordinarily, the number sequence for RNS *i* is 100,000 * *i*. In other words, the default starting element of RNS 1 is the 100,000th element of the sequence produced by the random number *generator*. The default starting element for RNS 2 is the 200,00th element, etc. Through the use of the RMULT control statement, this starting element can be changed for each successive run. For example, the block

```
RMULT    299,000+1000*&I
```

indicates that the starting element for RNS 3 will be 300,000 for the first run, 301,000 for the second run, 302,000 for the third run, etc. (&I is an ampervariable equal to 1 whose value is incremented by 1 with each repetition of the model). Therefore, each stochastically-controlled GPSS/H block statement will return a different value for corresponding transactions of successive runs (Banks and others, 1989:244-245).

The use of specified random number streams and random number stream starting elements (offsets) is extremely important in order to accurately compare the results of the two competing models. The objective in executing the models is to determine how the differences in intransit times affect model performance, with all other model characteristics being equal. The two models being compared are identical, except the advance times representing intransit times between processing points have been reduced to zero for the second model (simulating the virtually instantaneous transfer of 601 information via EDI). To ensure that corresponding transactions produce the same stochastic reactions from both models, the random number streams for corresponding block statements are the same. For instance, the GENERATE statement will produce the same interarrival time for the first transaction generated by both models. The second transaction produced will have a different interarrival time; however that time will still be equal for both models. ADVANCE statements representing 601 processing times and FUNCTION statements representing disapproval percentages will be similarly controlled, resulting in a mirror-image flow between corresponding transactions produced in the same run of the two models.

The random number streams used within the models have also been specified such that no two stochastically-controlled statements draw from the same random number stream. The first variable statement uses RNS 2 (use of RNS 1 was avoided to prevent conflict with non-specified variable statements whose RNS default would be RNS 1), the second uses RNS 3, etc. This staggering ensures that each variable step is completely independent in terms of the random numbers that control its variation.

Finally, an RMULT control statement is included which ensures that the RNS starting elements differ for each successive run. This will ensure the processing and interarrival times, as well as the disapproval percentages are different for each run yet still the same for both models. As in the example shown earlier, this is accomplished through the inclusion of an RMULT control statement which specifies a different RNS starting element for each successive run.

The combination of specified random number streams and offsets ensures that the two models are identical in all respects except the intransit time between processing points. Any differences between the two models' 601 residence times should therefore be entirely due to the difference in intransit times (the characteristic being changed by EDI), and not by variations in other model activities.

Another important aspect of model planning was statistical effectiveness. Two considerations had to be taken into account to ensure that the output from the two models was statistically accurate. One was sample size and the other was initialization bias. The first consideration was to ensure that enough 601 residence time samples could be obtained so that statistical tests could be performed on them. The second consideration was to ensure that the residence times reflected the steady-state operation of the system, and did not include samples from the low-biased initial stages of the run.

In order to get a sufficient number of samples, both models were set up to simulate two years of system operation. This was necessary not only to get a sufficient number of samples per run, but also to exclude the possibility that the residence time of any single transaction might exceed the planned run time. The number of samples returned for each replication of the run will vary due to the variations in random number stream offsets that will change processing times for successive runs. Similarly, the number of transactions returned for the two models should differ for the same run due to the shortened intransit times inherent in the second (EDI) model.

A final consideration in model planning was the format for the output data. As mentioned earlier, the PUTPIC statement in the model permits the data to be output to a separate file. It also allows the use of GPSS/H standard numerical attributes to identify and collect the statistics of interest -- in this case, the residence time for each 601 moving through the system.

Four different output files were specified for the two models -- a file for both approved and disapproved 601 residence times for each model. Because the residence times of approved 601s are the primary focus of the study, separate files for approved and disapproved 601 residence times were specified so that the data for approved 601s could be segregated.

Code Description. Once the flow of the process was defined, the data to provide variables and parameters obtained, and the model developed to produce the desired output, the GPSS/H code was finalized (see Appendix C). Following the mandatory SIMULATE statement in line 1, the first step was to define the ampervariables that would later be used to control the number of replications and differentiate between the initialization run and the subsequent run for effect. This statement in line 5 (the numbers in the left margin were added for reference purposes and are not part of the original code)

```
INTEGER    &I,&J
```

indicates that the values of the ampervariable will be whole, and not fractional or decimal numbers.

Following the ampervariable declaration is the declaration of the FUNCTIONs to be used in routing transactions. In lines 9 and 10, the statement

```
   MAJ    FUNCTION  RN4,D2
0.05,1/1.0,2
```

specifies the distribution of transactions which will be assigned a parameter value of 1 or 2. The operand RN4 specifies the random number stream which will be used to control the distribution of transactions, and D2 identifies the FUNCTION as a discrete function with two ordered pairs. This particular FUNCTION represents the disapproval rate for 601s at the MAJCOM level (five percent), and will be used later to determine transaction routing. Other FUNCTIONs identified in the declaration include AFLC (line 12), APPR (line 15), and CASC (line 18) which represent the percentage of 601s disapproved at WR-ALC, the percentage coordinated with the Item Manager, and the percentage coordinated with CASC, respectively.

Following the declaration of FUNCTIONs which determine routing percentages begins the block statements which represent the actual flow of 601s through the system. The first -- and possibly most important -- statement controls the interarrival time of 601s. The block

```
     GENERATE  RVEXPO(2,12)
```

simulates a 601 being submitted according to an exponential interarrival time with a mean of 12 days, with the probability being calculated according to a random number from RNS 2. This activity represents the submission of 601s at the base level.

Following submission, the 601 is mailed to the MAJCOM CEMO. The combination in blocks 24 through 27

```
ADVANCE    4
QUEUE      MAJOR
SEIZE      CEMO
DEPART     MAJOR
```

represents a four-day mailing time to the CEMO, and then arrival at the CEMO. QUEUE and DEPART statements are also used to facilitate queue measurement. The CEMO must then process the 601, a time which is simulated with the block statement

```
ADVANCE    RVEXPO(3,10)
```

This combination denotes an exponentially-distributed processing time with a mean of 10 days, calculated from RNS 3.

Following processing by the CEMO, the 601 is RELEASEd (line 29). Its fate is then determined by the TEST statement in line 30. The statement

```
TEST E     FN(MAJ),2,OUT
```

is read, "test the function labeled MAJ. If its value is equal to 2, the transaction goes to the subsequent block; otherwise, it is routed to the block labeled OUT." Recall that in the FUNCTION statement labeled MAJ, five percent of the transactions will be assigned a value of 1. The rest will be assigned a value of 2. The TEST statement routes that five percent to the block labeled OUT, an action which simulates the five percent MAJCOM disapproval rate. The remaining 601s go on for further evaluation.

601s which are approved at the MAJCOM level are routed via the ADVANCE 4 block to WR-ALC (line 31). There they SEIZE the person responsible for processing 601s. In line 35, the block

```
ADVANCE    RVEXPO(5,7)
```

represents the processing time, once again exponentially distributed with a mean of seven days, and using RNS 5 as its basis for calculation.

Once RELEASEd from WR-ALC, the block

```
TEST E    FN(AFLC),2,OUT
```

routes 601s according to the distribution specified in the FUNCTION statement labeled AFLC. The three percent that are disapproved at the WR-ALC level have been assigned a value of 1 and are routed to the block labeled OUT; the rest go for further coordination.

Another TEST statement at line 39 routes four percent of the approved 601s to the Item Manager for coordination by that agency. The block

```
TEST E    FN(APPR),1,LAST
```

sends that small percentage that require further coordination to the next block. The rest are routed to the block labeled LAST a represent 601s which require no further coordination.

Line 40 begins a coordination process including the IM and possibly CASC. The ADVANCE 4 statement at line 40 simulates the mail time for those 601s going to the IM. 601s then SEIZE the IM who determines the type vehicle necessary to fill the requirement. This activity is represented by the block

```
ADVANCE    RVEXPO(8,34)
```

again, an exponentially distributed processing time with a mean of 34 days. RNS 8 was dedicated to this process to assure independence from other processes.

Of those 601s which must go to the IM for coordination, five percent must be coordinated with CASC to obtain new stock numbers. This activity is represented in line 45 by the statement

```
TEST E    FN(CASC),1,LAST
```

which uses the FUNCTION labeled CASC to achieve the distribution of 601s to be routed to CASC for cataloging. Those 601s assigned a value of 1 will be routed to CASC. The remainder will be returned to WR-ALC.

Like other processing times, CASC processing time is represented by an ADVANCE block. The statement

```
ADVANCE    RVEXPO(10,34)
```

simulates an exponentially distributed processing time with a mean of 34 days. This time, RNS 10 controls the probability distribution. Once cataloging is complete, the 601 is released by both CASC and the IM, and the 601 is returned to WR-ALC for final processing.

