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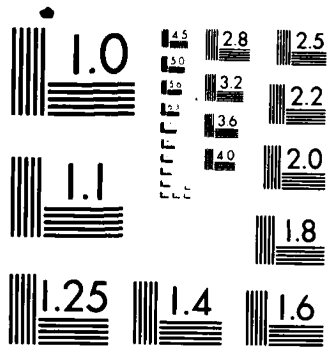

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THESIS

Elise Killian Pitterle
Captain, USAF

AFIT/GSM/LSY/85S-26

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AN IDENTIFICATION OF OPERATING AND SUPPORT COST DRIVERS FOR COMMAND, CONTROL, COMMUNICATIONS, AND INTELLIGENCE SYSTEMS

THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Systems Management

Elise Killian Pitterle, B.S.

Captain, USAF

September 1985

Approved for public release; distribution unlimited

Acknowledgements

I would first like to thank God for the strength to keep going and the discipline to accomplish the work, without which I would not be writing this. I would also like to express my gratitude for the abilities which He has given me which enabled me to do this thesis research and complete my degree.

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Elise Killian Pitterle

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Abstract

This thesis researched the problems with life cycle costing of command, control, communications, and intelligence (C^3I) systems. As operating and support costs skyrocket it is imperative that the military design systems for reliability and maintainability to slow escalating costs. However, the costs drivers are unknown and no life cycle cost model exists specifically for C^3I. This thesis used actual cost data categorized by type of equipment (radar, radio, wire, and special/combination) and by usage mode (ground, portable, transportable, fixed, and mobile). A discriminant analysis showed that the four groups in the type category were significantly different based on cost data, and, likewise, that the five mode groups differed significantly. Next, a regression was performed, and the resultant correlation table indicated which variable was the cost driver for each group. The simple regression yielded the regression coefficients and y-intercept for the regression equations. These equations are the cost estimating relationships for C^3I systems, based on the cost drivers identified by this thesis.

AN IDENTIFICATION OF OPERATING AND SUPPORT COST DRIVERS FOR COMMAND, CONTROL, COMMUNICATIONS, AND INTELLIGENCE SYSTEMS

I. Introduction

General Issue

A strong defense is necessary for maintaining our freedom and security as a nation in a world of powerful aggressors. That defense must include not only the weapon systems, but also the command, control, communications, and intelligence (C^3I) equipment and capabilities to integrate the weapon systems into a viable deterrent and war-fighting machine. C^3I is a necessity if our conventional and nuclear weapon systems, and the people who operate them, are to interact as an effective, efficient system to win wars. For this reason, C^3I must be given the same priority as weapon systems in planning, budgeting, and acquisition. On the whole, C^3I has not been given sufficient priority in planning and budgeting in the past, and, sadly enough, increased emphasis on the acquisition of C^3I systems will only add to an existing problem by placing additional demands on an already severely limited military budget. With rising costs and decreasing budgets fast becoming the norm, the military is pricing itself out of the defense market.

This chapter gives an overview of the thesis topic. Specifically, a problem description is given, to include why the situation is a problem, and why the problem is important. It also gives a brief background for the problem and the scope of this thesis. The definitions of terms central to the thesis are then provided. Lastly, the research questions which this thesis answers are listed.

Specific Problem

It is imperative that C^3I systems be developed for maximum cost effectiveness if the Air Force is to obtain the best C^3I systems while placing the smallest demand on our limited military budget. Current DOD policy requires that the life cycle costing method of cost estimating be used. Currently, life cycle cost (LCC) estimates for C^3I systems are inadequate due to undefined variables, unknown cost drivers and the lack of a specific model for estimating C^3I life cycle costs.

Background

Several recurring themes are found in most of the literature or discussions on the C^3I subject. The first is that C^3I is absolutely essential to our capability to fight, sustain, and win a war (7:219; 6:13; 19:9). C^3I systems are used to coordinate the actions of people with pieces of hardware to make our fighting machine as efficient as possible. The second theme is the observation that C^3I technology is changing at an extremely rapid pace and is maturing to the point where it matches the technical capabilities of our weapon systems (7:219-221; 1; 32:39; 48:53). Although technological forecasting is used, it is never possible to predict exactly what all the changes will be. As the importance of C^3I is recognized throughout the government, this recognition must be reflected in the funding priority C^3I receives in the military budget. C^3I is not a weapon system and it is essential that it not be considered one in the budget process, so that C^3I does not get bargained away at the budget bargain table in exchange for new weapon systems. It must, though, be considered as important as the weapon systems, for without C^3I, they cannot be used effectively.

This increased priority for C^3I is necessary because new and modified C^3I systems are having to compete with weapon systems for the limited defense dollars now, and will continue to do so in the foreseeable future (9:54). The military must find ways to control all costs in order to have the functionally reliable systems it needs (36:1-1). In the absence of controls, costs will escalate to the extent that few systems will be affordable. The military will be able to either support existing systems or buy new systems, but not both. To control costs the military is applying the technique of life cycle cost analysis to all its new systems. The objective is to make costs visible and keep costs to a minimum, while still obtaining a system which meets performance goals (3:11).

Scope

While this thesis examined actual cost data for C^3I systems, not all systems were entered in the database for the statistical analysis. Only the primary categories of ground C^3I systems were examined because the largest amount of data was available in these categories. Some of these categories are radar systems, radios, mobile and fixed equipment. For statistical validity, it was necessary that each group or sample have as many cases as possible. Also, this thesis was limited to an examination of operating and support (O&S) costs because those are the costs which make life cycle costing unique among costing methods.

Definitions

The following definitions are central to this thesis.

Command, Control, Communications, and Intelligence (C^3I). Although the term is widely used, a single common definition of C^3I is not universally shared. One author puts the emphasis on the hardware aspect: "an assortment of equipment, systems, techniques, technologies, and even organizational structures by which the military people talk to each other; collect, store, and assess threat information; deploy forces; transmit decisions; and launch weapons" (54:56). Another definition stresses the process: "the entire flow of information (friendly and enemy), the facilities where decision makers are located, the means of assisting decision-making, the decision process, and the dissemination of decisions and orders" (19:9). A composite of the above would be the following simple but complete definition: C^3I is the employment of equipment (data transfer, data gathering, and communication) to enhance the decision-making process (including the dissemination of decisions) and human judgement in military applications.

Life Cycle Cost (LCC). Air Force Regulation (AFR) 800-11, Life Cycle Cost Management Program, gives the simplest definition of this term: "the total cost to the government for a system over its full life" (16:1). The system life cycle can be broken into four periods or phases: research and development; production or acquisition; operating and support; and disposal (35:2-1; 16:1). The life cycle has been diagrammed in Figure 1. The life of a system begins with the research and development projects which often investigate the feasibility of new concepts, and systems which will make the concepts a reality. If a decision is made that the system will meet a need of the Air Force then the system enters the acquisition cycle which has four phases, as outlined in Department of Defense Directive (DODD) 5000.1,

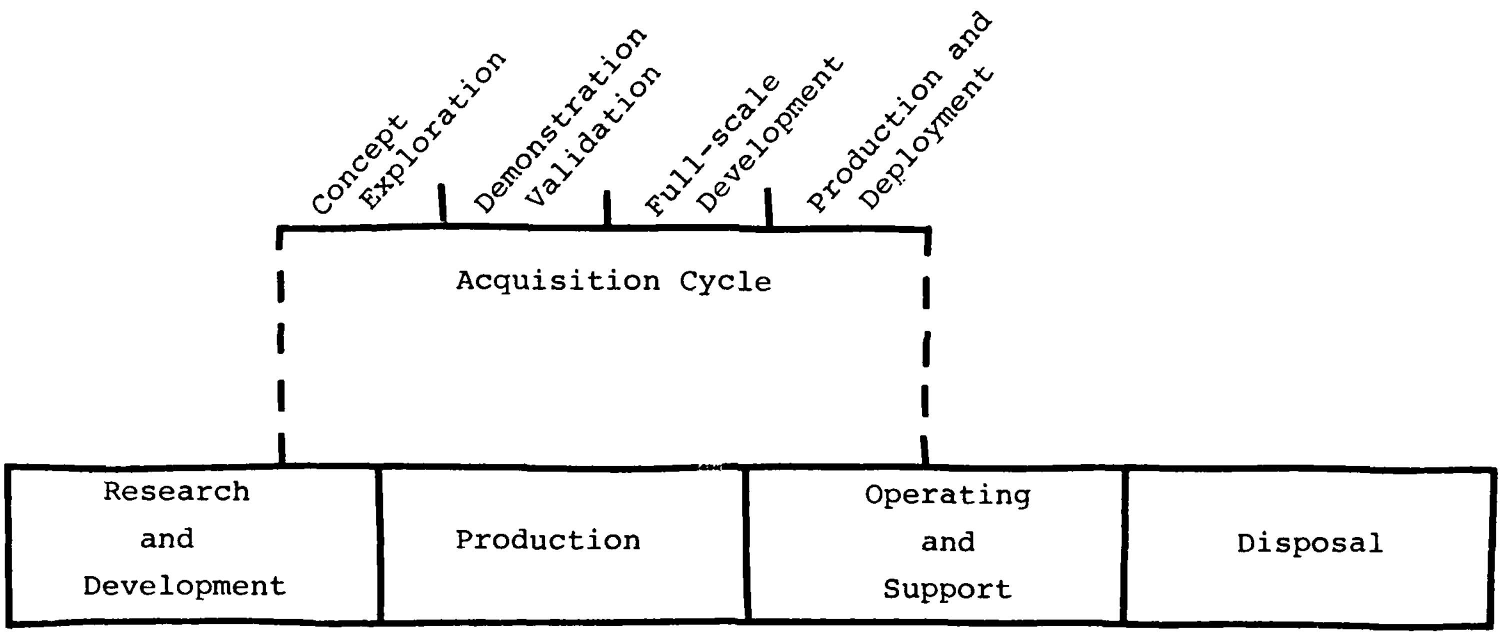


Figure 1. System Life Cycle Diagram

Major Systems Acquisition (13:4). The acquisition cycle begins with the concept exploration phase, during which alternative systems are explored. The project then proceeds through the demonstration and validation phase where prototypes are designed, built, and tested; the full-scale development phase where the pre-production prototype is manufactured and tested; and the production and deployment phase where the final system is manufactured and then turned over to the using command for operation (3:6; 50:9; 36:2-1 - 2-7; 38:18-28). At the point when the using command accepts the system, the acquisition phase of the life cycle ends. The individual system then enters what is normally the longest phase of its life cycle, the ownership, or operating and support phase, which is the time period when the system is used and maintained in the field. Finally, at the end of its life cycle the system enters the disposal phase in which it is removed from the active inventory.

The key to LCC is that "costs considered be 'total costs driven by the decision' " to develop and acquire a system (30:28). In other words, total costs for the life of the system must be determined, even in the acquisition phase when alternative systems are being compared.

Design to Cost (DTC). This term describes the method by which the goal of meeting the cost requirement is achieved. It is a management technique which establishes the cost goals during the design phase in order to control costs and balance the three priorities: cost, performance, and schedule (56:2-9 - 2-10; 15:5). DODD 4245.3, Design to Cost, (formerly DODD 5000.28), defines DTC as follows:

> An acquisition management technique to achieve defense system designs that meet stated cost requirements. Cost is addressed on a continuing basis as part of a system's development and production process. The technique embodies early establishment of realistic but rigorous cost objectives, goals, and thresholds[,] and a determined effort to achieve them [12:2-1].

This directive requires that cost be established as a parameter equal to schedule and performance (12:1). DTC requires coordinated effort and sometimes techniques such as value engineering (33:17). Once the DTC goal is established, the cost is allocated among components, which are then designed so as to meet that goal throughout the life cycle (51:12; 30:28; 16:1; 36:5-25). "The design to cost concept establishes life cycle cost as a system/product design parameter along with performance, effectiveness, capacity, accuracy, size, weight, reliability, maintainability, etc." (3:12). The primary benefit of using DTC is that it forces the military to consider downstream costs, such as O&S costs, early in the life cycle, (i.e. during design). Although the benefit of using DTC is often hard to measure, some experts are reporting that procedures are being developed, especially in the O&S area, to compare the cost savings from reliability improvement with the cost of gaining the improvement (33:16).

Life Cycle Cost Models. Following is a definition of a general model as given by noted life cycle cost expert, Benjamin S. Blanchard, in his book, Design and Manage to Life Cycle Cost:

> A model, in principle, is a simplified representation of the real world which abstracts certain features of the situation relative to the problem being analyzed. A model can be used as a tool to gain knowledge through analysis . . . [3:81].

It follows then that LCC models are collections of formulae for systematically evaluating the life cycle cost of a system. Models are used for the formal analysis of LCC, as opposed to the informal expert opinion-based estimates often made for quick, real-time analysis of the acquisition. Models can be simple or highly complicated, manual or automated (50:157-9; 3:81; 34:1-2). Information from the models is used by the manager as a basis for deciding between alternative designs and/or systems. The data for each alternative are evaluated with the model and the outputs compared. Thus the model is used not only for predicting costs but also for performing trade-off analysis.

Cost Driver. A cost driver is a factor or variable which ultimately affects LCC. It can be at any level of the system, macro or micro. "Cost drivers, like interfaces, exist at all levels of the system WBS [work breakdown structure]" (33:16). The cost driver can be a factor as broad as a political consideration or as narrow as the solenoid chosen for a pump motor. Most often cost drivers are determined from historical data (49:22). Whatever the factor, it is the variable which is a primary driver of the total system cost. It makes up a large portion of the total cost, and thus has a high positive correlation to the total. As a result, even a small percentage change in a cost driver yields a large dollar change in the total cost. For example, if a system costs one billion dollars and a change in a cost driver variable will result in 0.1 per cent cost reduction, then the total cost will be reduced by one million dollars. This is a large amount of money for such a small percentage of change. Consequently, it behooves designers and managers to look for and implement even small changes to the cost drivers.

An identification of the system cost drivers is also essential to determining the best LCC model. Since cost drivers are highly correlated to total cost, they are the best variables for predicting system cost. The LCC model chosen or designed should, as a minimum, address the variables which are known to have an influence on the system cost drivers. More specifically, before the best model for determining LCC for C^3I systems can be found or developed, those factors which are the cost drivers for C^3I must be determined.

RESEARCH QUESTION: What factors must be considered when developing cost-effective C^3I systems?

RESEARCH SUB-QUESTIONS:

1. What are the important factors in C^3I development (e.g. technology change)?
2. Should all primary categories of C^3I systems be costed using the same variables and cost relationship?
3. What are the cost drivers for C^3I systems?

II. Background

Chapter Overview

This chapter contains a review of the literature concerning both C^3I and life cycle costing. The literature reveals the various view points held in these areas. The chapter also discusses some actual examples of the problem of life cycle costing C^3I systems and the solutions that were found in these instances. The chapter concludes with the author's comments on the literature. The literature searched includes scientific journals, government journals and reports, theses, and trade magazines.

Command, Control, Communications, and Intelligence

Although the acronym C^3I encompasses a wide range of systems, there is no question that the proponents of all types of C^3I agree on its importance to the military. Specifically, "C^3I is essential for the location, acquisition and damage assessment of the targets . . . an integral part of highly accurate and destructive weapons systems" (7:219-221). Air Force Lt Col Carl R. Huebner, Chief of the Tactical C^3 Division, states it in broader terms:

> The role of C^3 has become so central to strategic doctrine that it can be safely asserted that our success in deterring nuclear attack depends at least as much on

> the viability of our C^3 as it does on the relative numbers of warheads, megatonnage, and missile accuracy [29:61].

C^3I is the "central nervous-sensory system that holds (weapon systems) together and gives them their credibility" (6:13). These C^3I systems must be flexible, durable, capable of relaying clear, timely information, and easy to use by non-experts (29:58; 1).

> Communication, command, and control systems are generally defined as the complete collection of sensors, facilities, equipment, computers, software, communications, procedures, and personnel essential to the commander for the planning, directing, and controlling the operations of assigned forces pursuant to the mission assigned. From a technology point of view, C^3 needs are met by building on computer science, systems and information science, and communications [20:181].

Dr. Jon L. Boyes, International President of the Armed Forces Communications and Electronics Association, states that C^3I systems are so vital that they cannot be bargained away as weapon systems might be, and concludes that "C^3I plays an important role in arms control and international peacekeeping" (6:13).