Thus far, all of the 601s that have been coordinated outside WR-ALC have been routed to the block labeled SKIP (line 51). At this point, WR-ALC performs final processing prior to notifying the appropriate command. 601s that did not require outside coordination have been routed to the block labeled OKED (line 56). These are the last actions performed on the 601.

The next set of statements concerns the format of the output data, which in this case will be the residence time of each 601. The first statement

```
TEST E    &J,2,STOP
```

is a means of eliminating the data from the initialization period from the output report. In the initialization period, the ampervariable &J has a value of 1, and all approved 601s are routed to the block labeled STOP. These bypass the subsequent BPUTPIC block. In the run for effect, all approved 601s are routed to the blocks

```
       BPUTPIC     FILE=QUOOK,LINES=1,&I,N(OKED),M1
**       ***          ***.****
```

which designate an output file and format for 601 residence time data. The BPUTPIC (or block PUTPIC) block outputs the data from approved 601s to a file named QUOOK. One line is needed to contain the data which is taken on each individual transaction. The asterisks below are decimal holding places for the three types of output that correspond with the items at the end of the BPUTPIC statement. The first, &I, is an ampervariable which is incremented with each replication and represents each replication number. This data will go into the first two asterisks. N(OKED) is a Standard Numerical Attribute (SNA) that identifies the number of transactions that have entered that block. This number will go into the second set of transactions. Finally, M1 is another SNA that measures the residence times of transactions moving through that block. The output file QUOOK will therefore contain the replication number, the transaction number, and the residence time of each 601 that is approved. These transactions are then routed to the TERMINATE 0 block in line 60 where they are destroyed.

As 601s are disapproved in the model, they have been routed to the block labeled OUT (line 61). Initialization data is once again filtered out of the output file through the use of the TEST statement in line 62. Another BPUTPIC file has been identified in line 63 to collect output statistics for disapproved 601s, should they be examined later. Like the approved 601s, disapproved 601 transactions are destroyed by a TERMINATE 0 statement.

Although the model block statements represent the actual 601 flow, other control statements are needed to establish the behavior of the model. The first of these is the GENERATE 730 statement at line 69. When 730 days have elapsed, this statement introduces a transaction that enters the subsequent block, TERMINATE 1, and stops the run. Therefore, the duration of each run of the model is 730 days.

Other run control statements also determine the behavior of the model. At line 74, the block

```
DO    &I=1,10,1
```

performs a repeated loop of the commands that follow. The operand &I, an integer ampervariable, is incremented by 1 for each replication. When its value equals the value of the second operand, 10, the DO-loop is terminated. The final operand tells the model to increase the value of the first operand in increments of 1.

The LET &J=1 statement at block 75 assigns a value of 1 to the ampervariable &J. Although not crucial to the model flow, this value is used in the TEST statement in blocks 57 and 62 to exclude initialization data from the output files. This will simplify evaluation of the output data.

Another block that does not influence the model flow, but does control the variances in processing times and routing from run to run is the RMULT block in lines 76 through 84. This block performs a computation which defines a new starting point for RNS 2-10, a starting point which changes with each incrementation of &I. Therefore, each RNS has a new offset for each run in order to vary the output from stochastically-controlled commands in the block statements. In other words, each step in the process will return a different value from run to run.

Once the model has compiled the instructions contained in the code, the START 1,NP command in line 85 executes the model. In this case, it runs the model for one 730 day period, but does not print the results to a model file (to prevent the model from using disk space for unneeded data). Following this initialization run, the RESET statement resets all statistics to zero, but does not remove the current transactions from the model. In this manner, model statistics are recorded beginning at a point in which the process has reached steady state.

For the second run, the value of &J is changed to 2 (line 87). This ampervariable is used in the TEST statements in lines 57 and 62 to route transactions through the BPUTPIC blocks so that data can be recorded for the run for effect. Again, the model is STARTed and run. Following each run for effect, the CLEAR statement in line 89 clears all transactions from the model and zeroes out all statistics.

The model continues this process for ten replications. Because cost and computer time were not a consideration given the language used and the size of the model, ten replications will provide more than a sufficient number of individual 601 samples for statistical significance, and will also facilitate additional variation in activity times. The ENDDO statement at line 90 increments &I, and begins a new iteration of the DO-loop, until the first and second operands of the DO statement are equal. After this run, the ENDDO statement is bypassed, the END statement is encountered, and model execution is terminated.

As mentioned previously, the second model -- the one which simulates the 601 process with the integration of EDI -- is identical to the first with the exception of the blocks which represent intransit times between processing points (see Appendix D). For the second model the times for these ADVANCE blocks have been reduced to zero to simulate the virtually instantaneous transmittal of the information contained on the form 601.

Summary

This chapter has outlined some of the concepts of the GPSS/H simulation language, and has explained some of the considerations used in model development including variability, syncronization, and statistical significance. The chapter also explained the application of GPSS/H simulation code to each step of the 601 process, as well as other features which permit data collection and multiple executions of each model.

The completion of the model code, the culmination of the model formulation process, leads to the next phase, experimentation. In this phase the two models will be run, the output compared, and conclusions formed. Additionally, the output will be evaluated to identify system behavior such as bottlenecks, flow rates, etc. to determine the effects of EDI on statistics other than residence times.

V. Experimentation and Conclusions

Introduction

Following development of the two GPSS/H models, the next step is to execute the models to examine differences in 601 residence times, as well as other differences that become apparent through experimentation. Comparison will consist of compiling the residence time data in an output file, determining differences in average residence times for each model replication, and determining confidence intervals for those average differences. Experimentation may also reveal unanticipated behavior resulting from the inclusion of EDI into the process. Further model modification may be necessary in order to characterize and quantify that behavior.

Output Comparison

Output comparison will first involve determining the average 601 residence time for each run. Using the paired-t test described by Schriber, average 601 residence times for each run of the model representing the system with EDI included will be matched with the ten averages of corresponding runs of the base model. Differences will be taken between the matched pairs, and confidence intervals obtained for the average differences. The result will provide a reliable measure of the actual time savings independent of other uncontrollable factors such as process times and transaction routing.

Model Execution

In order to employ the paired-t test, the model was run, and the resulting residence times for approved 601s were output to two files -- QUOOK containing residence times for the status quo system and EDIOK containing residence times for the system simulating EDI integration. These ASCII files were imported into a spreadsheet program to facilitate operations associated with the paired-t test. Average system residence times were taken for each of the ten replications of both models. The average of the first replication for the base (without EDI) model was paired with the average for the first replication of the experimental (with EDI) model. This was done for the remaining nine replications as well. Table 1 displays the results of the experiment.

Confidence Intervals for Model Experimentation

The differences in paired averages of the model using mail as the primary source of transmitting 601s and the model incorporating EDI were recorded and confidence intervals were obtained for the mean of those differences. The confidence intervals were calculated according to the formula annotated in Eq (1) in chapter 3.

The mean difference in the residence times was approximately nine days, a processing time improvement of about ten percent. A 90 percent confidence interval calculation revealed a mean residence time difference of between 8.31 and 9.81 days. A 95 percent confidence interval was calculated with a mean residence time difference of between 8.07 and 10.05 days. Because the confidence interval did not span zero, the inclusion of EDI can be interpreted as having improved system residence times as measured by this experiment. Thus, the mean

TABLE 1

601 RESIDENCE TIMES

REP #	CURRENT SYSTEM	SYSTEM W/EDI	DIFFERENCE
1	81.46149	75.0052	6.456291
2	38.69103	30.5525	8.138532
3	199.8258	188.9785	10.84731
4	190.0858	181.9644	8.121457
5	50.7014	43.2427	7.458706
6	93.13842	83.4275	9.710913
7	73.83199	65.22892	8.60307
8	69.07305	58.69518	10.37787
9	105.3278	93.17144	12.15634
10	46.99104	38.27762	8.713423
MEAN:	94.91278	85.85439	9.058391
STD DEV:	56.64835	56.12435	1.7108982

CONFIDENCE INTERVALS
FOR MEAN DIFFERENCE:

	LOWER	UPPER
90% CI:	8.310142	9.806641
95% CI:	8.066677	10.05011

improvement in residence times can be predicted with 95 percent probability as being between eight and ten days for this experiment.

These results fail to reject the original hypothesis that the inclusion of EDI will improve (reduce) overall 601 residence times. With all uncontrollable factors accounted for, the integration of an instantaneous transmittal of information via EDI appears to reduce the average 601 residence tim· by approximately nine days over an identical system using mail as the primary means of transmittal. An important note, however, is that the models evaluate only the effects of faster transmittal inherent with EDI -- no other benefits such as improved accuracy or reduced processing time were incorporated into this experiment.