As noted earlier, there are many systems under the C^3I umbrella, each of which serves a specific purpose. On the battlefield C^3I systems are used to locate targets as well as friendly units (individuals, vehicles), to relay intelligence information from the field units to their commander, and to communicate orders from the commander to the field units (7; 1:53). C^3I systems also include the radar systems which signal tactical warning, the communications systems which transmit the launch order for nuclear weapons, and the satellites which provide the intelligence and reconnaissance data (32:40; 11:44; 29; 53:23). Despite the variety of C^3I, experts agree that C^3I cannot be separated into parts or subdivided. The systems view or concept must be applied. The military must know how its subsystems and those of allied military organizations are integrated, or it will have nothing but unassociated groups of people, systems, and processes (6:13; 19:9).

"The strategic modernization plan laid out by the Reagan Administration puts unprecedented emphasis on command[,] control[,] communications[,] and intelligence" (11:44). This emphasis, along with the growing interest of individuals in high level government and military positions, is encouraging (6:13; 48:53). Despite all this recent attention, the need for C^3I is not a new, but rather, an old, or continuously existing, need. Today's C^3I must be upgraded to match the capabilities of the highly sophisticated weapon systems it will be used to control (7:219-222; 48:52-3). "Modernization of strategic weapons may go for naught if command control and communications improvements do not keep pace" (9:54). An up-front investment in C^3I is "an investment in the future"

(20:189). The result will be effective, cost efficient systems in the field, and reduced expenditures in the long-run.

This recognition of the importance of C^3I and the interest of government officials must be backed by money if improvement is to occur. With the "increased scrutiny over and decreased buying power of our nation's defense budget" (21:iii), funding is not to be taken for granted. As the defense budget becomes a larger percentage of the total budget each year, the DOD comes under heavier fire from all factions of Congress, friend and foe. Even though the budgets are larger they have less buying power because the increases don't always keep up with inflation and new system costs are rising at tremendous rate (49:3). High technology systems, including C^3I, are extremely expensive. The military must lower the costs of acquiring, operating, and supporting all of its systems if it is to maintain its capabilities within the limitations of the budget (43:1; 31:3). Today's war is being fought with "reliability, maintainability, and standardization. . . . Unless we can win this war of affordability we cannot hope to continue our technological advancement" (47:1). The military always needs more systems than it can afford. But, if it cannot "acquire and operate a proposed weapon system in an efficient and effective manner" the military will never be able to procure those systems to meet the needs (56:2-5).

Life Cycle Cost

Funding problems are not specific to C^3I systems, but apply to all military programs. Consequently, the military has implemented a cost analysis program, life cycle costing, as a method of controlling the costs of system acquisition and support. The following directive appears in AFR 800-11:

> The full impact of life cycle costs will be considered in decisions associated with the selection, designs, development, procurement, production, modification, use, and support of defense materiel [16:1].

Prior to life cycle costing, system performance was the primary criteria considered in system design. Little or no consideration was given to the operating and support (O&S) costs for a system after deployment (3:3-5). And yet, O&S costs are a full half of the total cost of our systems (33:15; 44:1).

This fact was realized by the top echelons of the Department of Defense in the early 1970s. In 1975 the Deputy Secretary of Defense set up a task group to begin the job of collecting O&S costs in a new DOD system called "Visibility and Management of Support Costs" (VAMOSC) (49:19; 44:2). All military departments were directed to make O&S costs visible and help build this O&S cost collection system (44:2). The purpose was to bring O&S

costs to the attention of everyone involved, to collect the costs in a DOD-wide database, and to institute cost-reduction plans and methods. Initially, two databases were developed, one for aircraft and one for communications- electronics-meteorological equipment.

There were problems in developing the system, though, and there was no change in the rising O&S costs. Highly concerned over this lack of progress, the Deputy Secretary of Defense in 1977 directed that another effort be made at developing a cost collection system. Responsibility for overseeing the system was given to Headquarters, Air Force Logistics Command. This second attempt is called VAMOSC II and it has three databases: 1) weapon system support cost; 2) communications-electronics (C-E); and 3) component support cost system (45:5-7). The historical costs in these databases can be used by program managers for cost analysis and trade-off studies during the acquisition cycle. They can also be used for planning, for determining the relationship between design and O&S costs for a given system, for weapon system comparisons, and for affordability studies (44:6-7). The VAMOSC database for C-E is in operation but not complete; when it is complete it will include information in 19 categories of O&S costs, e.g. temporary duty costs, operations and maintenance personnel, and training (55).

Increasing costs and development time have necessitated a change in the approach to system design; specifically, "cost-effectiveness and life-cycle-cost" are being recognized as important considerations in design (40:5-1). The military is realizing that the costs of designing a system for reliability and maintainability, while making the system more expensive initially, are paid back several times over in the form of reduced O&S costs. This is because, although the original procurement costs are high, the majority of a system's costs are incurred during the O&S phase. To put this concept into practice, though, and reduce O&S costs by design changes, life cycle costing must be implemented early in the acquisition cycle. It is not sufficient to consider only development and acquisition costs; total life cycle costs must be minimized (40:5-1; 47:1; 56:1-1).

Due primarily to rapidly escalating O&S costs, the military has been forced to consider cost as a parameter as important as system performance, and to determine the magnitude of those costs over a system's life. "Traditionally, performance has been the overriding factor with a sacrifice of reliability. Experience has shown that . . . performance . . . is usually exceeded. However, reliability requirements are being missed by wide margins" (2.20). This lack of built-in reliability results in extremely high O&S costs, and thus unnecessarily high LCC. The cost of logistic elements is the first cost neglected by managers, though, because they are so far downstream and they are difficult to measure (23:3-4; 15:2). The purpose of life cycle costing is to compare alternative systems by predicting costs, and then performing trade-off analyses, thus optimizing LCC by obtaining the best system possible within the constraints. For example, the Navy predicted that 78 million O&S dollars were saved on the F-18 program by performing trade-off studies (2:28). On the ARC-164 program, one of the earliest attempts at using LCC, the Air Force found that performing trade-offs and designing for reliability paid off with substantially lower costs (5:33-36). The purpose is not to sacrifice performance and operation for the sake of minimum cost (16:1-2; 3:11,14; 33:15). In other words, the military is "looking for a best balance, not a least cost" (31:3).

To achieve this, it is essential that the cost drivers, particularly O&S parameters, be considered in the design from the outset of the acquisition. For example, "maintainability must be a design requirement, not an afterthought" (47:2). The design is the driving factor determining how large the future O&S costs will be (25:4). Total O&S costs should be considered, not simply the component costs. Alternative designs should be compared early in the design phase to ensure minimum LCC (40:5-1 - 5-5; 37:21). Late in development when designs become frozen, it is very difficult to reduce LCC (37:14). DTC goals and threshold values have to be established early in the cycle, at least prior to full-scale development, as directed by DODD 4245.3 (12:3).

Instead of ignoring O&S costs, the military must manage them and make the necessary decisions in the design phase which will result in lower O&S costs in the future (2:21; 49:23). The Army's Black Hawk program is an excellent example where early consideration of O&S costs resulted in an affordable system over its life (2:21-24).

The military has recognized that decisions made during acquisition, and especially during design, affect the O&S costs later (51:12; 50:224; 42:1,20). Collectively, the Departments of the Army, Navy, and Air Force published a guide for applying the DTC concept. The guide was written to provide managers help in applying DTC to their programs in order to reduce costs, particularly those O&S costs which can be influenced by the design (15:1-2; 23).

> The design to cost process has therefore been introduced to identify the optimum cost effective solution within the above limits [of the performance floor and the cost ceiling], and develop a design which can be successfully produced to the established cost goal [15:4].

In order for DTC to be applied to a system acquisition there has to be flexibility in performance and schedule parameters allowing time for design iterations and room for choice in the design/performance relationship (15:18). The manager must also establish cost goals which are high but attainable, especially for O&S costs (15:23-26). These goals must be reviewed regularly throughout the acquisition cycle (15:31).

M. Robert Seldon, an expert in life cycle costing, discussed the importance of cost drivers to LCC:

> LCC is the search for the significant costs that can be influenced by planning and design decisions. Therefore a major task of LCC analysis is to discover and illuminate such cost drivers [50:18].

Some of the major cost drivers have been identified as standardization, quality, reliability, testability, and repairability (47:1-2). O&S cost drivers include spare parts, fuel, personnel, training, maintenance concepts, and mean-time-between-failure (MTBF) (33:19; 56:1-7). Cost drivers for a given system can be identified even more specifically than this, if necessary, since they are system unique.

When a new system is designed, the parameters (system requirements) and the cost drivers have to be identified. Then an LCC analysis method must be chosen or designed. This method will be determined by the complexity of the parameters, the types of cost drivers, the stage of the program, and by whether an LCC model currently exists which accounts for the chosen parameters (4:119-121; 36:4-2). "LCC models serve as the analytical tools used to determine what effect design decision tradeoffs will have on acquisition, and operating and support costs" (26:10). As such, models vary in format and methodology. Very few models are designed to estimate costs for the entire life of a project; rather, they are used for a specific phase of the life cycle or for an aspect of cost (parts inventory, for instance), and the tabulated results of each give a total LCC estimate (50:15; 36:5-11).

Problems with C^3I Costing

In their 1979 master's thesis, Drobot and Johnson noted that no generalized cost model was available for life cycle costing or comparing communications-electronics-meterological systems (22). These systems are also C^3I systems. To date, no LCC models have been designed specifically for estimating C^3I costs, a point which was brought out in an interview with Mr Ralph Graves, a life cycle costing expert from MITRE Corporation. He went on to comment that the cost driving parameters are also not known, which is a key problem (27). A company called Desmatics, Inc. is presently developing a model which will make O&S cost predictions for C^3I equipment and help with replacement decisions. It will then perform trade-off analyses using the predictions which will indicate the alternative effects of replacing a system with new equipment, modifying, or simply maintaining an existing system (52; 46). The company is not attempting to identify cost drivers, but instead is developing the system to be used with the VAMOSC database.

Another problem is that, although there are many LCC models in use today, none satisfactorily account for the relationship between the design phase and the O&S phase (42:5). This problem leads the analyst to develop a model specifically for each new system as it goes through the acquisition phase. This is done either by taking an existing model and adapting it, or by designing an entirely new model. This is expensive and time-comsuming.

It has been common practice, when designing or modifying a model, to use cost-estimating relationships (CERs). CERs are mathematical relationships which show the cost of equipment or systems as a function of specific variables. These can be simple relationships such as the following calculation of fuel costs:

$$FC = GH\ (FH)(N)(C) \qquad (1)$$

where FC equals fuel cost per month, GH equals gallons per hour per aircraft, N is the number of aircraft in the unit, and C equals the cost per gallon of fuel. CERs can also use more complicated multiple regression techniques, as well. The following CER is an example:

$$y = a + bx^{e1} + cz^{e2} \qquad (2)$$

where y is the total cost, a equals a constant generated by the regression, b and c are regression coefficients, x and z are cost variables which are highly related to total cost, and e1 and e2 are exponents of the independent variables. Based on past experience, these variables are those which have been found to have the most significant impact on the magnitude of total costs (2:11). The multiple regression equation shows the relationship of these variables to total cost. CERs can be used for systems such as aircraft, as well as equipment items, such as avionics components (42:1-4). There are three common types of CERs which differ on the basis of how they develop costs. Costs can be estimated "by type of aircraft structure, such as skin composition or machine plate; by functional cost elements, such as direct labor; and by acquisition phase" (42:3).

A report by the Air Force Human Resources Laboratory (AFHRL) suggests a technique which goes a step farther than CERs, which they call causal modeling. The objective is to specifically relate system design to its effects on manpower and materials, in other words, O&S costs (42:5).

AFHRL developed a prototype model for avionics components, many of which have C^3I functions. Each piece of equipment was placed in one of the following categories: transmitters, receivers, processors, sensors, displays, and controls. Equations were then developed to estimate costs for each category based on the differences in design (42:8). "The relationships were developed to analyze the functional rather than the physical unit . . . through multivariate regression" (42:12). AFHRL then tested these relationships on components not in the original database and found that the estimated costs were close to the actual costs. "The concept governing these relationships appears valid. The relationships were developed for individual categories of electronic and nonelectronic functions so that predictions could be based on trends of similar functions" (42:14).

The primary problem in costing C^3I systems has been the instability in C^3I technology and predicting future technological developments. Most of our C^3I hardware requires high technology electronics and/or computers. These fields are evolving on an almost daily basis, and because of this, so is the field of C^3I (27). Along with the changes occuring in hardware design, there is the rapidly advancing area of software development. Software acquisition is currently considered to be the primary cost driver by most in the C^3I field, despite the past and present emphasis solely on hardware costs (20:178,183). Robert B. Doane of the Electronic Systems Division, Air Force Systems Command, sees software as such an important cost that he feels the Air Force should base system purchases on software costs, not hardware costs, and should buy equipment compatible with existing software (20:187-8).

The nature of C^3I systems also dictates that there be extensive human interface with the equipment. To get the most effective C^3I, systems should be developed on-line with the user, utilizing an evolutionary approach (20:184). This is contrary to the traditional acquisition method used for weapon systems. "Communications, command, and control system requirements are intrinsically evolutionary, partly because they must operate in a constantly, but not always predictably, changing environment, and because they must support human decision making . . . [this] implies a continuous and close cooperation between the end users of the system and the developers . . ." (20:180).

Because of this changing environment, system design and the acquisition process must be flexible, capable of meeting changing needs and assimilating changing technology. Systems must also be flexible when it is necessary to join forces with allies in creating a world-wide C^3I net. Although all these systems will be different, they ultimately must be interoperative if joint operations are to be successful (20:181).

Three Examples

A study conducted by the Rome Air Development Center (RADC) in 1981 found that some of these problems were present in the Tactical Air Control System (TACS), the primary C^3 system used in rapid reaction scenarios (41:1). The study reported that the TACS "cannot rapidly deploy, accomplish its mission and survive," and as a result U.S. and allied forces could possibly be unable to "detect, identify, intercept and destroy enemy air forces" (41:1). RADC presented a solution in the study report. Since the goals of C^3I are to provide effective coordination and enemy detection during battle, and to survive in order to provide this service, RADC developed a system which allowed individual components to coordinate with each other while being distributed over the battle area for survival (41:1,6). One key development was that the equipment was made interoperable by the use of a universal adapter called the External Bus Interface Unit (41:9). The system was also designed to be highly user-oriented with touch screen technology and programmable operator control functions (41:12). The system was also specifically designed to have standardized maintenance procedures and reduced maintenance requirements through better MTBF and mean-time-to-repair (MTTR) (41:13).

Another example of the problems facing C^3I can be found in the Air Force SEEK IGLOO Program which was initiated to modify radar stations in the Alaskan Air Command. The goal was to reduce O&S costs but maintain the present operational capability. At the outset of the program, Electronic Systems Division (ESD) of Air Force Systems

Command (AFSC) gave all the prospective contractors the SEEK IGLOO LCC Model which had been specifically developed for this program from an existing model by the MITRE Corporation (37:4). This gave both the contractors and ESD a common method for estimating LCC costs. The model identified the cost drivers, permitted trade-off analyses of the proposed designs, and facilitated comparison of the contractors' proposals. It also served notice to the contractors that the Air Force is serious about reducing O&S costs (37:6).

Because the LCC model was available to and used by the contractors before the design was frozen, they were able to easily make design changes which resulted in lower LCC, due to substantial savings in O&S costs, despite the higher initial cost (37:9). By using the model, the contractor was also able to identify the individual equipment items which were the cost drivers for this system (37:11). In this program, using the LCC model was successful because the information produced by the model was used in the contract award process. This gave the contractors incentive to heavily utilize the model in their design process (37:13).

This last example is about a C^3 system acquisition that was not so successful. It is the acquisition of the C^3 system for the NORAD Cheyenne Mountain Complex Combat Operations Center. This system was to replace the existing system in early 1977, but it was plagued by a multitude of problems which caused cost overruns and schedule slips. The first problem was that the performance requirements were too strict, with too many unnecessary but "nice to have" requirements (57:18-20). There was no flexibility for the design team to use to keep costs down with design changes. By the time some of the requirements were relaxed, the cost had overrun millions of dollars and the initial operational capability date had been slipped two years. Now, instead of using DTC concepts, the project was having to use "design-to-available-funds" procedures (57:21).

At the same time, NORAD was being faced with the problem of buying a computer system which was inadequate and did not meet the performance requirements. It was a business-oriented computer which was also used by the World Wide Military Command and Control System (WWMCCS), but its capabilities could not meet the capacity requirements of NORAD. It would, however, provide lower cost as it was already in the inventory, and it would allow compatibility with WWMCCS. The end result was that NORAD was forced to buy three of these mainframe computers in order to just meet their requirements, which cost an additional 100 million dollars, not to mention much wasted time (57:24-29). The system did not provide any capabilities above what was provided by the existing system.

Lastly, this program had the almost universal problem of lack of coordination and communication between the program acquisition office and the using command due to distance. The program office was at ESD, Hanscom MA, while, of course, NORAD is in Colorado Springs CO. This distance made communication difficult, and caused problems with duplication of effort and lack of coordination (57:30-33).

Despite these difficulties, the new C^3I system at NORAD did become operational. It was three and a half years late, though, and almost twice as costly as planned (57:3).

Comments and Conclusions from Literature Review

C^3I is not only important, it is necessary for this nation's survival, both in peacetime as an early warning system, and in war-time as a command and control system. It is the link between the commander, the weapon system, and the operators in the battlefield. Every effort must be made to insure that C^3I is given equal priority with weapon systems in the budgeting process. Specific attention will be needed since the tendency will be to reduce funding for C^3I primarily due to the tremendous cost of the advanced technology used in these systems.

Many attempts have been made on a variety of programs to use a life cycle costing approach and to incorporate design to cost methodologies. A few of these have been mentioned in this review. They have served their purpose. None, though, has solved the problem. These attempts have been temporary fixes which worked on a given program. For the most part we are still borrowing models and methods from the large weapon systems, and modifying them. There are still no models built specifically for C^3I, which account for the design characteristics of C^3I, and no method for using life cycle costing for C^3I This is not to say that there is only one method that would work or that there is only one model that would be correct; just that, there are no LCC models or methodologies developed for the peculiarities of C^3I equipment. No models are available which can be applied to C^3I equipment in general, as there are models for aircraft in general.

The costs of C^3I systems will have to be controlled, in order for the military to procure the best possible system for the least amount of money. The use of LCC analysis to determine the lowest life cycle cost will enable the military to achieve this objective. LCC analysis includes the identification of cost drivers, which this thesis will accomplish specifically for C^3I system O&S costs. A model must then be located among existing models that will estimate costs for the identified drivers. Finally, the "best" model amongst existing models must be determined, or a new model suggested or developed.

III. Methodology

Chapter Overview

The methods used to conduct this thesis research will be discussed in this chapter. The initial work consisted of phone and personal interviews, as well as a search of the literature. The next step was to collect actual cost data from C^3I systems and perform several statistical tests. Lastly, the statistical results were analyzed to determine the important C^3I variables. The analysis was conducted to answer the research question.

Initial Search and Problem Determination

The purpose of the initial search was to determine the exact status of C^3I LCC. This meant determining the characteristics of the overall problem of costing C^3I equipment, determining the work already accomplished and that currently being done, determining the specific aspects and intricacies of the problem, determining the policies and rules involved, and determining the attitudes of the people in the field. To do this, an extensive search of the literature in this area was conducted. The literature included books by experts in the field of life cycle costing, other theses on LCC and C^3I, government reports, articles in scientific journals, and trade magazines.

At the same time interviews by phone or in person were conducted with personnel knowledgeable in the field of C^3I life cycle costing. The purpose of these interviews was to obtain expert opinions on the factors and cost drivers these individuals see as important, based on their experience in C^3I and LCC. Personnel interviewed are both military and contractors working in comptroller branches and C^3I design offices at AFSC/ESD/ASD, HQ AFLC/MML (VAMOSC), and the Air Force Institute of Technology School of Systems and Logistics. The author also attended a demonstration by Desmatics, Inc. on a costing model currently being developed.

Data Collection and Statistical Testing

The actual cost data was obtained from the VAMOSC office at HQ AFLC, Wright-Patterson AFB. The data comprises five categories of O&S costs for several hundred pieces of C^3I equipment, for one to seven years, and is filed by type-model-series number. The type-model-series (TMS) codes are listed in Appendix A. Through discussion with VAMOSC personnel, it was determined that only a relatively small number of the categories of equipment were numerous or predominant in the inventory. On the basis of their expert opinion, and a study of the actual database, the most important equipment categories were chosen for the statistical analysis. These were also the categories which contained the largest numbers of items. The categories were grouped by type of equipment or mode of use. One group consisted of four types of equipment: 1) radar; 2) radio; 3) wire; 4) special combination systems. The second group contained equipment designated by five different modes of use: 1) ground; 2) portable; 3) transportable; 4) fixed; 5) mobile. These are the primary types of equipment or configurations. It was necessary to select only primary types of equipment in order to have a large enough group to conduct a valid statistical test. Some types of equipment were not well represented in the database because there are not numerous items of that type in operation; these equipment items were not included in the analysis.

The next step was to perform the statistical tests on the database. The purpose was to determine the cost drivers for C^3I systems from statistical analysis. More specifically, the goal was to determine whether all types of C^3I systems had the same or different cost drivers. The first procedure performed was a discriminant analysis. The purpose was to determine if it is possible to statistically discriminate between the groups on the basis of specific variables, which would then indicate that costs are not the same for each group and that different cost drivers would be applicable for each category of equipment. In this case, each category should be costed separately. Three discriminant analyses were performed to determine if one pattern of groupings was better than another for costing purposes. The first discriminant used the four groups of equipment types, the second used the five groups of equipment usage modes, and the last was based on a combination of type and mode.

The objective in performing a discriminant analysis on this data is to determine if group centroids from the population are significantly different from one another, in other words, whether it can be assumed that the groups are from the same population (39:7-1). For example, it is to determine if it can be assumed that, based on the cost data, both radio and radar components come from the same population. The analysis is made based on the same cost variables for each group, variables "on which the groups are expected to differ" (28:435). Each group, instead of having a mean, has a centroid, which is a column vector, the elements of which are the mean for each variable in that specific group. Since there are five variables, the vector has five elements. Figure 2 illustrates graphically two samples of observations (X and O) for two group centroids and the resulting centroids. In this figure the centroids are represented in two dimensional space because there are two variables. More often, though, there are a number of variables and thus the centroids would be in multidimensional space.

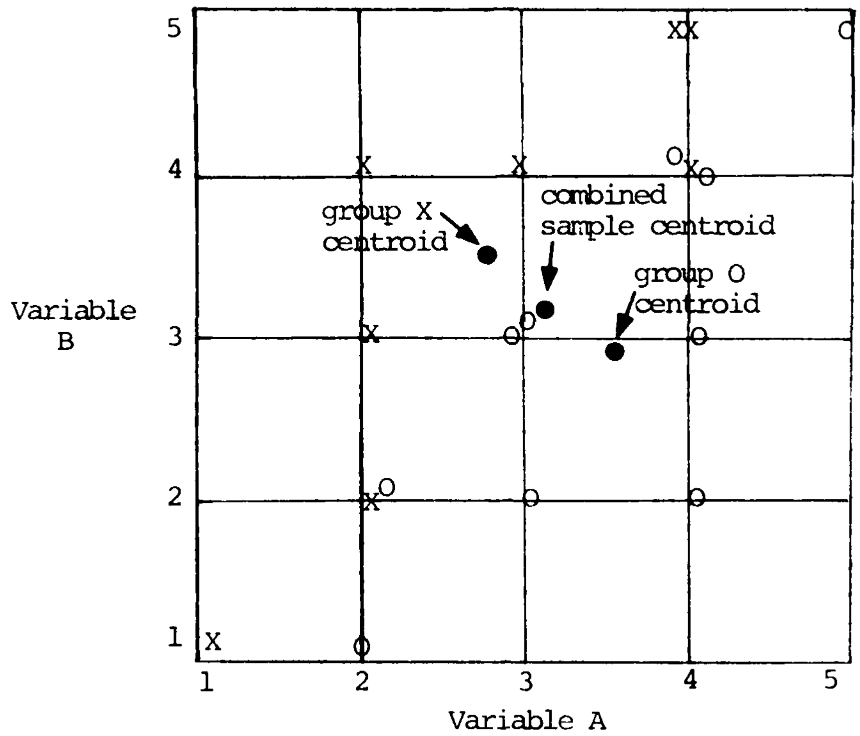


Figure 2. Two-dimensional Graph of Group Centroids (39:7-2)

The following discussion of discriminant analysis is a summary of class notes from Applied Multivariate Analysis, SM 6.85, conducted by Lt Col Joseph W. Coleman, at the School of Engineering, Air Force Institute of Technology (10). The centroid for one of the groups in the types of equipment category would be represented as follows:

$$\underline{\bar{x}}_k = \begin{bmatrix} \bar{x}_{1k} \\ \bar{x}_{2k} \\ \bar{x}_{3k} \\ \bar{x}_{4k} \\ \bar{x}_{5k} \end{bmatrix} \qquad (3)$$

where $\underline{\bar{x}}_k$ is the centroid for the kth of four groups in the category, and $\bar{x}_{1k}$ through $\bar{x}_{5k}$ are the sample means for the five variables in the kth group. There are g groups where g = 4 for the equipment type discriminant, g = 5 for the mode discriminant, and g = 20 for the third discriminant which combined type and mode; there are p = 5 variables. A combined group centroid can then be calculated which is the vector of the sample means for each variable for all g groups:

$$\underline{\bar{X}} = (1/n) \sum_{k=1}^{g} n_k \underline{\bar{X}}_k \quad (4)$$

where $\underline{\bar{X}}$ is the combined group centroid, n is the total sample size, n_k is the sample size of the kth of g groups, and $\underline{\bar{X}}_k$ is the centroid for the kth group. The group centroid and the combined group centroid are needed for performing the discriminant analysis.

In order to determine whether and how the groups differ, a number of discriminant functions must first be built. These are linear combinations of the five discriminating variables. They can be thought of as various planes in multidimensional space. The centroids are also located in this space, and so have coordinates on the discriminant functions. The idea is to build functions which give maximum separation between the groups, where the planes provide maximum separation. If this is achieved, cases which are from the same group will have similar scores for the discriminant functions, and cases from other groups will have very different values.

Before the discriminant functions can be built, the partitioning of the variances must be accomplished. The total sample variance is divided into its parts, the within group variance and the among group variance. This is similar to the partitioning of the sum-of-squares for univariate analysis of variance (ANOVA) (18:343-352, 456). The total sum-of- squares and crossproducts is represented as follows:

$$T = \sum_{k=1}^{g} \sum_{i=1}^{n_k} (\underline{x}_{ik} - \bar{\underline{x}})(\underline{x}_{ik} - \bar{\underline{x}})' \qquad (5)$$

where T is the total sample variance, or the variance/covariance matrix, $\underline{x}_{ik}$ is the vector of the ith of n observations in the kth of g groups, and $\bar{\underline{x}}$ is the combined group centroid. The within sum-of-squares and crossproducts for group k is:

$$W = \sum_{k=1}^{g} W_k = \sum_{k=1}^{g} \sum_{i=1}^{n_k} (\underline{x}_{ik} - \bar{\underline{x}}_k)(\underline{x}_{ik} - \bar{\underline{x}}_k)' \qquad (6)$$

where W is the summation of all within group variances, W_k is the within group variance for the kth group, $\underline{x}_{ik}$ is the vector of the ith observation in the kth group, and $\bar{\underline{x}}_k$ is the group centroid of the kth group. From this the within groups covariance matrix can be derived, which is the multivariate version of the pooled estimate of variance:

$$S_w = \frac{1}{n - g} \quad (W) \tag{7}$$

where S_w is the within groups covariance matrix, n is the number of observations, g is the number of groups, and W is the within group variance. The among sum-of-squares and crossproducts is:

$$A = \sum_{k=1}^{g} n_k(\bar{x}_k - \bar{x})(\bar{x}_k - \bar{x})' \tag{8}$$

where A is the among group variance, n_k is the number of observations in the kth group, $\bar{x}_k$ is the kth group centroid, and $\bar{x}$ is the combined group centroid. Since the total variance equals the within and among variations, then it is clear that the following equality holds:

$$T = W + A \tag{9}$$

where T is the total sample variance, W is the within group variance, and A is the among group variance.

Now it is possible to develop the linear discriminant functions of the general form

$$f_i = \sum_{j=1}^{p} a_j(x_{ij} - \bar{x}_j) \tag{10}$$

where f_i is the function score for each ith observation, a_j is a weighting factor for the jth of p variables, x_{ij} is the ith observation for the jth of p variables, and $\bar{x}_j$ is the mean of the jth of p variables. This represents the weighted sum of the deviations of each of the i observations of each variable from the mean of the variable. The function score is similar to the factor score in factor analysis (28:468-478, 487-490; 39:6-1 - 6-31). As was discussed earlier, the values of this function score should be similar for cases from the same group and population. This function can now be extended to the kth group:

$$f_{ik} = \sum_{j=1}^{p} a_j (x_{ijk} - \bar{x}_j) \qquad (11)$$

where f_{ik} is the function score for the ith observation of the kth group, a_j is a weighting factor for the jth of p variables, x_{ijk} is the ith observation of the jth of p variables in the kth group, and $\bar{x}_j$ is the mean of the jth of p variables. In matrix terms, the function score is:

$$f_{ik} = \underline{a}'(\underline{x}_{ik} - \underline{\bar{x}}) \qquad (12)$$

where f_{ik} is the function score for the ith observation of the kth group, $\underline{a}'$ is the vector of weighting factors for the p variables, $\underline{x}_{ik}$ is the vector of the ith observation in the kth group, and $\underline{\bar{x}}$ is the combined group centroid. By several processes which will be omitted here, the total of the function scores squared can be found to be the total sum-of-squared deviations:

$$\underline{a}'T\underline{a} = \underline{a}'W\underline{a} + \underline{a}'A\underline{a} \qquad (13)$$

where $\underline{a}'T\underline{a}$ is the sum-of-squared deviations of the function scores, f_{ik}, from their mean, $\underline{a}'W\underline{a}$ is the sum-of-squared deviations from the within group mean or centroid, and $\underline{a}'A\underline{a}$ is the sum-of-squared deviations from the between group centroid. As mentioned earlier, in determining the discriminant, the goal is maximum group separation or, in other words, maximum among group distance and minimum within group distance. To find this, the following maximizing objective function will be used:

$$\text{Max} \quad \frac{\underline{a}'A\underline{a}}{\underline{a}'W\underline{a}} \qquad (14)$$

$$\text{subject to:} \quad \underline{a}'W\underline{a} = n - g \quad \text{or} \quad \underline{a}'S_w\underline{a} = 1$$

where $\underline{a}'A\underline{a}$ is the sum-of-squared deviations from the among group centroid, $\underline{a}'W\underline{a}$ is the sum-of-squared deviations from the within group centroid, n is the number of observations, g the number of groups, and S_w is the within groups covariance matrix. The alternative form of the constraint comes from the identity in equation 7. The constraint is imposed on the value of $\underline{a}$ so that a unique solution to the maximization problem is possible. The objective function is now set equal to λ, the eigenvalue, which means that now the objective is to maximize λ. By solving using the Lagrange multiplier technique, the following is equation obtained:

$$(W^{-1}A - \lambda I)\underline{a} = \emptyset \qquad \min[p,g-1] \qquad (15)$$

where W is the within group variance, A is the between group variance, λ is the function being maximized, I is the identity matrix, $\underline{a}$ is the vector of the weighting coefficients, and the rank of this matrix is the minimum of p, the number of variables, and g - 1, one less than the number of groups.

In order to maximize the original objective function which has been set equal to λ, the largest λ is chosen, along with its associated eigenvector, $\underline{a}$. The number of non-zero eigenvalues is the minimum of (p, g -1). The eigenvalues are placed in descending order, λ_1, λ_2. . . . The maximizing constraint is satisfied by scaling the eigenvector, $\underline{a}$, which requires that $\underline{a}$ be multiplied by $\pm [(n - g)/c]^{1/2}$ since $\underline{a}'W\underline{a} = c$ where n is the number of observations, g is the number of groups, $\underline{a}'W\underline{a}$ is the sum-of-squared deviations from the within group centroid, and c is some numeric value.

The last step in calculating the discriminant is determining its power, or how good the function actually is in separating the groups. By derivation, the following equation is obtained:

$$\frac{\lambda}{\lambda + 1}(100) \qquad (16)$$

where λ is the eigenvalue which is being maximized. This is the percentage of the variation which is explained by each eigenvalue. The larger the eigenvalue and the higher the percentage of variation it explains, the better the function is for separating groups. The number of functions which will be built is either equal to the number of variables, or one less than the number of groups. All these functions may not be useful in separating the groups, as will be determined by the magnitude of the eigenvalue. Although there is no rule, the analyst may accept only those functions which are felt to contribute to explaining the variation or are statistically significant. When the percentage of the eigenvalue becomes too small, the remaining functions might not be used.