Variability

Another important finding was that the time savings apparently resulting from EDI remained relatively fixed over the entire range of 601 residence times. While the standard deviation for time savings was only 1.72 days, the standard deviation for residence times for the experimental (including EDI) model was 56.12 days. Time savings do not increase proportionally with increases in residence times resulting from stochastic variation in processing times and routing. In other words, the time savings do not vary much whether the entire residence time was 20 days or 100 days. Thus, it appears that reductions in intransit times do not result in a synergy that reduces the time spent at each processing point.

Impact of EDI on Queue Length

Intuitively, improved intransit times should improve system throughput and therefore reduce overall residence times. Although instantaneous transmittal does appear to reduce overall residence times by six to twelve days, processing points do not appear able to exploit the intransit time advantages provided by EDI, thus providing time savings over and above the savings in intransit times alone. One possible explanation for this counterintuitive behavior is that improvements in transmittal time are offset by increased queue sizes that accumulate at each processing point. In other words, although EDI does speed transmittal time, processing points do not process faster (at least given the assumptions of this model) and 601s which arrived more quickly end up waiting anyway.

To examine this effect more closely, both models were modified to incorporate an additional PUTPIC statement into the control statements at the end of the models. This statement, inserted after the START 1 statement in block 89, took the form

PUTPIC FILE=QSIZE,LINES=1,&I,QA(MAJOR),QM(MAJOR),QA(ALC),_
QM(ALC)

where QA(MAJOR) is a Standard Numerical Attribute (SNA) that records the average contents of a queue named MAJOR, QM(MAJOR) is an SNA that records the maximum contents of the queue named MAJOR, QA(ALC) records the average contents of the queue ALC, and QM(ALC) records the maximum contents of the queue ALC.

Both models were run once more, with the output of the new experiment going to a file named QSIZE for the base model and EDISIZE for the experimental model. Once again the ASCII files were imported to a spreadsheet to facilitate mathematical comparison; however, the queue statistics for both models were found to be identical. Surprisingly, queue sizes and maximum queue lengths did not vary despite the faster transmittal time offered by EDI.

Average queue sizes, however, did reveal some interesting data. Although the queue sizes for the base model MAJCOM facility were expected to be shorter overall due to the buffering effect of the longer transmittal time, this was not the case. The continuous presence of at least one 601 in the queue seems to negate this buffering effect and perpetuates the same queuing behavior as the model with EDI. Again, Forrester's counterintuitive behavior attribute of systems became apparent. Average queue sizes for the MAJCOM processing point ranged from one to fifteen 601s for both models. Although this phenomena was less apparent for the facility ROBINS, a faster processing time at this facility would probably account for the smaller queue sizes. This data also points to the MAJCOM as the system's primary constraint point.

Not surprisingly, replications characterized by longer average residence times also had longer average queue lengths. The first-in, first-out processing system results in dependent residence times among sequential transactions. In other words, if a transaction experiences an abnormally-long residence time, the next transaction will probably have to wait in queue and will therefore suffer a similarly-long residence time. This effect can also be seen in the raw residence time data (see Appendix E and F). One long residence time seems to spawn a string of longer residence times. Short residence times likewise appear to perpetuate strings of shorter processing times. Forrester noted this interdependent behavior as an attribute of some systems.

How significant is the MAJCOM processing time to the overall residence time of 601s? To compare the relative effects of processing times versus faster transmittal times, a paired-t test was performed between the base model and one in which the MAJCOM mean processing time was reduced from ten to seven days. The average residence times for each replication were paired and differences obtained. Table 2 displays the results.

While the average difference between the base model and the EDI-incorporated model was approximately nine days, the difference between the base model and one incorporating a shorter MAJCOM processing time was an average of 52 days. This equates to a 54 percent improvement in residence times. Confidence intervals for the mean difference spanned from 30.48 to 74.91 at the .90 level of significance to 23.25 to 82.14

TABLE 2

AVERAGE 601 RESIDENCE TIMES -
REDUCED MAJCOM PROCESSING TIME

REP #	CURRENT MAJCOM TIME	MAJCOM TIME REDUCED	DIFFERENCE
1	73.19944	46.89783	26.30161
2	128.1276	27.2437	100.8839
3	207.1168	45.21561	161.9012
4	115.2391	37.35338	77.88574
5	87.25546	43.2427	44.01276
6	77.21047	50.27331	26.93716
7	76.68494	46.22276	30.46219
8	100.8262	36.04825	64.77796
9	61.3832	68.562	-7.1788
10	30.00082	29.04116	0.959659
MEAN:	95.70441	43.01007	52.69434
STD DEV:	47.89845	11.83302	50.7936

CONFIDENCE INTERVALS
FOR MEAN DIFFERENCE

	LOWER	UPPER
90% CI:	30.48011	74.90856
95% CI:	23.25206	82.13662

at the .95 level of significance. Again, the confidence interval did not span zero and the results indicate with 95 percent probability that the actual mean time savings for the experiment is between 23 and 82 days. Given the reductions in process times noted by such companies as Conrail and Interamerican Transport Systems (Chapter 2), process time reductions and time savings such as these would not be unexpected.

This finding is important because it indicates that overall residence times can probably be improved more through reductions in processing times than through improvements in transmittal flow rates, at least given the current variables and parameters in the model. For these models, a three-day reduction in MAJCOM processing time had a greater effect on residence times than did a four-day reduction in intransit times. These results indicate that most of the 601 residence time is spent waiting to be processed, at least at the MAJCOM level. As process times decrease, transmittal times should have more of an effect on overall system residence times.

In summary, faster transmittal times do appear to have a positive, if not relatively small effect on overall 601 residence times. Reductions in transmittal times alone, however, will continue to produce only marginal improvements in residence times until processing times can be reduced as well. The overall governor of system residence times will be the activity with the longest duration -- in this case, the MAJCOM processing time. As noted earlier, some improvements in processing times may result from other benefits of EDI -- more accuracy, fewer keystrokes, and better database utilization. Making more conclusive evaluations of the effects of shorter processing times will require a more in-depth study of the actual mechanics of 601 processing at each point, as well as a standardized EDI format on which to base improvements in those processing mechanics.

Findings

The data obtained from the execution of the GPSS/H model supports the hypothesis that the faster transmittal time made possible through the integration of EDI into the 601 process reduces the overall residence times of 601s in the system. By reducing transmittal times from four days to zero, an average of nine days can be reduced from the average 601 system residence time. The data also suggests that improvements in 601 residence times will be limited by processing times at the MAJCOM and other activity centers. More substantial reductions in residence times will occur when MAJCOM and other activity processing times can be reduced so that they can exploit the faster transmittal times inherent in EDI. In fact, reductions in processing times at the MAJCOM appear to have a far greater effect on system residence times than reductions in transmittal times.

Although not studied in this research, the incorporation of an integrated EDI system such as AFEMS will certainly offer reductions in transmittal times, and may offer substantial reductions in processing time through improved accuracy, reduced research requirements, and better database utilization and management. This would accomplish the goal of developing a 601 process that is more responsive to managers at all levels.

Suggestions for Further Research

Although the research explored some useful methods for evaluating the effects of EDI, and resulted in some useful information about the behavior of the 601 process, some further research should be accomplished to expand the effectiveness of this methodology as a means of EDI evaluation. First, the model should be modified to incorporate actual variable and parameter data from a limited number of bases under a single MAJCOM. Actual data would allow firm assessments to be made concerning data distribution and other characteristics that would possibly make the model a more accurate representation of the actual system. Although gathering enough data to make the model representative of all USAF bases would be extremely difficult if not impossible, limiting data to actual historical data from a few bases and a single

MAJCOM could allow the modeler to make scientific judgements about the effects of EDI at those bases.

To accomplish this task, the researcher should establish and maintain a log of actual 601 variables and parameters as observed over the course of several months. The log should include the same variables and parameters that were estimated for this model -- processing times, interarrival times, and intransit times.

As mentioned previously, another key focus of future research should be potential for reductions in processing times. Because processing times appear to hold the most promise for reducing overall 601 residence times, they should be researched carefully to determine the extent to which they might offer savings, both in time and money. Such research will require an in-depth analysis of the mechanics of 601 processing. Current processing methods must be compared with those accomplished using a standardized EDI format such as AFEMS. Comparisons could use the same methodology established in this research, and combined with expected reductions in intransit times, result in a total benefit package for EDI.