After developing the discriminant functions it is necessary to test for the equality of group centroids and the significance of the discriminant functions. The Wilks' lambda statistic is used to do this. It is assumed that the populations are multivariate normal and have equal covariances:

$$\underline{x}_{ik} \sim N(\boldsymbol{\mu}_k, \Sigma) \qquad (17)$$

where $\underline{x}_{ik}$ is the vector of a sample of i observations in the kth group, and the right hand side indicates that this statistic is distributed normally with a mean of $\boldsymbol{\mu}_k$ and a covariance of Σ. Likewise, by the Central Limit Theorem, the distribution of the sample centroids can be shown to be normal:

$$\bar{X}_k \sim N(\boldsymbol{\mu}_k,\ 1/n_k\Sigma) \qquad (18)$$

where $\bar{X}_k$ is the centroid for the kth group, which is normally distributed with a mean of $\boldsymbol{\mu}_k$ and a covariance of $1/n_k\Sigma$, where n_k is the number of observations in the kth group. The null and alternative hypotheses to be tested, that the population group centroids are equal, can be written as follows:

$$H_o:\ \boldsymbol{\mu}_1 = \boldsymbol{\mu}_2 \ldots = \boldsymbol{\mu}_g$$

$$H_a:\ \text{At least one } \boldsymbol{\mu}_k \text{ not equal}$$

where the $\boldsymbol{\mu}$s are the group means, as noted in equation 18. If the null hypothesis is rejected, then the assumption is that the centroids differ, and that the groups do not come from the same population, so they should not be costed identically. The test statistic starts with the Wilks' lambda, which represents a likelihood ratio test of the hypothesis that all groups have identical centroids:

$$\Lambda = \frac{\text{Error SSCP}}{\text{Total SSCP}} = \frac{|W|}{|T|} \qquad (19)$$

where Λ is the Wilks' lambda value, SSCP stands for sum-of-squares and crossproducts, W is the within SSCP or the within variance, and T is the total SSCP. There is no simple convenient distribution for lambda, though, so approximations are used. One of these approximate evaluations is the Bartlett's chi-square which is based on a transformation of Wilks' lambda:

$$\chi_o^2 = -[n - \frac{p + q}{2} - 1] \ln \Lambda \quad \sim \chi^2_{\alpha, p(g-1)} \qquad (20)$$

where χ_o^2 is the chi-square value, n is the number of observations, p is the number of variables, q is the minimum of (p, g - 1), g being the number of groups, Λ is the Wilks' lambda value, and $\chi^2_{\alpha, p(g-1)}$ indicates a chi-square distribution with a level of significance of α and degrees of freedom of p(g -1). The level of significance used for this test was 0.05.

A Wilks' lambda is calculated as each variable is entered into the discriminant. The significance of the equivalent F statistic for this lambda indicates whether there is a significant difference between the group centroids. If the value for the significance of F is below the level of confidence of 0.05, there is a significant difference.

A Wilks' lambda and chi-square are also calculated before the first discriminant function is built. This indicates how much discriminating power exists in the variables being used. The lower the lambda, the more discriminating power (28:440). As each discriminant function is built some of the discriminating power is removed, which is indicated by increasing Wilks' lambda values and less significant chi-squares. It is possible for the lambda to become very large, and thus non-significant, before all the discriminant functions are built. It is the researcher's decision which determines when the lambda is so large as to be non-significant.

The last part of the discriminant analysis is to build the classification functions. The primary use of this function is to identify the group to which a new observation most likely belongs, when only the values for the discriminating variables for that case are known. The classification function can also be used to determine how well the discriminant functions will perform. The cases in the database which were used to build the discriminant functions are classified using only those functions, and then the actual group membership is compared with the membership predicted by the functions. The percentage correctly classified is a measure of the success of the discriminant function.

The second purpose for the classification function is the only one used in this thesis. Due to this, the mathematical derivation of classification will not be discussed here, since the function will not be used to classify new cases. For a complete discussion of classification and discriminant analysis and for the full mathematical derivations, consult An Intro to Applied

Multivariate Analysis, by Charles W. McNichols (39).

Finally, no analysis can be assumed to be correct unless the assumptions are followed. The first assumption is that of homogeneity of the population variance/covariance matrix. The matrix, S_w, which is known, is the unbiased estimate of the population matrix. The Box-M test will be used to test for homogeneity. The hypotheses are as follows:

$$H_o: \Sigma_1 = \Sigma_2 = . . . = \Sigma_g$$

$$H_a: \text{At least one } \Sigma \text{ not equal}$$

where Σ is the variance/covariance matrix. The level of significance used for this test is 0.001. It is set at this level because the test is very sensitive. The objective is to fail to reject the null hypothesis. If the null hypothesis is rejected there are other conditions which can be considered. If each group has 20 more observations than the number of variables, then the Bartlett's approximation of the Wilks' lambda can still be considered robust, even though the Box-M was rejected.

The next assumption concerns multicollinearity, which is the existence of a relationship between two or more of the independent variables. If multicollinearity exists it is a problem in analyzing the effects of the variables, but not in prediction. To get around a multicollinearity problem stepwise insertion of variables can be used, and was used for this analysis. This method maximizes the minimum distance while minimizing multicollinearity.

The third assumption is normality. Normality is robust to skewness but not to outliers. It is very difficult to find outliers in a multivariate function, though, due to the many dimensions. However, if the sample is large, normality can be assumed, unless there is obvious evidence otherwise.

The last assumption is linearity of the relationship between the groups and the variables. It is also very difficult to determine, due to the many dimensions of the space. It will not be specifically tested for since the degree of discrimination is a measure of linearity.

The next test that was performed was a regression on each group, which also generates a correlation matrix. The correlation coefficients, r, in the matrix indicate the strength of the linear relationship between the dependent and independent variables. The correlation coefficient can be a value between -1 and 1. The closer r is to either of those values, the higher the correlation, or the stronger the linear relationship. If the correlation is a positive number then there is a direct relationship, whereas if r is negative there is an inverse relationship. The hypotheses tested for correlation are:

$$H_o: \rho = 0$$
$$H_a: \rho \neq 0$$

where ρ is the correlation coefficient. If the null hypothesis is rejected then it is assumed that a linear relationship exists between the dependent and independent variables. Since the purpose of this thesis is simply to determine which independent variable is most highly correlated with the dependent variable (i.e. that variable with the highest correlation coefficient with respect to the dependent variable) a further discussion of the mathematical derivation of correlation and the test statistic will not be conducted here. The independent variables are the cost variables while the dependent variable is total cost. For each group, the independent variable which is most highly correlated with total cost is the cost driver. It is important to insure that this relationship is logical, also, since a numerical correlation does not necessarily prove correlation (35:3-4). This was done for all groups.

The regression analysis further determines what the mathematical relationship is between the dependent and independent variables. This relationship tells how the independent variable can be used to predict the dependent variable. The purpose of this is to build a CER for estimating the total cost based on the cost driver identified by the correlation. The most highly correlated independent variable, the cost driver, will be the first variable inserted in the regression. The simple linear regression is of the following form:

$$y_i = \beta_0 + \beta_1 x_{i1} + \epsilon_i \qquad i = 1, 2, \ldots, n \qquad (21)$$

where y_i is the value of the dependent variable for the ith of n cases, x_{i1} is the first independent variable of the ith of n cases, ϵ_i is a random error term, and β_0 and β_1 are the coefficients. The error term accounts for any deviation from the predicted values of y_i and x_{i1} due to random behavior. Figure 3 is a graph of the general linear regression line in equation 21.

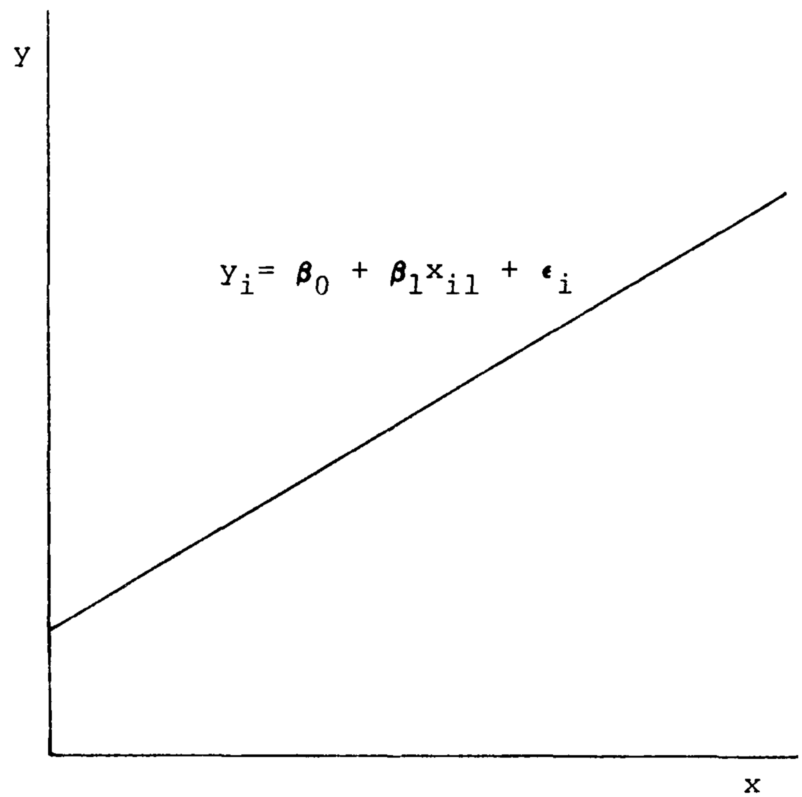


Figure 3. General Linear Regression Line

The least squares technique is most commonly used to estimate the coefficients of the regression. The coefficients are found which minimize the sum-of-squared differences between y_i (i = 1, 2, . . . , n), which is the observed value of the dependent variable, and $\hat{y}_i$, which is the expected value obtained by using the estimated coefficients, β_j or b_j. This is also called the best fit approach. The difference between the actual value and the expected value of the dependent variable is the expected error, ϵ_i, or e_i, also called the residual. Thus, since deviation of the expected from the actual is unwanted, the objective is to find regression coefficients which minimize the sum-of-squared residual terms:

$$\sum_{i=1}^{n} e_i^2 = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 \qquad (21)$$

where e_i is the residual, y_i is the ith actual value of the independent variable, and y_i is the expected value of y_i. Through the use of matrix calculus, the minimization yields the two normal equations in two unknowns, β_0 and β_1:

$$\begin{aligned} (\Sigma x_{i1})\, \hat{\beta}_0 + (\Sigma x_{i1})\, \hat{\beta}_1 &= \Sigma x_i y_i \\ n\, \hat{\beta}_0 + (\Sigma x_{i1})\, \hat{\beta}_1 &= \Sigma y_i \end{aligned} \qquad (22)$$

where n is the number of observations, $\hat{\beta}_0$ and $\hat{\beta}_1$ are the expected values of the coefficients, x_i is the value for the independent variable, and y_i the value of the dependent variable. Since the values of the coefficients are unknown, they must be estimated. Further derivation of the normal equations yields the expression for calculating the estimated coefficients, $b_\emptyset$ and b_1, as follows:

$$b_1 = \frac{\Sigma (x_i - \bar{x})(y_i - \bar{y})}{\Sigma (x_i - \bar{x})^2}$$

$$b_\emptyset = 1/n(\Sigma y_i - b_1 \Sigma x_i) \qquad (23)$$

where n is the number of observations, x_i and $\bar{x}$ are the ith observation and the mean of the independent variable, respectively, and y_i and $\bar{y}$ are the value and the mean of the dependent variable, respectively. With estimated values for the coefficients, the regression model now becomes:

$$\hat{y}_i = b_\emptyset + b_1 x_{i1} \qquad (24)$$

where $\hat{y}_i$ is the expected value of the dependent variable, $b_\emptyset$ and b_1 are the estimates of the coefficients, and x_{i1} is the ith observation of the independent variable.

There are several tests to determine the presence of a linear relationship and to judge its strength. To test if a linear relationship actually exists, the following hypotheses regarding the value of β_1 are used:

$$H_o: \beta_1 = \emptyset$$

$$H_a: \beta_1 \neq \emptyset$$

where β_1 is the cofficient of the independent variable. If the null hypothesis is rejected, then it is assumed that there is a linear relationship since the coefficient is non-zero. A value of zero for the coefficient means that the independent variable would take on the value of zero in the regression, indicating it has no influence on the dependent variable. To test this hypothesis, an F statistic is used. Calculation of this requires a partitioning of the total variation (SST), the sum of the squared variations, into the sum-of-squares regression (SSR) and the sum-of-squares error (SSE). This is a similar concept to the partitioning of the variance already described for the discriminant analysis, so the process will not be derived here. Figure 4 is a graph of the partitioned variation. A further description can be found in any elementary statistics book.

The SSR and SSE are each divided by there respective degrees of freedom to obtain the mean square regression (MSR) and the mean square error (MSE). These are then used to calculate the F statistic:

$$F_{calc} = \frac{MSR}{MSE} \tag{26}$$

where F_{calc} is the calculated value of the F statistic. This value can then be compared to $F_{critical}$ from the critical value table for the F distribution. For the

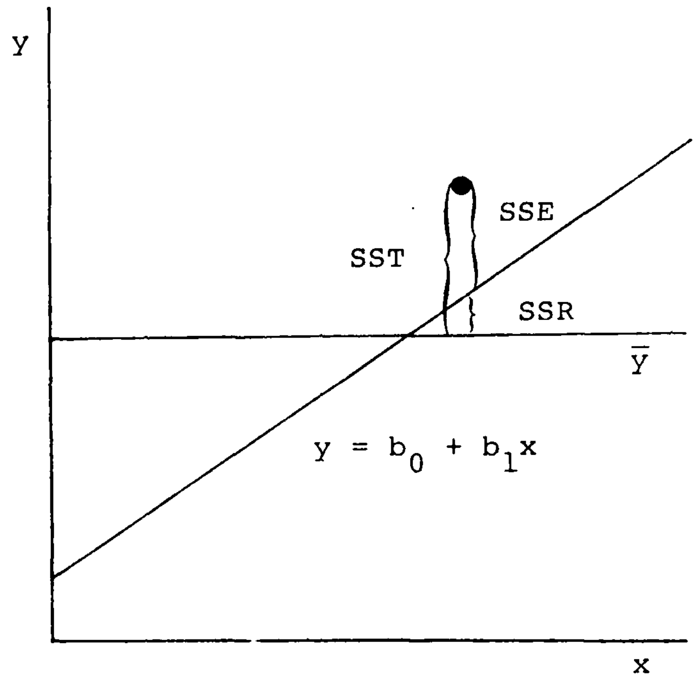


Figure 4. Partitioning of the Variance for Regression (10)

purposes of this analysis, a general rule of thumb was used instead: if F_{calc} is greater than 4.0 then the null hypothesis is rejected and a relationship is assumed to exist (8). This rule comes from the fact that the F_{crit} value from the critical values table is 3.84 for a sample larger than 120 cases (18:624). If the F_{calc} value is greater than the F_{crit} value then the null hypothesis is rejected. The F_{crit} value can be found in the critical values table by using the statistic $F_{(\alpha,k,n-k-1)}$ where k equals the number of independent variables and n equals the number of cases (10; 18:456). For this research, then, the value of $F_{(\alpha,1,442)}$ is 3.84, which is approximately 4.0.

The level of significance for this test was set at 0.05.

The next test of the regression is to determine the strength of the relationship; in other words, what proportion or percentage of the variation in the dependent variable is explained by the regression relationship. This is measured by the coefficient of determination, R^2, or r^2 for a simple regression. The r^2 can be calculated by taking the ratio of the SSR to the SST:

$$r^2 = \frac{SSR}{SST} \qquad (27)$$

where r^2 is the coefficient of determination, SSR is the regression sum-of-squares, and SST is the total sum-of-squares. As is clear from the notation, r^2 can also be calculated by squaring the correlation coefficient, r. Since the r^2 is interval data and tells how significant the independent variable is, the r^2 values for each regression can be used for comparing regression equations, the higher the value, the better.