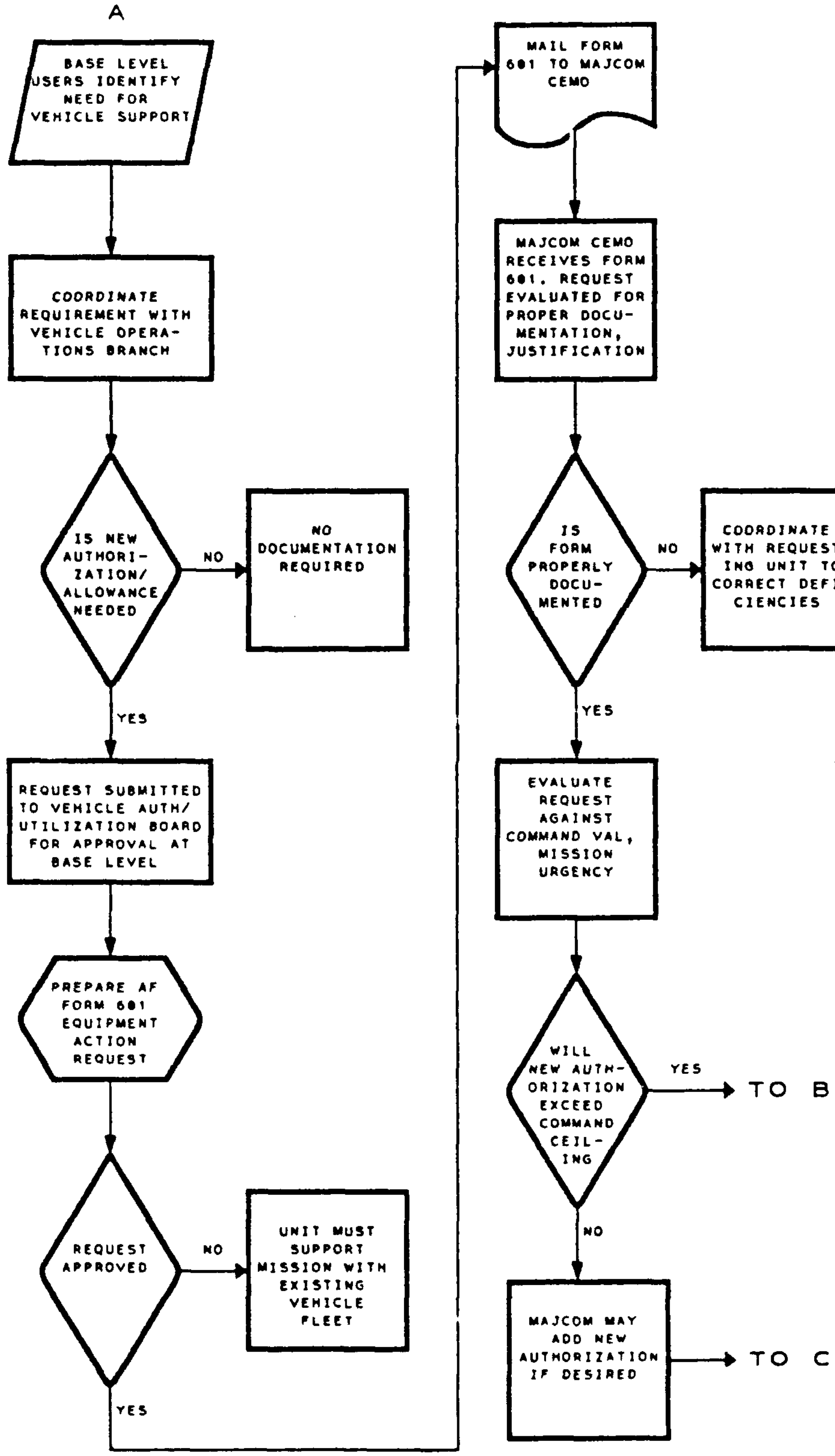
This research has barely touched the surface of the capabilities of computer simulation as a tool for measuring the effects of EDI on this and other coordination processes, particularly if processing time reductions are evaluated and quantified. For example, AFEMS features could be evaluated to obtain not only the degree of time savings resulting from AFEMS, but labor cost savings as well.

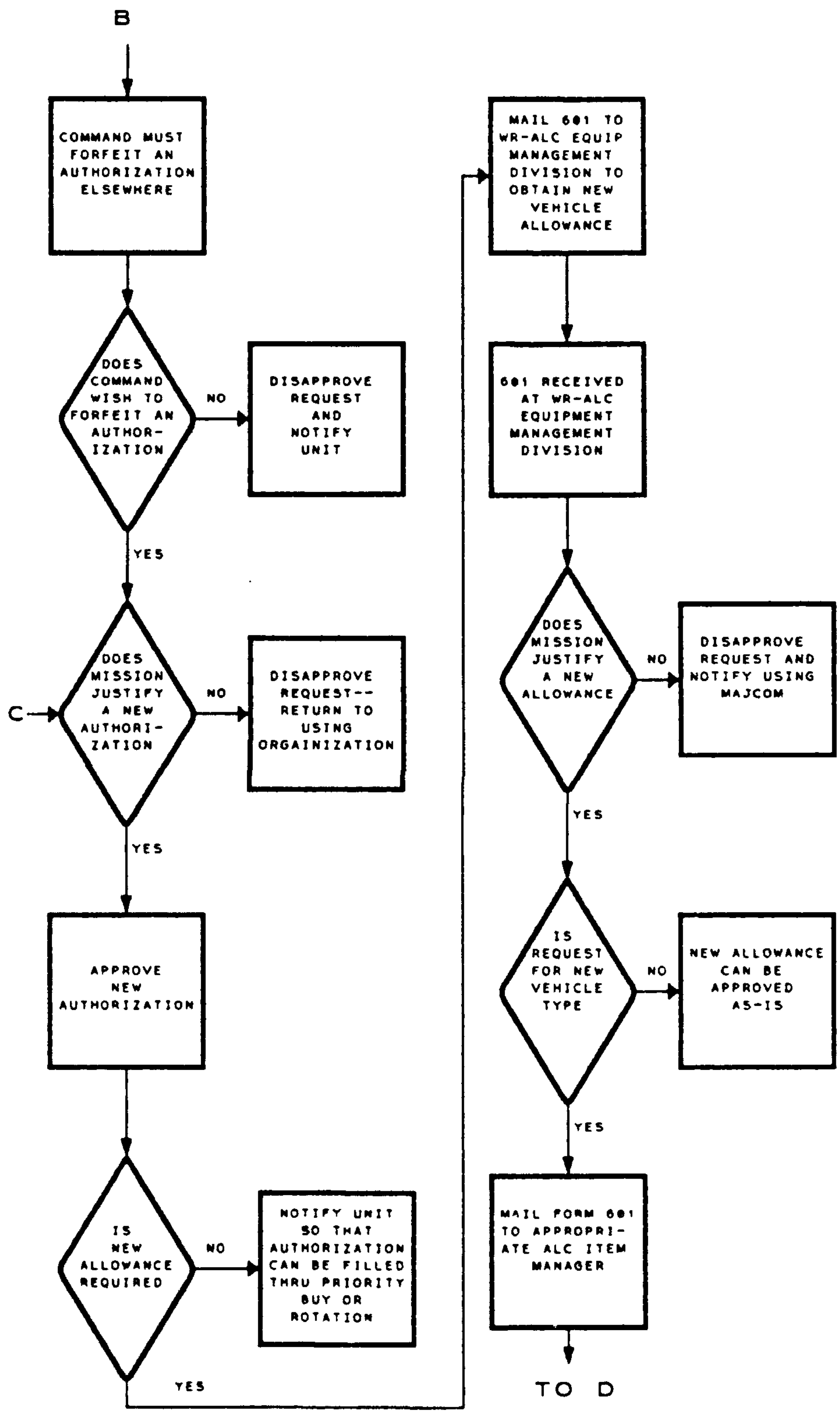
The model could also be used to perform cost/benefit analysis for the various features of AFEMS or other EDI formats. Some features obviously cost more than others to develop and deploy. By using the model as a tool to determine which features result in the most efficient program management, program developers could avoid the costs of implementing "gold plated" features which offer little in the way of benefit.

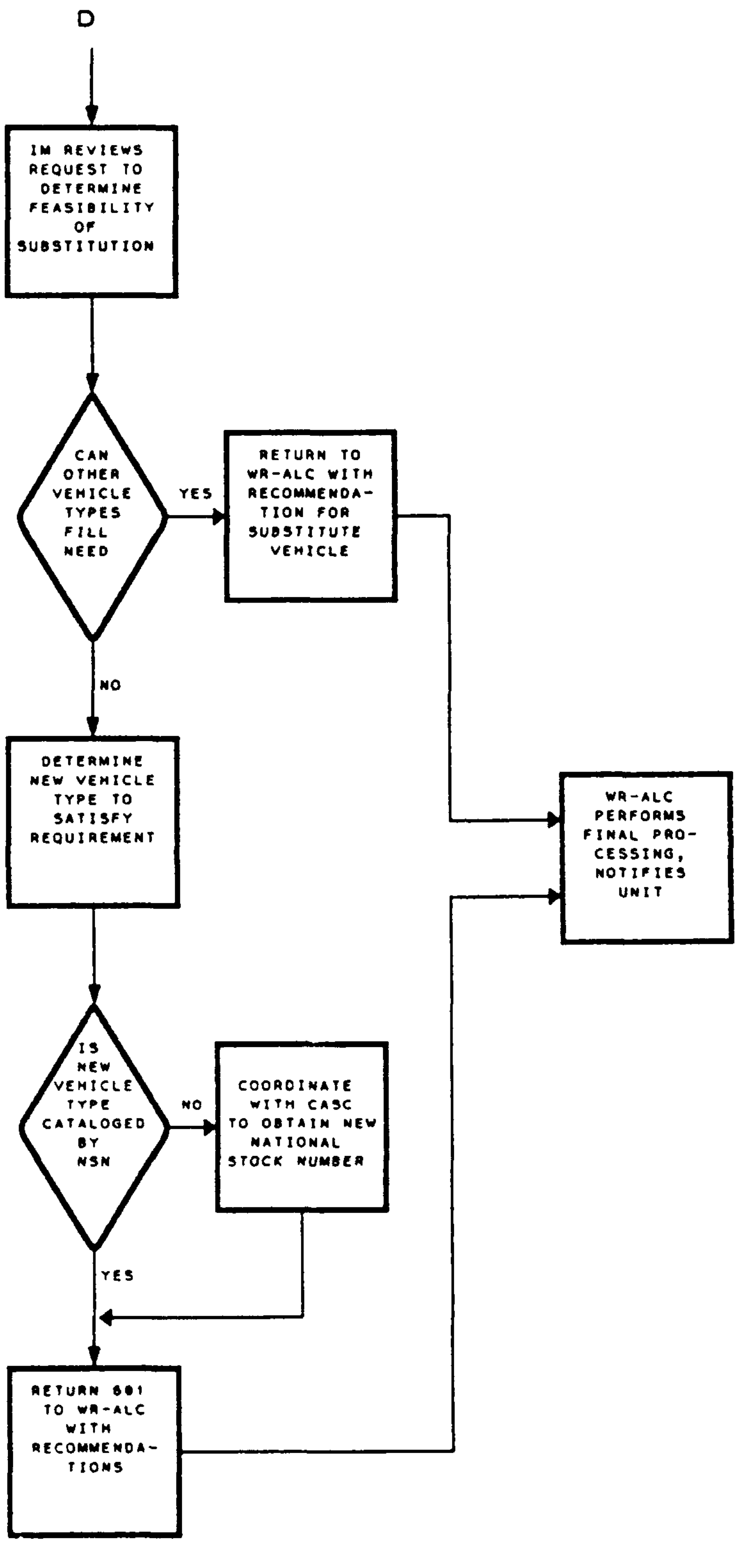
Finally, the model could be used to determine if AFEMS will offer sufficient overall manpower savings to offset its development and implementation costs. System maintenance and other factors should also be evaluated to weigh the tradeoffs between system costs and manpower savings and effectiveness.

Overall, the implementation of EDI as a means of transmitting critical vehicle data appears to offer significant benefits, particularly if the program incorporates features which reduce not only transmittal time but processing time as well. The true measure of success will be not only the degree to which EDI reduces 601 turnaround time, but the degree to which it adds value to the managers who depend on the process at all levels.

Appendix A: Flow of AF Form 601




B
COMMAND MUST FORFEIT AN AUTHORIZATION ELSEWHERE
DOES COMMAND WISH TO FORFEIT AN AUTHOR-IZATION
NO
DISAPPROVE REQUEST AND NOTIFY UNIT
YES
C
DOES MISSION JUSTIFY A NEW AUTHORI-ZATION
NO
DISAPPROVE REQUEST-- RETURN TO USING ORGAINIZATION
YES
APPROVE NEW AUTHORIZATION
IS NEW ALLOWANCE REQUIRED
NO
NOTIFY UNIT SO THAT AUTHORIZATION CAN BE FILLED THRU PRIORITY BUY OR ROTATION
YES
MAIL 601 TO WR-ALC EQUIP MANAGEMENT DIVISION TO OBTAIN NEW VEHICLE ALLOWANCE
601 RECEIVED AT WR-ALC EQUIPMENT MANAGEMENT DIVISION
DOES MISSION JUSTIFY A NEW ALLOWANCE
NO
DISAPPROVE REQUEST AND NOTIFY USING MAJCOM
YES
IS REQUEST FOR NEW VEHICLE TYPE
NO
NEW ALLOWANCE CAN BE APPROVED AS-IS
YES
MAIL FORM 601 TO APPROPRI-ATE ALC ITEM MANAGER
TO D


D
IM REVIEWS REQUEST TO DETERMINE FEASIBILITY OF SUBSTITUTION
CAN OTHER VEHICLE TYPES FILL NEED
YES
RETURN TO WR-ALC WITH RECOMMENDA-TION FOR SUBSTITUTE VEHICLE
NO
DETERMINE NEW VEHICLE TYPE TO SATISFY REQUIREMENT
WR-ALC PERFORMS FINAL PRO-CESSING, NOTIFIES UNIT
IS NEW VEHICLE TYPE CATALOGED BY NSN
NO
COORDINATE WITH CASC TO OBTAIN NEW NATIONAL STOCK NUMBER
YES
RETURN 601 TO WR-ALC WITH RECOMMENDA-TIONS

Appendix B: Model Variables and Parameters

A. Base-level inputs. Inputs for model variables and parameters were obtained through structured telephone interviews with fleet managers at the respective bases. Questions and responses are noted below:

1. How often are 601s submitted?

EGLIN: 80 per year	EDWARDS: 60 per year
WHITEMAN: 12 per year	LORING: 12 per year
MOODY: 36 per year	MACDILL: 15 per year
TRAVIS: 18 per year	DOVER: 16 per year

AVG: 249 per year or 1 every 11.73 days. Rounded up to 12, this figure becomes the average interarrival time for 601s in the model.

2. What is the intransit time to the servicing MAJCOM?

EGLIN: 4 days	EDWARDS: 5 days
WHITEMAN: 3 days	LORING: 3 days
MOODY: 4 days	MACDILL: 4 days
TRAVIS: 4 days	DOVER: 4 days

AVG: 3.875 days. Rounded up to 4, this figure becomes the intransit time from base level to the MAJCOM.

B. MAJCOM inputs. These inputs were obtained from the CEMO managers at the respective MAJCOMs through structured telephone interviews.

1. Approximately what percentage of the 601s that you receive are disapproved due to administrative errors or inadequate justification?

AFSC: 2 percent MAC: 4 percent

TAC: 6 percent SAC: 5 percent

AVG: 4.25 percent. Rounded up to 5, this figure becomes the disapproval rate at MAJCOM.

2. What is your average processing time for 601s?

AFSC: 5 days MAC: 21 days

TAC: 10 days SAC: 2 days

AVG: 9.5 days. Rounded up to 10, this figure becomes the MAJCOM processing time.

3. What is the approximate intransit time to WR-ALC?

AFSC: 3 days MAC: 4 days

TAC: 5 days SAC: 4 days

AVG: 4 days. This figure becomes the intransit time from the MAJCOM to WR-ALC.

C. WR-ALC level. All model variables and parameters for WR-ALC were obtained through personal and telephone interviews with AFSED personnel and are reflected directly in the model.

1. What percentage of the 601s that you receive are disapproved due to administrative error or inadequate justification? Answer: 3 percent. Becomes WR-ALC disapproval percentage for the model.

2. What is the average processing time for 601s at WR-ALC? Answer: 7 days. This figure becomes the WR-ALC processing time for the model.

3. What is the percentage of 601s that must be coordinated with the Item Manager? Answer: 4 percent. This figure becomes the percentage routed to the Item Manager in the model.

4. What is the average 601 processing time for IMs? Answer: 34 days. Becomes IM processing time in the model.

5. Of those 601s that go to the IM, what percentage must be coordinated with CASC? Answer: 5 percent. Becomes percentage of 601s that are routed from the IM to CASC in the model.