As a final step, the assumptions must be tested. The first assumption is that linearity exists, in other words that the expected value of the residual is zero. This is determined by an examination of the scattergram on which all data points are plotted. The presence of any obvious non-linearity must be corrected by data transformation.

The second assumption is that the variance of the error terms is a constant, and thus that the data exhibits homoscedasticity. This is tested by plotting the residuals against the predicted values of the dependent variable on a scatterplot and examining for unusual patterns. In the desired pattern, the residuals would be evenly distributed in a horizontal band across the plot. If the pattern becomes wider moving from left to right (or vice versa), it is indicative of heteroscedasticity, a condition which should be corrected, if severe, by using a weighted least squares technique.

The third assumption is that the covariance of the error terms is zero. If this is not the case, then the condition is called autocorrelation, which is a relationship between the error terms. This is also determined from the residual scatterplot. In this case the pattern may be a diagonal across the plot, or a wave. Serious cases of this should also be corrected for by data transformation.

The fourth assumption is that of normality. The residuals are plotted on a histogram and a normality plot. Any outliers are identified on the histogram. Skewness is checked for on the normality plot.

Lastly, the possibility of multicollinearity can be investigated with the correlation matrix. This condition exists when independent variables are related to each other. This is obvious if there is a high correlation coefficient between independent variables. It should be corrected by one of a variety of methods (18:512-513). One of the methods is the elimination of one of the highly correlated independent variables.

Analysis of Results

Once the statistical tests were completed, the results were analyzed to determine if the groups should be costed separately, and what the O&S cost drivers for C^3I systems should be. This entailed a study of the discriminant analysis to determine if there was a significant difference between the groups first. Following that, the correlation table was analyzed to identify the O&S cost drivers for each group. The regression results were analyzed to formulate the equation for predicting total cost from the independent variable, the cost driver. Lastly, the statistical assumptions of linearity, normality, multicollinearity, and autocorrelation were discussed.

Formulation of Conclusions and Recommendations

The conclusions of this thesis were based on the analysis of the statistical results and an intense study of the literature. They are the result of much time and thought given to the subject, but are, of course, still the opinions of the author. The recommendations come from the recognition that there is much more to be done in this area. They are suggestions for further research which could not be accomplished within the time and scope of this thesis effort.

IV. Analysis of Results

Chapter Overview

This chapter contains the results of the data analysis and the statistical testing. The statistical results are presented in summary form in the chapter. The results of the discriminant analysis and the regression are analyzed with respect to the methodology discussion in the previous chapter.

Database Analysis

The database used for this research was the Logistics Management Engineering (LME) database, named after the company that developed it. This database is controlled by the VAMOSC office at AFLC headquarters. The database contains C-E costs for the years 1977 to 1983, when the contract ended. Since this thesis only addresses C^3I equipment which is in the realm of C-E equipment, i.e. ground C^3I, this database was sufficient. Containing only five categories of logistics costs it is not as comprehensive as was desired; however, it is a far more accurate database, at this time, than the VAMOSC C-E database. The database is contained in Appendix B.

Initially, the C-E O&S database at VAMOSC was to be used for this thesis. This database was designed to store information on 19 categories of O&S costs which are shown in Table I. Although in operation, the VAMOSC database is incomplete, and inaccurate as well. This made it an unsatisfactory database for this thesis.

TABLE I

Communications-Electronics O&S Cost Categories (17:20)

Category	Subcategory
Unit Mission Personnel	
	Operations Personnel
	Base Maintenance Personnel
	Administrative Personnel
	Supply Support Personnel
Unit Level Consumption	
	Fuel
	Maintenance Material
	Utilities
Depot Maintenance	
Replacement Investment	
Installation Support	
	Base Operating Support
	Real Property Maintenance
	Communications
Indirect Personnel Costs	
	Temporary Duty
	Permanent Change of Station
	Unit Mission Personnel Health Care
Depot Non-maintenance	
	General Depot Support
	Engineering Support
	Transportation and Packaging
Advanced Training	
Operating and Support Cost - TMS Total	

There are five costs categories in the LME database: 1) adjusted depot maintenance cost; 2) replacement investment cost; 3) transportation and packaging cost; 4) base maintenance labor cost; and 5) base maintenance material cost. The total O&S cost is also included, which is a summation of these five costs. The costs are a combination of directly collected costs, factors, and allocated costs. LME calculated the five costs in the following manner. The adjusted depot maintenance cost (ADMC) is calculated by adding across the various categories of actual depot maintenance costs for any given system, and then multiplying this sum by the recoverable allocation factor (RAF). This factor is computed as a ratio of components installed in end items, an end item being a C-E system such as TACAN, and the component being the power supply for the TACAN:

$$RAF = \frac{\text{quantity of X installed in end item Y}}{\text{quantity of X installed in all end items}}$$

where X is the component power supply and Y is the end item such as a TACAN. The ADMC is then adjusted for inflation. Each year all costs in the database were adjusted to latest year dollars.

The replacement investment cost (RIC) is the cost of condemned recoverables, i.e. components which are normally repaired. It is determined by obtaining the number of total condemnations for the year from the depot, multiplying the number by the cost of the component, and finally by the RAF. This value is then adjusted for inflation.

The transportation and packaging cost (TPC) is the most complicated cost that is calculated. First, two factors are computed, one for CONUS shipments and one for overseas. These two factors are then combined into a single transportation and packaging factor. For each component, the total number of repairs is multiplied by the RAF, which gives the expected number of shipments. Combined with the pounds of crated component shipped, this results in the following equation:

TPC = TPF x expected shipments x pounds of component

where TPC is the transportation and packaging cost and TPF is the transportation and packaging factor. This cost is then adjusted for inflation.

The base maintenance labor cost (BMLC) is a combination of scheduled and unscheduled maintenance costs. The documented hours for unscheduled maintenance were added to the programmed hours for scheduled equipment inspections. This sum is multiplied by the hourly labor rate which was supplied to LME by the Air Force. This cost was also adjusted for inflation.

The last category is also a factored cost, base maintenance material cost (BMMC). As this database was being designed, LME collected actual maintenance material costs and related those to the number of labor hours used to yield a factor for dollars of material costs for each labor hour. This factor, when multiplied by the BMLC, resulted in the BMMC. The BMMC was then adjusted for inflation.

The next step was to analyze the database in order to determine what it contained specifically and what was pertinent. The database contains approximately 300 equipment items, representing many of the TMS categories. An interview with personnel at the communications electronics ground support branch (LOC/CFEC) at AFLC revealed that all ground C^3I systems can be narrowed down to five crucial installation or use categories: 1) ground; 2) portable; 3) transportable; 4) fixed; and 5) mobile (ZZ). These are the most important categories of ground equipment in terms of accomplishing the C^3I mission, and also the most numerous in the ground C^3I inventory. Within these categories, four types of equipment predominate: 1) radar; 2) radio; 3) wire; and 4) special/combination systems. Since these types of equipment fall into one of the five use categories, a matrix was formed to show what equipment was in the database and how many in each category. The results are in Table II.

Only these primary categories were used in the

TABLE II

Database Items by Type and Mode of Installation

	Mode of Installation				
Type	Ground	Portable	Transportable	Fixed	Mobile
Radar	4	0	3	6	7
Radio	19	4	9	13	6
Wire	2	0	12	11	1
Special	1	0	7	3	3

analysis. There were two reasons for this. First, since they are the most crucially needed and most numerous categories of C^3I ground equipment, it is imperative that these systems be cost-effective. To determine cost-effectiveness, the cost drivers must be known. Second, in order to be statistically valid, it was necessary that the largest sample of equipment items available be used. These categories provided the largest samples. It was also found that all equipment items were not costed in all seven years during which the database was maintained. In order to insure an even weighting and to prevent bias by systems with a larger or smaller number of samples, only items with at least the last four years of data were chosen for the statistical test.

Discriminant Analysis

Before the statistical tests were conducted, the data was coded in three ways. The first grouping was based on type of equipment (four types), the second by mode of use (five modes), and the third by the combination of type and mode (20 combinations). The purpose was to determine which characteristic, or combination of characteristics, was best for costing C^3I equipment. The assumption was that pieces of equipment of a given type, e.g. radar, would have similarities whether the use mode was fixed or mobile, and likewise, that all transportable equipment, for example, would have similarities, whether it was radar or wire. The statistical tests were then used to determine if these similarities affected costs in such a way that different costing methods need to be developed. If so, methods could be developed for costing categories of systems making C^3I costing more accurate and less costly than the current method of developing costing equations for single systems. The type and use categories were combined to determine if costing would be more accurate when the equipment was grouped more specifically; in other words, to determine if there was a difference in costs of radar systems depending on whether they were used in the fixed or mobile mode.

The first statistical tests conducted were discriminant analyses of the three groupings. The first discriminant was used to determine if the four types of equipment were significantly different from each other, based on the cost data. The second discriminant tested for a significant difference in the five use categories, while the third tested the 20 combination groups.

Results. All tests were run using the Statistical Package for the Social Sciences (SPSS). Tables III through V present a summary of the results for the three discriminant analyses. The discriminant programs are in Appendix C while the complete statistical results may be found in Appendices D through F. The variables were entered in a stepwise manner for two purposes: 1) to determine the most important variables for the category; 2) to prevent multicollinearity, the correlation of two or more independent variables.

Analysis. The first discriminant produced a good distribution of cases by group in that there was a fairly large number in each group. In the second discriminant, group 2 is rather small in comparison to the others. The third discriminant had some groups with no cases and others with very few. This simply indicates that there were no cases with that particular combination of type and mode, but it does reduce the number of groups. The small number of cases in each group has an effect in several ways. Groups with small numbers of cases do not give as accurate a picture of total costs for that equipment as larger groups.

Table III

Results of Discriminant Analysis 1

Discriminant 1: TYPE

Group	Number of Cases
1	80
2	204
3	104
4	56

Group Separation

Variables Entered	Significance - F	Between Groups	
RIC	.0495	2	4
ADMC	.0000	3	4
TPC	.0000	3	4
BMLC	.0000	2	3

Eigenvalues

Function	Eigenvalue	Percentage of Variation
1	.285	82.35
2	.044	12.61
3	.017	5.04

Functions

After Function	Wilks'Lambda	Chi-Squared	Significance
0	.733	136.293	.000
1	.942	26.321	.000
2	.983	7.589	.022

Classification

Percentage of Grouped Cases Correctly Classified - 43.92

Box M Test

Significance of the F - 0

TABLE IV

Results of Discriminant Analysis 2

Discriminant 2: MODE

Group	Number of Cases
1	104
2	16
3	124
4	132
5	68

Group Separation

Variables Entered	Significance - F	Between Groups	
BMLC	.0000	3	4
RIC	.0000	1	2
TPC	.0000	1	2
ADMC	.0000	1	2

Eigenvalues

Function	Eigenvalue	Percentage of Variation
1	.305	89.54
2	.026	7.63
3	.009	2.77
4	.000	.06

Functions

After Function	Wilks'Lambda	Chi-Squared	Significance
0	.740	132.215	.000
1	.965	15.460	.079
2	.990	4.210	.378
3	1.000	.393	.760

Classification

Percentage of Grouped Cases Correctly Classified - 30.86

Box M Test

Significance of the F - 0

TABLE V

Results of Discriminant Analysis 3

Discriminant 3: TYPE/MODE COMBINATION

Group	Number of Cases	Group	Number of Cases
1	16	11	48
2	76	12	28
3	8	13	24
4	4	14	52
5	0	15	15
6	16	16	12
7	0	17	28
8	0	18	24
9	12	19	4
10	36	20	12

Group Separation

Variables Entered	Significance - F	Between Groups	
BMLC	.0000	15	16
RICC	.0000	3	6
ADMC	.0000	3	6
TPC	.0000	3	6

Eigenvalues

Function	Eigenvalue	Percentage of Variation
1	.701	64.60
2	.194	17.87
3	.120	11.09
4	.070	6.44

Functions

After Function	Wilks'Lambda	Chi-Squared	Significance
0	.411	384.787	0
1	.699	155.017	.000
2	.834	78.348	.000
3	.935	29.214	.006

Classification

Percentage of Grouped Cases Correctly Classified - 17.57

Box M Test

Significance of the F - 0

In all three discriminants all variables with the exception of BMMC, the base maintenance material cost, entered. The variables did not enter in the same order for each discriminant, though. This indicates that the variables have differing levels of importance depending on the method of categorizing equipment. BMMC was not as important in separating groups on the basis of cost data as the other four variables, so it did not enter. Variables are entered by SPSS in the order which maximizes the minimum distance between groups, thus providing the greatest separation of the discriminant functions. The significance of the Equivalent F for the Wilks' lambda was below the 0.05 level of confidence for all groups in all discriminants. This indicates there is a significant difference between the group centroids based on the cost variables. The between groups column shows which two groups had the closest values for that variable.

All discriminants built the maximum number of functions possible, one less than the number of groups or equal to the number of variables, whichever is less. In discriminants 1 and 2 the first function was very powerful and explained most of the variation between the groups, as indicated by the high percentages of variation explained, 92.35 and 89.54 respectively. Discriminant 3 was also good, but not as high at 64.60 per cent. This discriminant also relied much more on its second and third functions to separate the groups. This is most likely due to the small number of cases in each group. The fourth function on discriminant 2 can be eliminated as it contributes no predictive value with an eigenvalue of .000.

The low Wilks' lambda and high chi-squared values for the functions indicate that considerable discriminating power existed in the variables before the first discriminant function was built. By building the first function in discriminants 1 and 2, most of the discriminating power was removed as shown by the very high Wilks' Lambda and the dramtically lower chi-squared values. Function 3 of discriminant 2 removed virtually all of the remaining discriminating power. This was also clear from the low eigenvalue and percentage of variation for function 4, as was discussed earlier.

The classification functions (see Appendices D - F) are the last indication of how well the functions are able to discriminate. In comparing actual group membership with group predicted by the discriminant functions, the discriminant analysis based on types of equipment was clearly better. It predicted 43.92 per cent correctly, against the 30.36 correctly classified in discriminant 2, and 17.57 per cent correct in discriminant 3. Even 43 per cent is not outstanding (50 per cent is desirable, but often not achieved with real world data), but it is much better than random which would be 25 per cent for a discriminant with four groups, such as number 1. Although discriminants 2 and 3 are also better than random prediction, they are still much lower than what is possible if discriminant 1 is used, which indicates that those groupings are not as good for predicting costs as the first grouping. The effect of the large number of groups and correspondingly small number of cases per group is evident in the low percentage for the third discriminant. Without as many sample cases from which to build the discriminant function, the function is not as accurate a discriminator.

Before the discussion of the analysis is complete, the assumptions must be reviewed. The first assumption is that of homogeneity of the covariance matrix and is tested by using the Box M test. Based on the significance of the F value, which is less than the level of significance, 0.05, the null hypothesis must be rejected, indicating that the covariance matrices are not equal. In this case the next test is to determine if each group has 20 more observations than the number of variables. If so, the chi-square approximation of the Wilks' lambda can still be considered to be robust, or reasonably accurate over a range. The only discriminant analysis which passes this test is the first discriminant.

The second assumption concerns the independent variables and their relationship. To avoid the problems of multicollinearity, stepwise insertion was used.

Multicollinearity can create problems in analyzing the effects of the variables, so it was necessary to eliminate it.

As mentioned in the methodology, the last two assumptions, normality and linearity were not specifically tested for in the discriminant analysis. They are very difficult to test due to the multiple dimensions of this type of analysis. There are no programmed tests available for these assumptions because of this difficulty. However, normality was assumed since the sample was large and there was no obvious evidence to the contrary. Linearity was also assumed since the degree of discrimination was good and can be used as an indication of linearity.

Regression Analysis

Results. Since the discriminant showed that the method of grouping equipment by type was the best for providing group separation based on the cost variables, this grouping was also used in the regression analysis. Since the first discriminant was the only one which passed all the tests of the assumptions the other discriminants were not tested at all in the regression. Four regressions were run, one each for radar, radio, wire, and special/combination systems. The regression program is in Appendix C. Complete statistical results are contained in Appendices G through J. A summary is provided in Tables VI through IX.