6. What is the average CASC processing time for 601s? Answer: 34 days. Becomes CASC processing time for the model.

Appendix C: Computer Code for Present 601 Flow

```
      SIMULATE
*********************************************************************************
*     Ampervariable Declaration
*********************************************************************************
      INTEGER   &I,&J
**********************************************************************************
*     Control Statements (functions)
*********************************************************************************
  MAJ  FUNCTION RN4,D2
0.05,1/1.0,2                  5 percent disapproved by MAJCOM
*
  AFLC FUNCTION RN6,D2
0.03,1/1.0,2                  3 percent disapproved by WR-ALC
*
 APPR FUNCTION RN7,D2
0.04,1/1.0,2                  4 percent coordinated with IM
*
 CASC FUNCTION RN9,D2
0.05,1/1.0,2                  5 percent coordinated with CASC
********************************************************************************
      *     Status Quo 601 Flow
*********************************************************************************
      GENERATE  RVEXPO(2,12)  601 submitted every 12 days on average
      ADVANCE   4             Transit time for 601 to MAJCOM
      QUEUE     MAJOR         Collect waiting time stats for CEMO
      SEIZE     CEMO          601 Arrives at MAJCOM
      DEPART    MAJOR         Calculate waiting time stats for CEMO
      ADVANCE   RVEXPO(3,10)  MAJCOM processing time for 601's
      RELEASE   CEMO          MAJCOM completes 601 processing
      TEST E    FN(MAJ),2,OUT  5% of 601s disapproved -- go to OUT
      ADVANCE   4             Transit time for 601 to WR-ALC
      QUEUE     ALC           Collect waiting time stats for ROBINS
      SEIZE     ROBINS        601 arrives at WR-ALC
      DEPART    ALC           Calculate waiting time stats for ROBINS
      ADVANCE   RVEXPO(5,7)   WR-ALC processing time for 601's
      RELEASE   ROBINS        WR-ALC coord, approves, or disapproves 601
      TEST E    FN(AFLC),2,OUT  3% of 601s disapproved -- go to OUT
      ADVANCE   0
      TEST E    FN(APPR),1,OKED  4% go to IM for coordination
      ADVANCE   4             Intransit time to IM
      QUEUE     ITEM          Collect waiting time stats for ITEMMGR
      SEIZE     ITEMMGR       601's received by appropriate IM
      DEPART    ITEM          Calculate waiting time stats for ITEMMGR
      ADVANCE   RVEXPO(8,34)  Item manager processing time for 601's
      TEST E    FN(CASC),1,SKIP  5% coordinated with CASC
      QUEUE     CREEK         Collect waiting time stats for CASC
      SEIZE     BATTLE        CASC begins processing
      DEPART    CREEK         Calculate waiting time stats for CASC
```

```
      ADVANCE   RVEXPO(10,34) CASC processing time
      RELEASE   BATTLE        CASC completes processing
 SKIP RELEASE   ITEMMGR       IM returns 601 to WR-ALC
      ADVANCE   4             Transit time from IM to WR-ALC
      SEIZE     ROBINS        WR-ALC receives 601
      ADVANCE   3             WR-ALC performs final processing
      RELEASE   ROBINS        WR-ALC notifies base of approved 601
 OKED ADVANCE   0
      TEST E    &J,2,STOP     Do not record times for initialization
      BPUTPIC   FILE=QUOOK,LINES=1,&I,N(OKED),M1
 **     ***       ***.*****
      TERMINATE 0
  OUT ADVANCE   0
      TEST E    &J,2,STOP     Do not record times for initialization
      BPUTPIC   FILE=QUOBAD,LINES=1,&I,N(OUT),M1
 **     ***       ***.*****
 STOP TERMINATE 0
*******************************************************************************
*     Run-Control Xact
*******************************************************************************
      GENERATE  730           Simulate 730 days (2 years) system operation
      TERMINATE 1             Terminate run at end of 2 years
*******************************************************************************
*     Run-Control Statements
*******************************************************************************
      DO       &I=1,10,1          Perform 10 replications
      LET      &J=1               Assign value of &J
      RMULT    ,199000+1000*&I,_  RN2 offset for current replication
                299000+1000*&I,_  RN3 offset for current replication
                399000+1000*&I,_  RN4 offset for current replication
                499000+1000*&I,_  RN5 offset for current replication
                599000+1000*&I,_  RN6 offset for current replication
                699000+1000*&I,_  RN7 offset for current replication
                799000+1000*&I,_  RN8 offset for current replication
                899000+1000*&I,_  RN9 offset for current replication
                999000+1000*&I,   RN10 offset for current replication
      START     1,NP              2-year initialization period
      RESET                       Reset all statistics to zero
      LET       &J=2              Change value of &J
      START     1                 Run model for effect
      CLEAR                       Clear stats and transactions from model
      ENDDO                       Next value of &I
      END
```

Appendix D: Computer Code for 601 Flow With EDI

```
     SIMULATE
*********************************************************************************
*    Ampervariable Declaration
*********************************************************************************
     INTEGER   &I,&J
*********************************************************************************
*    Control Statements (functions)
*********************************************************************************
 MAJ  FUNCTION RN4,D2
0.05,1/1.0,2                  5 percent disapproved by MAJCOM
*
 AFLC FUNCTION RN6,D2
0.03,1/1.0,2                  3 percent disapproved by WR-ALC
*
 APPR FUNCTION RN7,D2
0.04,1/1.0,2                  4 percent coordinated with IM
*
 CASC FUNCTION RN9,D2
0.05,1/1.0,2                  5 percent coordinated with CASC
*********************************************************************************
       *     601 Flow With EDI
*********************************************************************************
     GENERATE  RVEXPO(2,12)  601 submitted every 12 days on average
     ADVANCE   0             Transit time for 601 to MAJCOM
     QUEUE     MAJOR         Collect waiting time stats for CEMO
     SEIZE     CEMO          601 Arrives at MAJCOM
     DEPART    MAJOR         Calculate waiting time stats for CEMO
     ADVANCE   RVEXPO(3,10)  MAJCOM processing time for 601's
     RELEASE   CEMO          MAJCOM completes 601 processing
     TEST E    FN(MAJ),2,OUT  5% of 601s disapproved -- go to OUT
     ADVANCE   0             Transit time for 601 to WR-ALC
     QUEUE     ALC           Collect waiting time stats for ROBINS
     SEIZE     ROBINS        601 arrives at WR-ALC
     DEPART    ALC           Calculate waiting time stats for ROBINS
     ADVANCE   RVEXPO(5,7)   WR-ALC processing time for 601's
     RELEASE   ROBINS        WR-ALC coord, approves, or disapproves 601
     TEST E    FN(AFLC),2,OUT  3% of 601s disapproved -- go to OUT
     ADVANCE   0
     TEST E    FN(APPR),1,OKED  4% go to IM for coordination
     ADVANCE   0             Intransit time to IM
     QUEUE     ITEM          Collect waiting time stats for ITEMMGR
     SEIZE     ITEMMGR       601's received by appropriate IM
     DEPART    ITEM          Calculate waiting time stats for ITEMMGR
     ADVANCE   RVEXPO(6,34)  Item manager processing time for 601's
     TEST E    FN(CASC),1,SKIP  5% coordinated with CASC
     QUEUE     CREEK         Collect waiting time stats for CASC
     SEIZE     BATTLE        CASC begins processing
     DEPART    CREEK         Calculate waiting time stats for CASC
```

```
         ADVANCE   RVEXPO(10,34) CASC processing time
         RELEASE   BATTLE        CASC completes processing
    SKIP RELEASE   ITEMMGR       IM returns 601 to WR-ALC
         ADVANCE   0             Transit time from IM to WR-ALC
         SEIZE     ROBINS        WR-ALC receives 601
         ADVANCE   3             WR-ALC performs final processing
         RELEASE   ROBINS        WR-ALC notifies base of approved 601
    OKED ADVANCE   0
         TEST E    &J,2,STOP     Do not record times for initialization
         BPUTPIC   FILE=EDIOK,LINES=1,&I,N(OKED),M1
    **      ***        ***.*****
         TERMINATE 0
     OUT ADVANCE   0
         TEST E    &J,2,STOP     Do not record times for initialization
         BPUTPIC   FILE=EDIBAD,LINES=1,&I,N(OUT),M1
    **      ***        ***.*****
    STOP TERMINATE 0
    ******************************************************************************
    *    Run-Control Xact
    ******************************************************************************
         GENERATE  730           Simulate 730 days (2 years) system operation
         TERMINATE 1             Terminate run at end of 2 years
    ******************************************************************************
    *    Run-Control Statements
    ******************************************************************************
         DO        &I=1,10,1          Perform 10 replications
         LET       &J=1               Assign value of &J
         RMULT     ,199000+1000*&I,_  RN2 offset for current replication
                   299000+1000*&I,_   RN3 offset for current replication
                   399000+1000*&I,_   RN4 offset for current replication
                   499000+1000*&I,_   RN5 offset for current replication
                   599000+1000*&I,_   RN6 offset for current replication
                   699000+1000*&I,_   RN7 offset for current replication
                   799000+1000*&I,_   RN8 offset for current replication
                   899000+1000*&I,_   RN9 offset for current replication
                   999000+1000*&I,    RN10 offset for current replication
         START     1,NP               2-year initialization period
         RESET                        Reset all statistics to zero
         LET       &J=2               Change value of &J
         START     1                  Run model for effect
         CLEAR                        Clear all stats and XACTs from the model
         ENDDO                        Next value of &I
         END
```

Appendix E: Residence Times for System With EDI

XACT #	REP #1	REP #2	REP #3	REP #4	REP #5
1	42.7278	11.85436	181.2966	223.6124	103.9782
2	47.84005	217.8282	194.8314	229.753	46.3394
3	39.33842	9.78793	158.7268	247.1133	40.49846
4	22.8164	5.09682	165.6863	237.1745	45.40114
5	33.00583	5.21699	164.5875	227.991	44.5664
6	51.33335	5.87453	168.434	191.9103	31.33435
7	49.07894	36.10444	150.0653	202.5821	31.85215
8	49.85943	11.43354	149.8066	200.644	15.10377
9	53.87146	26.23198	159.2515	180.2545	30.43022
10	55.56799	27.27815	188.1374	283.221	28.83688
11	30.84295	56.04026	192.5133	186.0296	24.45954
12	50.04643	61.29762	195.5238	198.4319	19.63428
13	66.03025	57.64142	196.5886	208.93	25.76229
14	81.22055	79.13458	201.051	185.7512	66.88675
15	62.04048	47.27895	222.657	192.8402	64.96243
16	52.22305	39.48284	201.6441	207.8063	66.05727
17	65.48571	45.09724	182.9911	196.3557	31.30822
18	62.53956	44.98876	187.9934	206.8115	42.2227
19	29.80274	35.76682	188.3621	246.5719	35.13179
20	34.07672	27.62703	198.9616	210.9772	45.85458
21	66.82675	41.16817	195.2667	226.2791	27.40349
22	70.77209	32.22887	216.3875	215.6177	20.88828
23	68.01554	31.2227	225.1117	207.3959	13.39031
24	65.59581	22.25025	219.3263	200.3642	31.08375
25	67.026	46.0832	225.7422	167.9682	12.44669
26	49.78456	42.99889	227.4669	168.4422	24.75486
27	69.40281	25.62486	225.6077	165.443	52.26921
28	59.93754	18.22066	223.507	169.0547	49.68857
29	46.48272	4.44073	222.7387	177.0821	42.89822
30	33.37986	8.65941	217.505	174.9335	46.27781
31	30.3005	5.42769	215.3691	174.9649	29.99825
32	66.20164	24.54093	209.8294	174.3075	42.2245
33	60.57169	19.59505	196.4558	161.8412	52.03659
34	67.72539	16.98271	175.404	125.7424	72.75688
35	69.18561	12.15322	227.1061	127.4382	76.56377
36	69.70134	4.42169	229.3349	131.5102	54.49347
37	77.9874	26.14327	227.7938	141.188	54.41659
38	81.19093	20.87431	226.0796	148.6765	59.99099
39	113.6649	34.98624	239.4886	157.9607	55.30181
40	96.06559	26.26126	251.7107	160.5246	56.1822
41	112.0661	27.89202	241.0734	273.5017	55.09744
42	119.1545	30.17141	197.6523	162.0486	40.51691
43	100.4721	12.74399	179.8907	160.6173	43.82931
44	104.6132	4.92023	189.9544	153.8464	34.6279
45	101.0084	15.13147	149.3101	166.7477	46.7807
46	110.4153	22.54789	98.05981	160.6633	45.65864
47	126.1261	15.62365	315.4641	168.0749	48.4037
48	164.0514	26.84723	83.98438	166.8629	67.32918
49	174.0429	30.25698	104.7658	110.5096	79.23246
50	171.1084	26.14346	136.5037	139.7944	64.78769
51	153.9109		98.91993	138.9596	36.59103
52	153.7344		106.3768	142.5381	29.27048
53			67.56343	167.2745	15.00627
54				166.4144	10.31495
55				146.6977	15.44348
56				166.9669	60.40332
57				177.7742	55.85325
58				182.7733	
59				173.7856	
60				159.8122	
61				171.4959	
62				169.9997	
63				176.1682	
64				190.0168	
65				184.7491	
66				186.935	
67				185.0889	

XACT #	REP #6	REP #7	REP #8	REP #9	REP #10
1	10.31852	37.84066	126.8007	123.8475	41.7393
2	6.52784	28.9384	129.6811	122.2624	46.63668
3	8.44497	66.24899	128.8713	133.1072	20.35921
4	15.67442	53.9552	131.9865	124.5395	49.4661
5	21.58393	47.3342	97.56415	121.5082	33.4711
6	20.8057	36.61884	104.4926	123.7968	41.77757
7	45.49606	38.66945	109.7039	137.3254	57.06416
8	95.5033	94.82586	108.6564	152.5193	51.43037
9	92.34396	107.6794	112.2041	137.2321	50.81709
10	96.16786	129.2264	121.8049	137.1147	71.42684
11	139.958	141.0631	126.0762	141.5049	80.55523
12	156.6178	146.6555	97.62245	141.6986	69.58485
13	162.9326	158.1775	98.20595	244.1167	84.92345
14	157.1379	156.1628	96.17086	150.322	80.53965
15	162.7681	87.96666	69.57634	144.817	72.82928
16	135.7409	72.92975	60.46204	152.0922	14.20791
17	138.47	57.08402	43.67068	148.56	30.88009
18	164.9321	59.1157	42.46908	135.3422	15.93126
19	184.2088	55.63475	41.93582	142.6968	15.01346
20	181.1904	155.8797	65.15877	139.0418	35.22555
21	163.7991	63.61174	52.413	148.9942	32.2386
22	149.0126	30.61934	52.18565	150.7823	29.26082
23	133.1638	53.04606	23.29492	149.9081	31.51083
24	114.6798	47.29585	26.18981	161.8023	46.60726
25	106.4028	51.90448	22.23117	159.5826	38.11976
26	91.55043	40.34082	6.44629	160.6413	61.21326
27	97.5538	38.54698	23.26349	158.9356	21.25299
28	109.8813	31.71127	30.08697	161.7679	6.35916
29	93.05818	19.14757	34.12409	172.6891	16.60536
30	91.9749	35.85327	35.57551	144.4713	5.49746
31	101.0139	31.73573	20.24582	120.1001	23.06038
32	65.2769	40.9335	5.53099	83.53126	28.86358
33	77.95441	15.96468	18.4837	70.93952	40.63874
34	69.37328	39.79262	14.10946	74.6214	48.59453
35	59.70912	63.96114	13.62942	58.25199	30.58611
36	60.81654	63.78361	31.46104	54.69115	5.11386
37	56.64191	56.16543	20.94944	68.03328	22.8916
38	58.67494	57.33066	24.85808	54.92693	13.7982
39	54.76928	60.61861	27.04479	38.98641	26.73554
40	50.9931	66.19864	12.57216	49.41227	
41	44.84873	55.77011	25.41315	44.25215	
42	50.03415	59.64118	45.25393	39.64631	
43	69.51433	78.0384	54.42495	38.88472	
44	74.53004	55.67426	64.10153	43.76777	
45	71.38217	68.93377	57.65161	50.65476	
46	89.9503	63.61222	41.74872	15.6932	
47	85.37029	64.75095	39.2736	16.47093	
48	86.55273	71.7615	32.84553	35.2742	
49	89.74337	70.61278	40.24367	50.04114	
50	89.34081	32.08182	45.91155	52.70919	
51	86.59576		74.75143	56.80607	
52	81.92427		74.69634	57.29614	
53	74.77198		76.72619	82.41454	
54	70.89466		75.85272	72.63787	
55	52.95079		77.433	97.95514	
56	14.99959		70.34599	76.69074	
57	6.46253		63.42736	74.47732	
58	7.36991		60.96284	73.15781	
59	25.23032		60.51018	71.9466	
60	30.0602		32.32673	25.74213	
61				20.94905	
62				13.68248	
63				10.74889	
64				43.00255	
65				50.58874	
66				48.18953	
67				33.63722	
68				20.8356	
69				14.16249	