TABLE VI

Results of Regression A

Regression A: RADAR	
Correlation	
Variable Most Highly Correlated:	ADMC
Correlation Coefficient, r:	.983
Regression	
Coefficient of Determination, r^2:	.96593
b_0:	24349.35727
F_{calc}:	19.192
Significance of F:	.0000
b_1:	1.94865
F_{calc}:	2211.641
Significance of F:	.0000

TABLE VII

Results of Regression B

Regression B: RADIO	
Correlation	
Variable Most Highly Correlated:	ADMC
Correlation Coefficient, r:	.810
Regression	
Coefficient of Determination, r^2:	.65542
b_0:	9181.47308
F_{calc}:	66.191
Significance of F:	.0000
b_1:	1.54383
F_{calc}:	384.217
Significance of F:	.0000

TABLE VIII

Results of Regression C

Regression C: WIRE	
Correlation	
Variable Most Highly Correlated:	ADMC
Correlation Coefficient, r:	.963
Regression	
Coefficient of Determination, r^2:	.92748
b_0:	5916.95722
F_{calc}:	26.188
Significance of F:	.0000
b_1:	1.56810
F_{calc}:	1304.569
Significance of F:	.0000

TABLE IX

Results of Regression D

Regression D: SPECIAL/COMBINATION SYSTEMS	
Correlation	
Variable Most Highly Correlated:	BMLC
Correlation Coefficient, r:	.935
Regression	
Coefficient of Determination, r^2:	.87359
b_0:	12881.25504
F_{calc}:	4.043
Significance of F:	.0494
b_1:	1.65895
F_{calc}:	373.177
Significance of F:	.0000

Analysis The correlation matrix revealed that in all cases at least one variable was highly correlated with the dependent variable, total cost. For the first three regressions this was the same variable, ADMC. The relationship was not the same, though, as is evident from the regression coefficients. It does indicate that, for the most part, the adjusted depot maintenance cost is the most important contributor to total cost, and thus is the cost driver. For regression D, the most highly correlated variable was BMLC, base maintenance labor cost. The correlation coefficient for regression B was the lowest, but still very satisfactory. Regression A had a second variable which was also very highly correlated, TPC, with a correlation coefficient of .978. This is an indication of multicollinearity. This is also evident from the high correlation coefficient between these variables, .957. This problem was solved by only using one of the two correlated independent variables.

As would be expected, with such high correlation coefficients, all the regressions also had satisfactory coefficients of determination. For regression A, C, and D, this coefficient was exceptionally good. This indicates that the linear relationship between the dependent and independent variable is very strong and much of the variation in the dependent variable is explained by that independent variable. This is desirable in identifying cost drivers. The coefficient of determination for regression B is not as high as the coefficients for the other regressions, but it is still very good.

The remaining entries in the tables have to do with the regression coefficients. The values of b_0 and b_1 are given for each regression. These can be used to prepare the cost estimating equations as follows:

$$y_{radar} = 24349.35727 + 1.94865(ADMC)$$

$$y_{radio} = 9181.47308 + 1.54383(ADMC)$$

$$y_{wire} = 5916.95722 + 1.56810(ADMC)$$

$$y_{spec} = 12881.25504 + 1.65895(BMLC)$$

where y is the dependent variable, total O&S cost, for that system based on the value of the independent variable in parentheses. All the F_{calc} values for the coefficients are over the minimum 4.0, indicating that there is indeed a linear relationship between the independent and dependent variables; in other words, that $\beta_1 \neq 0$. The significance of F values for all the coefficients are also less than the level of significance, 0.05, which verifies that the F values are statistically significant and that the null hypothesis, $\beta_1 = 0$, should be rejected.

The assumptions must now be tested. The first is the assumption of linearity which is tested with a scattergram of all data points. There was no obvious indication of non-linearity, so linearity is assumed.

The second assumption, that the variance of the error terms is a constant, is tested by plotting the residuals against the predicted values of the dependent variable on a scatterplot. An examination of the scatterplots was then conducted to find unusual patterns which would indicate heteroscedasticity. Although the pattern of the distribution was not perfect, there was no indication of severe heteroscedasticity which would need to be corrected.

The next assumption is that the covariance of the error terms is zero. The scatterplots are again examined for this condition. There was no indication in any of the plots of autocorrelation.

The assumption of normality is tested with the histograms and normality plot. The histogram identified some outliers, but an investigation of these points did not reveal that they were unusual, thus they were left in the database. The normality plot showed that all the regressions had a slight amount of skewness; none were considered severe enough for corrective action since this was felt to be a normal condition for real world data.

The condition of multicollinearity has already been discussed. This was found in regression A, but was corrected for by eliminating one of the highly correlated independent variables by stepwise insertion of the variables into the regression.

V. Conclusions and Recommendations

Conclusions

This thesis has answered the research questions posed in chapter one. In addressing the first question, a search of the literature and interviews with experts in the field were conducted. This background investigation revealed the importance of high technology and user interface. C^3I systems hold a unique place in the implementation of military strategy and tactics. C^3I cannot be considered in the same category as weapon systems. It is neither a nuclear nor a conventional weapon, but it is a necessity if those weapons are to be used effectively by the military, both in deterring and fighting war. C^3I systems are the eyes, ears, and nervous system of the country and cannot be compromised. They cannot be taken to the bargaining table with our opponents as are weapon systems. This country cannot afford to bargain away its C^3I capability because it is so vital to survival.

Another factor that must be considered in the development and costing of C^3I systems is the extremely rapid rate of change of high technology, so much of which has to do with C^3I systems. Along with this is the fact that, by their nature, C^3I systems require an extensive user interface. These two factors combined make special acquisition techniques necessary. An evolutionary acquisition approach would work better than the traditional method. The evolutionary approach would require bulding an architecture for the systems, consisting of a core structure of requirements based on current technology. From this the system would be built as quickly as possible. There should be considerable user involvement during the entire process to insure that the user interface with the systems during operation is considered during design and development. The objective of this approach is to get systems out to the field earlier, so the user has a system to test and one with which to perform the mission. This testing involves both searching for problems and looking for areas for improvement to be integrated into the next system. Due to the constantly changing technology, if an approach such as this is not taken, the new systems will remain on the drawing board, being permanently redesigned for each change in technology and never reach the user. This approach to acquisition will also hopefully produce less costly, more affordable systems. Since the unproven technology is not being used, the system goes through fewer design changes, and spends less time in the acquisition phase. The combination of the use of more proven technology and less acquisition time should lower acquisition cost. This approach will not come into use overnight; it will require that the current desire for the state-of-the-art technology be tempered with cost considerations, and that current acquisition procedures be modified.

Increasing O&S costs, while not a C^3I-specific problem, must be dealt with nonetheless. The VAMOSC system, although not complete, is serving the important function of collecting all O&S costs in one common database. With this data, the real extent of O&S costs can be determined and the military will be able to take specific positive steps toward lowering and/or limiting these costs.

Another important set of factors is reliability and maintainability (R&M). These are just as important to C^3I systems as to weapon systems. Currently, the military is putting increased emphasis on R&M in order to obtain affordable systems in which it can have confidence. This current attention is good, but if R&M becomes simply another buzzword and falls by the wayside, the military will be back where it started or worse, due to today's ever rising costs. The military must continue to demand reliable, maintainable systems.

The problem of increasing costs and a decreasing military budget is going to have to be dealt with head on, from the top echelons of the military down. It will require, among other things, developing cost-effective systems. This means that DTC and LCC concepts will have to be vigorously applied. This is a problem for C^3I systems, since there are no specific C^3I LCC models. Even the costs drivers for C^3I systems are unknown. The second research sub-question was the preparatory step to determining the cost drivers. To determine if the primary categories of ground C^3I systems should be costed using the same variables and costs relationship, a discriminant analysis was performed. Three groupings of the data were tested, one based on type of equipment, the second based on mode of use, and the third on type/mode combinations. The discriminant analyses were all statistically significant and indicated that all groups should not be costed in the same manner.

The grouping based on type of equipment was the best statistically and so was chosen for the next part of the analysis which was to answer the third sub-question, identification of cost drivers. Regression analysis was used to find the cost drivers. Four regressions were run, one for each of the four types of equipment. The correlation matrix generated by the regression was used to identify the costs drivers. A simple regression indicated that there was a clear linear relationship between the cost driver and total O&S costs, and provided the coefficients for the cost estimating equation. The cost driver for each equipment type follows: 1) radar - adjusted depot maintenance cost (ADMC); 2) radio - ADMC; 3) wire - ADMC; and 4) special/combination systems - base maintenance labor cost. Although three of the four types of equipment have the same variable as the cost driver, the relationship of that variable with total O&S cost is not the same for each type. The estimating equations, which can be found in chapter four, show the exact mathematical relationship between the dependent variable and the independent cost driver variable. It is not surprising to find that ADMC is the cost driver for three groups. Depot maintenance has long been known to be a high cost item.

Recommendations

This research has generated a number of ideas and needs for further research. They are presented below in the order which the author felt they should be accomplished. It may not be possible to conduct the research in this order, though, due to circumstances beyond the researcher's control. This should not be a deterrent to tackling the problems. Each step should, at least, be accomplished when the prerequisite conditions are met.

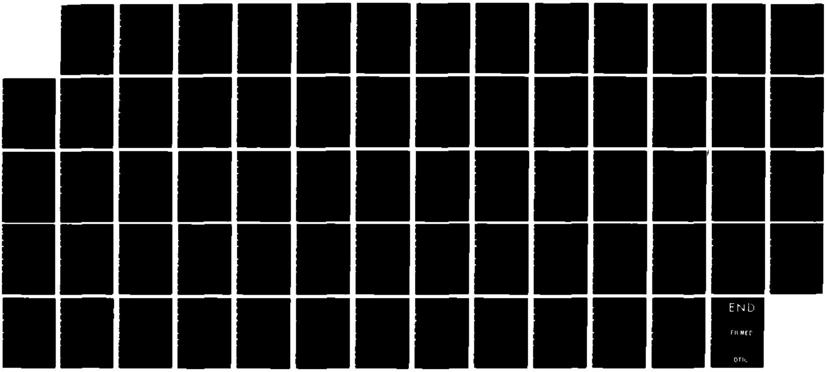
Recommendation 1. Another statistical analysis should be conducted using the methodology presented in this thesis, but with the completed VAMOSC C-E database. The VAMOSC database will be more comprehensive than the LME database.

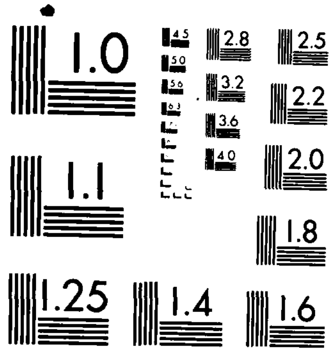
Recommendation 2. A study should be made of currently available LCC models in light of the cost drivers which this thesis has identified. These models should then be run using the VAMOSC database. The purpose of the investigation would be to identify those models, if any, which address the variables known to have an influence on the cost drivers, or those models which can be modified slightly to do this.

Recommendation 3. If no LCC models are found which are satisfactory for costing C^3I systems, a model should be designed specifically for use on C^3I acquisitions which contains variables appropriate for addressing the cost drivers. This model should then be distributed to ESD and ASD at AFSC.

Recommendation 4. The methodology of this thesis should also be used to perform a statistical analysis of the component support cost system (CSCS) database at VAMOSC. CSCS contains cost information on airborne C^3I equipment. It is just as important that the cost drivers for airborne C^3I be identified, but it was beyond the scope of this thesis effort. Once the cost drivers for the airborne C^3I systmes are identified, a LCC model can then be located or designed for use in acquiring cost-effective airborne C^3I systems.

AD-A162 280 AN IDENTIFICATION OF OPERATING AND SUPPORT COST DRIVERS 2/2
FOR COMMAND CONTR (U) AIR FORCE INST OF TECH
WRIGHT-PATTERSON AFB OH SCHOOL OF SYST E K PITTERLE
UNCLASSIFIED SEP 85 AFIT/GSM/LSY/85S-26 F/G 5/3 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Appendix A: Type-Model-Series Codes (14:1-2)

TABLE 1-1

JETDS EQUIPMENT INDICATORS

Installation (1st letter)	Type of Equipment (2d letter)	Purpose (3d letter)	Miscellaneous Identification
A - Piloted aircraft B - Underwater mobile, submarine D - Pilotless carrier F - Fixed ground G - General ground use K - Amphibious M - Ground, mobile P - Portable S - Water T - Ground, transportable U - General utility V - Ground, vehicular W - Water surface and underwater combination Z - Piloted and pilotless airborne vehicle combination	A - Invisible light, heat radiation C - Carrier D - Radiac G - Telegraph or teletype I - Interphone and public address J - Electromechanical or inertial wire covered K - Telemetering L - Countermeasures M - Meteorological N - Sound in air P - Radar Q - Sonar and underwater sound R - Radio S - Special types, magnetic, etc, or combinations of types T - Telephone (wire) V - Visual and visible light W - Armament (peculiar to armament, not otherwise covered) X - Facsimile or television Y - Data processing	B - Bombing C - Communications (receiving and transmitting) D - Direction finder reconnaissance and/or surveillance E - Ejection and/or release G - Fire control, or searchlight directing H - Recording and/or reproducing (graphic meteorological and sound) K - Computing M - Maintenance and/or test assemblies (including tools) N - Navigational aids (including altimeters, beacons, compasses, racons, depth, sounding, approach and landing) Q - Special, or combination of purposes R - Receiving, passive detecting S - Detecting and/or range and bearing, search T - Transmitting W - Automatic flight or remote control X - Identification and recognition	X,Y,Z - Changes in voltage, phase, or frequency T - Training (V) - Variable grouping

Appendix B: Thesis Database

GPA-125	1.	1.	1.	110.00	2.33	5.99	6206.16	37.35	6361.83
GPA-125	1.	1.	2.	171.64	5.17	9.64	6133.36	6.89	6326.69
GPA-125	1.	1.	3.	99.16	0.00	5.87	6189.72	30.47	6325.23
GPA-125	1.	1.	4.	225.08	0.00	10.77	6140.99	10.08	6386.91
GPA-131	1.	1.	1.	3451.21	3.31	804.28	9453.10	787.85	15934.99
GPA-131	1.	1.	2.	4036.38	48.84	691.90	9358.45	748.24	14883.80
GPA-131	1.	1.	3.	2692.82	69.29	456.83	4909.86	769.75	13398.59
GPA-131	1.	1.	4.	2685.49	16.74	418.62	9587.83	844.23	13552.91
GPA-133	1.	1.	1.	2265.08	10.45	101.78	9028.00	2206.64	13611.95
GPA-133	1.	1.	2.	2922.21	8.16	210.83	9091.08	2233.04	14465.32
GPA-133	1.	1.	3.	3470.33	41.79	207.39	9307.15	2323.46	15350.13
GPA-133	1.	1.	4.	4551.26	51.11	250.15	10544.24	2841.14	18237.90
GPN-12	1.	1.	1.	5422.36	24.19	1106.56	29265.37	4136.64	39955.11
GPN-12	1.	1.	2.	8831.04	27.72	14616.30	28859.00	3966.59	56300.85
GPN-12	1.	1.	3.	6224.67	79.68	2537.41	27620.71	3448.40	39910.87
GPN-12	1.	1.	4.	7091.96	829.25	4195.41	30712.10	4742.06	47570.78
GRA-111	2.	1.	1.	4449.92	122.23	718.33	2317.97	90.63	7899.08
GRA-111	2.	1.	2.	5401.57	38.25	844.41	2517.99	90.64	8892.87
GRA-111	2.	1.	3.	4846.57	305.95	840.91	2607.10	127.92	8728.46
GRA-111	2.	1.	4.	5984.85	377.95	886.43	2922.97	260.11	10432.31
GRA-116	2.	1.	1.	120.10	0.83	37.79	938.23	164.53	1261.48
GRA-116	2.	1.	2.	111.48	0.00	36.23	1107.16	235.22	1490.09
GRA-116	2.	1.	3.	68.86	1.97	11.91	1266.10	301.73	1650.56
GRA-116	2.	1.	4.	34.20	3.88	6.80	1416.71	364.76	1826.35
GRA-120	2.	1.	1.	713.77	0.00	1207.37	928.12	8.23	2857.48
GRA-120	2.	1.	2.	682.74	77.15	1184.64	941.16	13.69	2899.39
GRA-120	2.	1.	3.	1121.20	67.90	2125.21	957.57	20.55	4292.43
GRA-120	2.	1.	4.	2216.97	137.32	2544.54	990.81	34.46	5924.09
GRC-115	2.	1.	1.	0.00	0.00	0.00	25186.04	2074.73	27260.77
GRC-115	2.	1.	2.	0.00	0.00	0.00	23263.26	1270.10	24533.36
GRC-115	2.	1.	3.	0.00	0.00	0.00	22850.56	1097.40	23947.96
GRC-115	2.	1.	4.	0.00	0.00	0.00	23826.50	1505.80	25332.30
GRC-158	2.	1.	1.	40.32	0.60	11.65	1215.52	52.47	1320.56
GRC-158	2.	1.	2.	82.54	3.65	23.68	1241.21	63.22	1414.30
GRC-158	2.	1.	3.	81.14	1.40	27.10	1491.33	167.89	1768.84
GRC-158	2.	1.	4.	56.57	1.13	19.78	1823.34	306.82	2207.64
GRC-171	2.	1.	1.	585.43	3.77	49.48	1889.16	93.60	2621.44
GRC-171	2.	1.	2.	263.59	1.80	59.63	1923.44	107.94	2356.40
GRC-171	2.	1.	3.	308.27	6.16	55.91	1968.41	126.76	2465.51
GRC-171	2.	1.	4.	324.50	7.42	55.94	1942.82	116.05	2446.75
GRC-175	2.	1.	1.	279.27	10.81	26.99	1359.71	315.56	1992.35
GRC-175	2.	1.	2.	291.00	16.38	47.83	1279.83	282.13	1917.18
GRC-175	2.	1.	3.	439.92	11.90	60.65	1313.66	296.29	2122.42
GRC-175	2.	1.	4.	519.29	11.43	51.29	1568.80	403.06	2553.88
GRC-188	2.	1.	1.	1439.37	0.00	423.69	6530.25	768.56	9161.86
GRC-188	2.	1.	2.	9610.88	0.00	1944.46	9971.76	2208.74	23735.84
GRC-188	2.	1.	3.	1564.12	0.00	407.07	4782.99	37.38	6791.56

GRC-188	2.	1.	4.	827.52	0.00	11.02	7691.55	1254.53	9784.62
GRC-66V	2.	1.	1.	0.00	0.00	0.00	20312.96	8335.68	28648.64
GRC-66V	2.	1.	2.	0.00	0.00	0.00	29624.58	12232.34	41856.92
GRC-66V	2.	1.	3.	0.00	0.00	0.00	43157.46	17895.49	61052.96
GRC-66V	2.	1.	4.	0.00	0.00	0.00	26051.34	10737.04	36788.38
GRN-19A	2.	1.	1.	17418.12	25.26	1251.13	10946.88	2515.42	32156.82
GRN-19A	2.	1.	2.	5105.19	68.60	1401.15	10438.00	2302.47	19315.41
GRN-19A	2.	1.	3.	6380.07	58.24	1569.58	10885.39	2489.69	21382.97
GRN-19A	2.	1.	4.	7284.19	326.30	1571.40	10202.48	2203.91	21588.29
GRN-20A	2.	1.	1.	5526.77	0.00	858.45	7001.84	2144.41	15531.47
GRN-20A	2.	1.	2.	5601.19	2515.48	1721.57	10244.30	3501.29	23583.83
GRN-20A	2.	1.	3.	17087.47	611.58	1340.12	9750.70	3294.74	32034.62
GRN-20A	2.	1.	4.	1935.75	815.44	676.58	9712.47	3278.74	16418.99
GRN-20B	2.	1.	1.	3930.23	3.96	795.93	8987.73	1746.26	15464.12
GRN-20B	2.	1.	2.	3678.22	16.88	974.90	8348.89	1478.92	14497.81
GRN-20B	2.	1.	3.	6339.65	22.64	1228.86	9412.16	1923.88	18927.20
GRN-20B	2.	1.	4.	4664.56	17.97	889.74	9866.26	2113.90	17552.43
GRN-20C	2.	1.	1.	13675.96	169.87	1832.79	12405.38	1605.12	29689.12
GRN-20C	2.	1.	2.	3747.57	315.23	861.27	11756.05	1333.39	18013.51
GRN-20C	2.	1.	3.	3414.17	229.91	1418.06	12438.14	1618.83	19119.10
GRN-20C	2.	1.	4.	3253.59	215.41	1156.77	13100.98	1896.21	19622.95
GRN-26	2.	1.	1.	1442.16	0.00	515.49	1359.31	214.02	3530.98
GRN-26	2.	1.	2.	940.48	0.00	575.73	1196.88	146.05	2859.13
GRN-26	2.	1.	3.	439.02	0.00	13.23	1670.34	344.17	2466.75
GRN-26	2.	1.	4.	993.42	0.00	81.87	863.03	6.34	1944.66
GRN-27V	2.	1.	1.	4644.59	37.06	569.57	13372.16	4265.32	22888.70
GRN-27V	2.	1.	2.	4877.28	322.41	450.36	11859.34	3632.24	21141.64
GRN-27V	2.	1.	3.	22717.95	484.74	897.31	14108.24	4573.35	42781.59
GRN-27V	2.	1.	4.	17966.86	707.75	1297.10	14035.23	4542.80	38549.74
GRN-28	2.	1.	1.	2593.19	44.98	767.15	1565.84	300.45	5271.61
GRN-28	2.	1.	2.	303.71	0.00	111.79	1385.54	224.99	2026.03
GRN-28	2.	1.	3.	662.96	31.98	132.35	1434.01	245.27	2506.57
GRN-28	2.	1.	4.	732.58	35.58	226.70	1745.30	375.54	3115.71
GRR-23	2.	1.	1.	69.29	0.00	6.23	433.09	54.51	563.12
GRR-23	2.	1.	2.	54.82	0.01	165.64	450.32	61.73	732.52
GRR-23	2.	1.	3.	38.63	0.79	4.03	432.42	54.23	530.11
GRR-23	2.	1.	4.	36.56	0.27	2.81	425.38	51.29	516.32
GRR-24V	2.	1.	1.	147.46	0.24	18.25	913.98	53.00	1132.93
GRR-24V	2.	1.	2.	58.78	0.41	6.09	955.78	70.49	1091.56
GRR-24V	2.	1.	3.	47.41	0.82	5.07	922.69	56.65	1032.64
GRR-24V	2.	1.	4.	51.95	0.37	5.38	916.71	54.14	1028.56
GRT-21V	2.	1.	1.	355.48	0.08	118.84	674.06	231.39	1379.84
GRT-21V	2.	1.	2.	80.10	0.40	29.37	621.77	209.51	941.14
GRT-21V	2.	1.	3.	149.52	3.49	43.44	714.77	248.42	1159.65
GRT-21V	2.	1.	4.	165.87	3.71	34.18	690.06	238.08	1131.91
GSA-135	4.	1.	1.	45.16	1.59	8.77	4074.65	944.80	5074.98
GSA-135	4.	1.	2.	31.71	1.60	5.72	4243.48	1015.46	5297.98
GSA-135	4.	1.	3.	666.62	6.54	18.99	4472.54	1111.31	6276.00
GSA-135	4.	1.	4.	490.60	1.30	2.82	4951.68	1311.82	6758.22
GTA-6	3.	1.	1.	4.48	0.00	0.00	3242.21	89.57	3336.26
GTA-6	3.	1.	2.	289.97	0.00	52.48	3342.34	131.47	3816.27
GTA-6	3.	1.	3.	0.00	0.00	0.00	3214.44	77.95	3292.38

GTA-6	3.	1.	4.	0.00	0.00	0.00	3042.30	5.91	3048.21
GTC-28	3.	1.	1.	1075.06	26.17	40.32	1853.93	471.69	3467.17
GTC-28	3.	1.	2.	642.31	23.46	16.20	1271.12	227.80	2180.90
GTC-28	3.	1.	3.	713.67	0.00	17.57	1664.02	392.22	2787.47
GTC-28	3.	1.	4.	1465.29	46.78	29.31	1383.31	274.75	3199.43
PRC-25	2.	2.	1.	82.31	0.00	13.18	1694.28	12.04	1801.81
PRC-25	2.	2.	2.	41.05	0.00	4.28	1700.27	14.55	1760.16
PRC-25	2.	2.	3.	29.26	0.00	4.84	1713.79	20.21	1768.11
PRC-25	2.	2.	4.	36.26	0.00	4.35	1768.54	43.12	1852.28
PRC-66B	2.	2.	1.	50.84	0.00	9.61	2084.81	23.41	2168.67
PRC-66B	2.	2.	2.	154.12	0.00	25.67	2072.61	18.30	2270.70
PRC-66B	2.	2.	3.	357.62	405.05	12.03	2077.18	20.21	2872.09
PRC-66B	2.	2.	4.	531.90	614.95	10.93	2113.14	35.26	3306.18
PRC-77	2.	2.	1.	2.37	0.00	0.38	3204.87	10.58	3218.19
PRC-77	2.	2.	2.	7.21	0.00	0.92	3217.24	15.76	3241.14
PRC-77	2.	2.	3.	1.75	0.00	0.22	3219.69	16.79	3238.44
PRC-77	2.	2.	4.	14.55	0.00	1.73	3226.33	19.56	3262.17
PRC-104	2.	2.	1.	0.00	0.00	0.00	2732.40	2.95	2735.36
PRC-104	2.	2.	2.	0.00	0.00	0.00	2738.98	5.70	2744.68
PRC-104	2.	2.	3.	4.35	0.00	0.17	2746.93	9.03	2760.48
PRC-104	2.	2.	4.	18.49	0.83	1.62	2779.06	22.48	2822.47
TCC-20	3.	3.	1.	16.01	3.62	3.85	966.26	11.52	1001.26
TCC-20	3.	3.	2.	0.00	0.00	0.00	939.60	0.36	939.96
TCC-20	3.	3.	3.	0.00	0.00	0.00	981.46	17.88	999.34
TCC-20	3.	3.	4.	0.00	0.00	10.10	938.73	0.00	952.20
TCC-3	3.	3.	1.	500.54	369.25	438.64	3459.75	53.88	4822.07
TCC-3	3.	3.	2.	225.69	81.06	114.17	3411.55	33.71	3866.19
TCC-3	3.	3.	3.	0.00	0.00	0.00	3440.53	45.84	3486.38
TCC-3	3.	3.	4.	446.22	338.22	324.69	3706.82	157.27	4973.23
TCC-7	3.	3.	1.	150.67	23.61	76.80	1585.27	169.18	2005.53
TCC-7	3.	3.	2.	468.34	104.51	246.54	1623.05	184.99	2627.44
TCC-7	3.	3.	3.	402.04	176.33	281.57	1426.30	102.66	2388.89
TCC-7	3.	3.	4.	121.54	72.40	124.35	1406.64	94.43	1819.37
TCC-76	3.	3.	1.	5684.96	74.39	131.04	1020.49	34.21	6945.10
TCC-76	3.	3.	2.	30400.66	0.00	5724.72	1485.32	228.73	37839.42
TCC-76	3.	3.	3.	24961.12	0.00	8587.37	3210.30	950.59	37709.38
TCC-76	3.	3.	4.	7742.19	0.00	266.05	6601.83	2369.85	16979.92
TCC-77	3.	3.	1.	6410.03	74.39	170.16	923.59	82.37	7660.54
TCC-77	3.	3.	2.	51010.78	0.00	13406.10	1084.08	149.53	65650.49
TCC-77	3.	3.	3.	27114.59	0.00	8181.98	7335.29	2765.49	45397.35
TCC-77	3.	3.	4.	8123.60	0.00	271.64	13519.56	5353.44	27268.24
TGC-20	3.	3.	1.	8469.45	0.00	4481.97	5825.36	144.11	18920.89
TGC-20	3.	3.	2.	8712.07	0.00	5689.05	5943.29	193.46	20537.87
TGC-20	3.	3.	3.	16.84	29.74	31.41	6082.58	251.75	6412.31
TGC-20	3.	3.	4.	20310.34	0.00	14236.84	6179.25	292.20	41018.62
TGC-26	3.	3.	1.	92724.44	345.72	8066.41	18309.82	6242.89	125689.29
TGC-26	3.	3.	2.	1332.01	92.85	334.64	14242.99	4541.03	20543.53
TGC-26	3.	3.	3.	79269.21	27.99	7172.31	15558.73	5091.64	107118.88
TGC-26	3.	3.	4.	110109.63	138.74	18149.80	15130.01	4912.23	148440.40
TGC-27	3.	3.	1.	2026.27	336.14	2311.46	4580.78	1194.62	10449.27
TGC-27	3.	3.	2.	6217.28	94.01	1706.65	5732.56	1676.61	15427.12
TGC-27	3.	3.	3.	15136.63	10.56	4355.18	5575.60	1610.93	26668.89

TGC-27	3.	3.	4.	30666.42	39.78	7709.67	5016.67	1377.03	44809.57
TGC-28	3.	3.	1.	28794.72	336.49	9013.71	8936.13	1192.44	48273.50
TGC-28	3.	3.	2.	22778.22	84.83	5600.20	10484.41	1840.36	40788.02
TGC-28	3.	3.	3.	10189.89	5.83	5033.17	11012.61	2061.39	28302.90
TGC-28	3.	3.	4.	31701.27	17.84	11119.33	11671.12	2336.96	56846.53
TPB-1C	1.	3.	1.	16758.36	4440.58	3244.65	30528.79	4766.72	59739.10
TPB-1C	1.	3.	2.	27817.68	0.00	235.47	25658.01	2728.44	56439.60
TPB-1C	1.	3.	3.	60353.32	0.00	272.96	30903.90	4923.70	96453.88
TPB-1C	1.	3.	4.	113176.56	3683.69	2535.08	31593.59	5212.31	156201.23
TPS-43E	1.	3.	1.	31335.01	4627.83	3754.12	28383.01	6276.47	74376.45
TPS-43E	1.	3.	2.	46427.66	1249.64	4759.27	25855.76	5218.88	83511.21
TPS-43E	1.	3.	3.	69449.99	1555.84	9728.56	26725.88	5583.00	113043.27
TPS-43E	1.	3.	4.	116016.51	2562.43	15890.60	28597.69	6366.30	169433.54
TPX-42	1.	3.	1.	9675.34	33.29	1840.96	11796.16	3947.95	27293.71
TPX-42	1.	3.	2.	8522.73	45.34	1298.15	8998.16	2777.06	21641.44
TPX-42	1.	3.	3.	8930.77	157.52	1411.02	6081.01	1556.32	18136.65
TPX-42	1.	3.	4.	8419.89	218.34	1171.07	7478.27	2141.03	19428.60
TRC-89	2.	3.	1.	351.69	8.57	79.94	4362.46	925.85	5728.51
TRC-89	2.	3.	2.	1067.31	0.00	86.78	4061.78	800.03	6015.90
TRC-89	2.	3.	3.	420.30	1.68	109.53	4913.34	1156.38	6601.23
TRC-89	2.	3.	4.	264.63	0.00	51.30	3901.49	732.95	4950.37
TRC-136	2.	3.	1.	2988.96	282.76	2001.24	9363.44	3221.38	17857.78
TRC-136	2.	3.	2.	3593.04	3524.36	705.04	9718.61	3370.01	20911.06
TRC-136	2.	3.	3.	10936.85	762.03	4380.64	3613.14	815.04	20507.70
TRC-136	2.	3.	4.	11393.51	1507.83	4102.23	2024.03	150.04	19177.63
TRC-96	2.	3.	1.	3069.54	2373.71	827.69	21473.86	1382.99	29127.79
TRC-96	2.	3.	2.	7205.99	9500.25	3873.89	18738.31	238.23	39556.67
TRC-96	2.	3.	3.	1070.86	1178.22	221.95	18873.06	294.63	21638.73
TRC-96	2.	3.	4.	0.00	0.00	0.00	18390.07	92.51	18482.58
TRC-97A	2.	3.	1.	14537.43	520.55	3418.90	16499.60	2608.80	37585.28
TRC-97A	2.	3.	2.	11945.94	384.73	4405.53	15316.82	2113.84	34166.86
TRC-97A	2.	3.	3.	11426.50	669.71	3955.29	15024.71	1991.60	33077.81
TRC-97A	2.	3.	4.	12668.21	459.71	2547.95	16338.61	2541.44	34555.93
TRN-25	2.	3.	1.	0.00	0.00	0.00	21340.15	59.83	21399.98
TRN-25	2.	3.	2.	0.00	0.00	0.00	22141.97	395.37	22537.34
TRN-25	2.	3.	3.	0.00	0.00	0.00	21917.89	301.60	22219.48
TRN-25	2.	3.	4.	0.00	0.00	0.00	21318.31	50.69	21369.00
TRN-26	2.	3.	1.	7470.65	0.00	982.10	11774.40	834.19	21061.34
TRN-26	2.	3.	2.	4079.68	9.60	865.73	12535.61	1152.74	18643.36
TRN-26	2.	3.	3.	13204.01	285.95	1644.77	11277.25	626.14	27038.13
TRN-26	2.	3.	4.	21136.21	19.46	2409.18	12207.97	1015.63	36788.44
TRN-31	2.	3.	1.	8026.27	241.80	8239.45	11609.91	1817.14	29934.56
TRN-31	2.	3.	2.	8171.70	68.60	12140.45	10364.80	1296.09	32041.64
TRN-31	2.	3.	3.	24949.62	59.45	28811.48	12315.00	2112.20	68247.75
TRN-31	2.	3.	4.	15651.67	320.63	18036.24	10568.22	1381.22	45957.97
TRN-41	2.	3.	1.	0.00	0.00	0.00	423.94	0.00	423.94
TRN-41	2.	3.	2.	309.19	0.00	202.64	424.61	0.28	936.72
TRN-41	2.	3.	3.	359.73	0.00	73.50	442.53	7.78	883.54
TRN-41	2.	3.	4.	2103.11	0.00	134.05	475.35	21.51	2734.01
TRN-42V	2.	3.	1.	0.00	0.00	0.00	393.66	0.00	393.66
TRN-42V	2.	3.	2.	221.54	9.60	290.39	848.22	190.22	1559.98
TRN-42V	2.	3.	3.	25.18	18.53	93.69	663.49	112.91	913.80