Appendix F: 601 Residence Times for Current System

XACT #	REP #1	REP #2	REP #3	REP #4	REP #5
1	50.7278	19.85436	171.2131	231.6124	111.9782
2	55.84005	229.7719	189.2966	237.753	54.3394
3	47.33842	20.77087	202.8314	255.1133	48.49846
4	30.8164	13.09682	166.7268	245.1745	53.40114
5	41.00583	13.21699	173.6863	235.991	52.5664
6	59.33335	13.87453	172.5875	199.9103	39.33435
7	57.07894	44.10444	176.434	210.5821	39.85215
8	57.85943	19.43354	158.0653	208.644	23.10377
9	61.87146	34.23198	157.8066	188.2545	38.43022
10	63.56799	35.27815	167.2515	295.9841	36.83688
11	38.84295	64.04026	196.1374	195.0785	32.45954
12	58.04643	69.29762	200.5238	206.4319	27.63428
13	74.03025	65.64142	218.8318	216.93	33.76229
14	89.22055	87.13458	204.5886	193.7512	74.88675
15	70.04048	55.27895	209.051	200.8402	72.96243
16	60.22305	47.48284	230.657	215.8063	74.05727
17	73.48571	53.09724	190.9911	204.3557	39.30822
18	70.53956	52.98876	217.6441	214.8115	50.2227
19	37.80274	43.76682	195.9934	215.9772	43.13179
20	42.07672	35.62703	196.3621	269.8311	53.85458
21	74.82675	49.16817	206.9616	234.2791	35.40349
22	78.77209	40.22887	203.2667	223.6177	28.88828
23	76.01554	39.2227	224.3875	215.3959	21.39031
24	73.59581	30.25025	233.1117	208.3642	39.08375
25	75.026	54.0832	227.3263	175.9682	20.44669
26	57.78456	50.99889	233.7422	176.4422	32.75486
27	77.40281	33.62486	235.4669	173.443	60.26921
28	67.93754	26.22066	233.6077	177.0547	57.68857
29	54.48272	12.44073	231.507	185.0821	50.89822
30	41.37986	16.65941	230.7387	182.9335	54.27781
31	38.3005	13.42769	225.505	182.9649	37.99825
32	74.20164	32.54093	223.3691	182.3075	50.2245
33	68.57169	27.59505	217.8294	169.8412	60.03659
34	75.72539	24.98271	204.4558	133.7424	80.75688
35	77.18561	20.15322	183.404	135.4382	84.56377
36	77.70134	12.42169	235.1061	139.5102	62.49347
37	85.9874	34.14327	237.3349	149.188	62.41659
38	89.19093	28.87431	235.7938	156.6765	67.99099
39	121.6649	42.98624	234.0796	165.9607	63.30181
40	104.0656	34.26126	247.4886	168.5246	64.1822
41	120.0661	35.89202	259.7107	167.0486	63.09744
42	127.1545	38.17141	249.0734	282.4203	48.51691
43	108.4721	20.74399	205.6523	168.6173	51.82931
44	112.6132	12.92023	187.8907	161.8464	42.6279
45	109.0084	23.13147	197.9544	174.7477	54.7807
46	118.4153	30.54789	157.3101	168.6633	53.65864
47	134.1261	23.62365	106.0598	176.0749	56.4037
48	172.0514	34.84723	326.8989	174.8629	75.32918
49	182.0429	38.25698	91.98438	118.5096	87.23246
50	179.1084	34.14346	112.7658	147.7944	72.78769
51	161.9109		106.4723	146.9596	44.59103
52			113.9292	150.5381	37.27048
53			171.9032	175.2745	23.00627
54				174.4144	18.31495
55				154.6977	23.44348
56				174.9669	
57				185.7742	
58				190.7733	
59				181.7856	
60				167.8122	
61				179.4959	
62				177.9997	
63				184.1682	
64				198.0168	
65				192.7491	

XACT #	REP #6	REP #7	REP #8	REP #9	REP #10
1	227.4208	45.84066	110.0134	111.7676	58.07058
2	61.5108	36.9384	142.8007	131.8475	43.4795
3	18.31852	58.9552	137.6811	130.2624	49.7393
4	14.52784	104.2715	136.8713	141.1072	54.63668
5	16.44497	55.3342	139.9865	132.5395	28.35921
6	23.67442	44.61884	105.5642	129.5082	57.4661
7	29.58393	46.66945	112.4926	131.7968	41.4711
8	28.8057	102.8259	117.7039	145.3254	49.77757
9	53.49606	115.6794	116.6564	160.5193	65.06416
10	103.5033	137.2264	120.2041	145.2321	59.43037
11	100.344	149.0631	129.8049	145.1147	58.81709
12	104.1679	154.6555	103.8144	149.5049	87.42684
13	147.958	166.1775	104.3979	149.6986	88.55523
14	164.6178	164.1628	102.3628	155.322	77.58485
15	170.9326	95.96666	75.76831	263.4647	92.92345
16	165.1379	80.92975	158.3344	152.817	88.53965
17	170.7681	65.08402	69.65401	160.0922	80.82928
18	143.7409	67.1157	52.86265	156.56	22.20791
19	146.47	63.63475	51.66105	143.3422	38.88009
20	172.9321	69.17726	51.12778	150.6968	23.93126
21	192.2088	36.18486	73.15877	147.0418	23.01346
22	189.1904	171.8797	60.413	156.9942	43.22555
23	171.7991	61.04606	60.18565	158.7823	40.2386
24	157.0126	55.29585	31.29492	157.9081	37.26082
25	141.1638	59.90448	34.18981	169.8023	39.51083
26	122.6798	48.34082	30.23117	167.5826	54.60726
27	114.4028	46.54698	14.44629	168.6413	46.11976
28	99.55043	39.71127	31.26349	166.9356	69.21326
29	105.5538	27.14757	38.08697	169.7679	29.25299
30	117.8813	43.85327	42.12409	180.6891	14.35916
31	101.0582	39.73573	43.57551	152.4713	24.60536
32	99.9749	48.9335	28.24582	128.1001	13.49746
33	109.0139	23.96468	13.53099	91.53126	31.06038
34	73.2769	47.79262	26.4837	78.93952	36.86358
35	85.95441	71.96114	22.10946	82.6214	48.63874
36	77.37328	71.78361	21.62942	66.25199	56.59453
37	67.70912	64.16543	39.46104	62.69115	38.58611
38	68.81654	65.33066	28.94944	59.92693	13.11386
39	64.64191	68.61861	32.85808	76.11752	30.8916
40	66.67494	74.19864	35.04479	46.98641	21.7982
41	62.76928	63.77011	20.57216	57.41227	
42	58.9931	67.64118	53.25393	52.25215	
43	52.84873	86.0384	62.42495	47.64631	
44	58.03415	63.67426	82.47342	46.88472	
45	77.51433	76.93377	75.10153	51.76777	
46	82.53004	71.61222	68.65161	58.65476	
47	79.38217	72.75095	52.74872	23.6932	
48	97.9503	79.7615	50.2736	24.47093	
49	93.37029	78.61278	51.72337	43.2742	
50	94.55273	40.08182	48.24367	58.04114	
51	97.74337		53.91155	60.70919	
52	97.34081		82.75143	64.80607	
53	94.59576		82.69634	65.29614	
54	89.92427		84.72619	90.41454	
55	82.77198		83.85272	80.63787	
56	78.89466		85.433	105.9551	
57	60.95079		78.34599	84.69074	
58	22.99959		71.42736	82.47732	
59	14.46253		68.96284	81.15781	
60	15.36991		68.51018	79.9466	
61	33.23032		40.32673	33.74213	
62	38.0602			28.94905	
63				21.68248	
64				18.74889	
65				51.00255	
66				61.01781	
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Vita

Captain Charles T. Butler was born on 21 December 58 in Atlanta, Georgia. He graduated from Clarkston High School in Clarkston, Georgia in 1976 and enlisted in the USAF in 1978 as an Aircraft Maintenance Specialist working on F-4 aircraft. During his first tour at Moody AFB, Georgia, he attended Troy State University and graduated in 1983 with a Batchelor of Science in Aircraft Maintenance Facility Management. He entered Officer Training School in 1985 and earned a commission as a Transportation Officer. He served his first commissioned tour as Vehicle Management Officer and Plans and Programs Officer in the 379th Transportation Squadron, Wurtsmith AFB, Michigan. As Plans and Programs Officer he managed a variety of programs to include transportation plans and operations for 379th BMW mobility commitments. He attended Squadron Officer School in residence in 1987 while enroute to his next duty assignment at Clark Air Base, Republic of the Philippines. While at Clark he held positions as Air Terminal Operations Center Duty Officer, 374th Aerial Port Squadron, and Air Freight Officer, 624th Aerial Port Squadron. As Air Freight Officer he managed a freight operation employing over 100 military and local national personnel. He held that position until entering the School of Systems and Logistics, Air Force Institute of Technology in May, 1990.

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13. ABSTRACT (*Maximum 200 words*)
This research examined the effects of the incorporation of Electronic Data Interchange (EDI) on the USAF vehicle allowance/authorization process. The study utilized a computer simulation model to mimic the flow of the AF form 601, Equipment Action Request, as it is submitted at base level and coordinated through the MAJCOM and WR-ALC. The hypothesis was that the allowance/authorization cycle time could be made shorter by transmitting the information contained on the form 601 electronically, rather than mailing the form to each coordinating agency. In order to compare the process with and without the use of EDI, two computer simulation models were developed, one which reproduced the current system and another whose variables and parameters were modified to simulate the effects of EDI. The output from the models was compared by using a paired-t test to determine differences in average system residence time for the 601. The incorporation of EDI was found to produce modest improvements in 601 residence times -- the time elapsed in the coordination process between 601 submittal and approval. Mean residence times were reduced by approximately nine days by transmitting the information electronically. Additionally, it was found that reductions in processing times hinted at even greater reductions in average 601 residence times.

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