TRN-42V	2.	3.	4.	198.03	19.46	255.51	921.64	220.94	1615.58
TSC-15	4.	3.	1.	7865.74	196.07	2583.53	2800.07	778.92	14224.33
TSC-15	4.	3.	2.	4772.44	99.02	2110.99	1470.57	222.56	8675.59
TSC-15	4.	3.	3.	5403.80	24.47	2203.16	1421.47	202.01	9254.92
TSC-15	4.	3.	4.	4297.46	0.00	1513.03	2082.17	478.50	8371.16
TSC-53	4.	3.	1.	13249.36	1759.77	7323.86	23023.48	4984.05	50340.53
TSC-53	4.	3.	2.	15876.05	833.58	6990.26	20279.76	3835.88	47815.54
TSC-53	4.	3.	3.	29736.67	22.17	4564.68	16400.45	2212.49	52936.46
TSC-53	4.	3.	4.	24398.96	1125.57	7352.87	17189.98	2542.89	52610.27
TSC-62	4.	3.	1.	8326.52	330.42	4005.84	5753.49	1482.62	19898.71
TSC-62	4.	3.	2.	8932.41	96.30	2985.45	6875.80	1952.27	20842.22
TSC-62	4.	3.	3.	6748.80	14.31	1522.90	5757.13	1484.14	15527.29
TSC-62	4.	3.	4.	27395.53	89.06	6094.35	6266.37	1697.24	41542.55
TSM-109	4.	3.	1.	5002.25	0.00	150.90	736.22	156.02	6045.39
TSM-109	4.	3.	2.	2879.48	391.64	135.36	580.40	90.82	4077.69
TSM-109	4.	3.	3.	2329.27	68.38	12.00	568.99	86.04	3064.69
TSM-109	4.	3.	4.	5566.20	44.85	278.22	978.44	257.38	7125.10
TSQ-92V	4.	3.	1.	18106.61	412.66	13200.15	110997.53	2097.23	144814.18
TSQ-92V	4.	3.	2.	14442.36	353.04	6016.29	108406.43	1012.92	130231.05
TSQ-92V	4.	3.	3.	40824.44	3244.04	41332.35	122912.71	7083.40	215396.94
TSQ-92V	4.	3.	4.	49583.05	10904.83	27441.69	132767.04	11207.17	231903.79
TSQ-93V	4.	3.	1.	108654.86	14466.75	46850.75	125458.70	4359.77	299820.83
TSQ-93V	4.	3.	2.	7592.57	57.70	1923.75	121165.85	2550.77	133290.64
TSQ-93V	4.	3.	3.	19702.20	1335.85	11445.18	121289.19	2602.39	156374.81
TSQ-93V	4.	3.	4.	18325.95	1687.73	6308.99	130021.87	6256.77	162601.31
TSW-7	4.	3.	1.	10576.71	500.49	6125.44	11101.41	2757.50	31061.55
TSW-7	4.	3.	2.	13255.83	263.91	4883.69	10514.90	2512.06	31429.68
TSW-7	4.	3.	3.	12527.64	97.94	6339.64	11681.28	3000.16	33646.67
TSW-7	4.	3.	4.	11840.81	498.44	4605.79	13609.43	3807.04	34361.50
TTC-7	3.	3.	1.	0.00	0.00	0.00	6547.93	269.08	6817.01
TTC-7	3.	3.	2.	0.00	0.00	0.00	6381.36	199.37	6580.74
TTC-7	3.	3.	3.	1277.31	0.00	0.00	7120.58	508.72	8906.61
TTC-7	3.	3.	4.	7141.63	0.00	572.20	6247.55	143.38	14104.76
TTC-22	3.	3.	1.	12972.58	159.26	2748.70	33951.50	1827.17	51659.21
TTC-22	3.	3.	2.	16606.16	1221.56	6117.57	33887.10	1800.23	59632.62
TTC-22	3.	3.	3.	43773.36	0.00	8873.47	39529.35	4161.35	59337.54
TTC-22	3.	3.	4.	32245.94	685.79	10383.49	36565.78	2921.81	82802.17
TTC-30	3.	3.	1.	45735.82	89.21	9544.52	53753.20	3777.62	112900.10
TTC-30	3.	3.	2.	83902.44	427.35	12930.11	61415.45	6984.06	165659.40
TTC-30	3.	3.	3.	126865.77	1541.42	23322.58	57898.06	5512.13	215139.96
TTC-30	3.	3.	4.	85397.33	3219.19	17280.36	59645.96	6243.57	171786.42
FCC-17	3.	4.	1.	409.73	16.95	49.52	18171.15	267.01	18914.35
FCC-17	3.	4.	2.	1056.29	0.00	70.99	18389.00	358.17	19874.45
FCC-17	3.	4.	3.	1404.14	27.28	154.47	17887.34	148.24	19621.47
FCC-17	3.	4.	4.	1497.97	22.03	134.65	18146.38	256.64	20057.67
FCC-21	3.	4.	1.	515.05	9.44	127.57	1072.15	55.83	1780.05
FCC-21	3.	4.	2.	1207.85	0.00	139.99	1340.80	168.25	2856.90
FCC-21	3.	4.	3.	1437.47	27.28	174.13	1284.13	144.54	3067.56
FCC-21	3.	4.	4.	1198.52	22.03	145.04	1256.44	132.95	2754.99
FCC-22	3.	4.	1.	310.35	9.44	43.53	17683.56	62.96	18109.84
FCC-22	3.	4.	2.	1056.29	0.00	70.99	17860.65	137.07	19124.99
FCC-22	3.	4.	3.	1404.14	27.28	154.47	17850.37	132.77	19681.78

FCC-22	3. 4. 4.	1181.53	22.03	134.65	18104.47	239.10	19681.78
FCC-58V	3. 4. 1.	65.55	96.81	4.70	6082.20	10.82	6260.07
FCC-58V	3. 4. 2.	24.86	22.17	1.53	6245.28	79.07	6372.90
FCC-58V	3. 4. 3.	27.30	23.60	1.63	[illegible]0.97	31.23	6214.72
FCC-58V	3. 4. 4.	76.68	0.00	2.19	61[illegible].41	24.72	6219.00
FGC-20X	3. 4. 1.	0.00	0.00	0.00	1365.90	1.35	1367.25
FGC-20X	3. 4. 2.	0.00	0.00	0.00	1389.59	11.26	1400.86
FGC-20X	3. 4. 3.	0.00	0.00	0.00	1404.64	17.56	1422.21
FGC-20X	3. 4. 4.	1.87	0.00	2.14	1377.05	6.01	1387.07
FGC-25X	3. 4. 1.	0.00	0.00	0.00	2877.59	139.74	3017.32
FGC-25X	3. 4. 2.	0.00	0.00	0.00	2879.76	140.65	3020.41
FGC-25X	3. 4. 3.	0.00	0.00	0.00	2749.00	85.93	2834.93
FGC-25X	3. 4. 4.	414.86	0.00	129.83	2666.84	51.55	3263.07
FGC-52X	3. 4. 1.	115.47	0.00	45.61	2619.78	31.85	2812.72
FGC-52X	3. 4. 2.	0.00	0.00	0.00	2689.55	61.05	2750.59
FGC-52X	3. 4. 3.	0.00	0.00	0.00	2641.41	40.91	2682.32
FGC-52X	3. 4. 4.	0.00	0.00	0.00	2675.10	55.00	2730.10
FGC-61A	3. 4. 1.	0.00	0.00	0.00	8085.21	2673.81	10759.02
FGC-61A	3. 4. 2.	0.00	0.00	0.00	5217.54	1473.76	6691.30
FGC-61A	3. 4. 3.	0.00	0.00	0.00	9166.27	3126.20	12292.47
FGC-61A	3. 4. 4.	0.00	0.00	0.00	5420.42	1558.66	6979.09
FPN-16	1. 4. 1.	22295.87	1023.91	9295.95	122281.58	43099.42	197996.73
FPN-16	1. 4. 2.	31141.42	1592.56	8294.18	95068.54	31711.50	167808.19
FPN-16	1. 4. 3.	24411.71	2816.53	23012.12	86902.39	28294.19	165436.94
FPN-16	1. 4. 4.	35684.16	7651.69	14367.22	78625.90	24830.70	161159.68
FPN-16A	1. 4. 1.	17714.77	885.08	9440.75	47500.95	9866.93	85408.47
FPN-16A	1. 4. 2.	26720.13	1433.27	10572.78	46636.83	9505.32	94868.32
FPN-16A	1. 4. 3.	32475.84	2270.94	30340.96	42413.86	7738.12	115239.72
FPN-16A	1. 4. 4.	47607.84	3515.69	16960.91	29335.73	2265.27	99685.44
FPN-47	1. 4. 1.	8771.83	27.48	4402.15	42741.82	11829.04	67772.32
FPN-47	1. 4. 2.	13894.10	33.06	4359.39	38841.38	10196.81	67324.74
FPN-47	1. 4. 3.	8759.82	67.30	3811.90	44872.03	12720.48	70231.54
FPN-47	1. 4. 4.	10738.83	766.87	4522.76	47067.68	13639.30	76735.44
FPS-6	1. 4. 1.	12555.45	121.07	6808.43	27668.21	1098.60	48251.76
FPS-6	1. 4. 2.	12747.75	620.34	7476.79	27119.71	869.06	48833.65
FPS-6	1. 4. 3.	25857.86	2045.31	12187.21	27326.58	955.63	68372.59
FPS-6	1. 4. 4.	43449.97	412.47	17112.81	26546.54	629.21	88151.00
FPS-6A	1. 4. 1.	37679.98	16121.07	17277.93	26672.98	1619.85	99371.81
FPS-6A	1. 4. 2.	19610.43	620.34	8421.47	26066.48	1366.05	56084.77
FPS-6A	1. 4. 3.	37519.98	2071.72	12708.77	22977.75	73.50	75351.71
FPS-6A	1. 4. 4.	91589.68	412.47	18377.74	27389.79	1919.82	139689.49
FPS-8	1. 4. 1.	6757.31	3259.09	3551.70	22810.59	421.73	36800.42
FPS-8	1. 4. 2.	13347.34	1267.55	1229.64	24255.63	1026.44	41126.61
FPS-8	1. 4. 3.	28477.11	0.00	12127.72	65756.69	18393.50	124755.03
FPS-8	1. 4. 4.	46615.08	0.00	13129.43	37325.21	6495.70	103565.42
FRA-90	2. 4. 1.	1403.67	0.00	11.06	13183.13	5326.70	19924.57
FRA-90	2. 4. 2.	1106.99	0.00	31.82	27656.27	11383.32	40178.39
FRA-90	2. 4. 3.	15.73	0.00	5.10	6122.96	2372.21	8516.00
FRA-90	2. 4. 4.	1061.06	0.00	118.35	5704.06	2196.91	9080.38
FRC-109	2. 4. 1.	227.85	50.70	25.48	4750.13	239.05	5293.20
FRC-109	2. 4. 2.	0.00	0.00	0.00	5575.83	584.59	6160.42
FRC-109	2. 4. 3.	187.58	0.00	5.25	6012.30	767.24	6972.37

FRC-109	2.	4.	4.	215.43	0.00	11.56	4612.03	181.26	5020.28
FRC-155	2.	4.	1.	0.00	0.00	0.00	11278.92	246.68	11525.60
FRC-155	2.	4.	2.	0.00	0.00	0.00	11146.19	191.14	11337.32
FRC-155	2.	4.	3.	0.00	0.00	0.00	10848.92	66.74	10915.66
FRC-155	2.	4.	4.	0.00	0.00	0.00	10936.33	103.33	11039.67
FRC-19B	2.	4.	1.	536.94	23.15	365.19	1475.48	300.64	2701.40
FRC-19B	2.	4.	2.	344.36	0.00	45.66	1410.75	273.56	2074.33
FRC-19B	2.	4.	3.	0.00	0.00	0.00	1631.05	365.75	1996.79
FRC-19B	2.	4.	4.	3714.72	0.00	0.00	2176.47	593.99	6485.18
FRC-39A	2.	4.	1.	11284.55	28761.01	6108.28	32944.78	392.12	79490.74
FRC-39A	2.	4.	2.	9711.17	12797.81	3714.81	32932.41	386.95	58543.15
FRC-39A	2.	4.	3.	9799.71	4964.28	2296.93	34177.62	908.03	52146.58
FRC-39A	2.	4.	4.	30898.99	87689.10	18293.68	37237.01	2188.30	176307.09
FRN-31	2.	4.	1.	10626.78	256.04	3886.65	8956.34	1973.90	25699.70
FRN-31	2.	4.	2.	9436.13	278.44	4261.49	8564.79	1810.04	24330.88
FRN-31	2.	4.	3.	9403.81	145.35	3703.68	9476.15	2191.42	24920.41
FRN-31	2.	4.	4.	10658.63	300.85	4035.15	9558.64	2225.94	26779.22
FRN-37	2.	4.	1.	4970.67	0.00	919.49	16343.03	4760.89	26994.08
FRN-37	2.	4.	2.	9569.68	0.00	3081.75	8595.96	151[illegible]96	22766.35
FRN-37	2.	4.	3.	8505.80	0.00	1830.57	9986.90	2101.03	22424.31
FRN-37	2.	4.	4.	6326.47	0.00	2067.79	15693.99	4489.29	28577.54
FRN-38	2.	4.	1.	7720.48	177.82	2307.26	9265.06	2432.56	21903.18
FRN-38	2.	4.	2.	7633.12	171.62	1790.21	13343.25	4139.17	27077.38
FRN-38	2.	4.	3.	6796.49	93.87	1516.55	10394.36	2905.14	21706.41
FRN-38	2.	4.	4.	17414.65	105.16	2387.51	11885.56	3529.17	35322.06
FRQ-11V	2.	4.	1.	3352.71	5729.27	685.61	16863.05	2292.03	28922.66
FRQ-11V	2.	4.	2.	5313.24	82.58	296.91	13883.15	1045.02	20620.90
FRQ-11V	2.	4.	3.	3255.30	2927.70	166.67	14319.20	1227.50	21896.37
FRQ-11V	2.	4.	4.	26459.95	0.00	1503.09	15760.61	1830.69	45554.34
FRR-75	2.	4.	1.	16304.81	53.01	1624.99	1251.02	16.64	19250.46
FRR-75	2.	4.	2.	10709.72	190.15	2134.23	1276.37	27.24	14337.73
FRR-75	2.	4.	3.	10694.12	87.29	1857.07	1296.06	35.48	13970.01
FRR-75	2.	4.	4.	11163.77	281.38	2226.81	1216.21	2.07	14890.23
FRR-76	2.	4.	1.	16131.17	53.01	1601.49	2527.98	779.11	21092.75
FRR-76	2.	4.	2.	10478.01	190.15	2105.04	2780.20	884.55	16438.05
FRR-76	2.	4.	3.	9599.63	87.29	1828.42	4150.42	1458.05	17123.81
FRR-76	2.	4.	4.	10899.90	281.38	2201.17	3828.65	1323.40	18534.49
FRR-77	2.	4.	1.	16502.22	53.01	1701.75	1120.15	227.98	19605.11
FRR-77	2.	4.	2.	10485.41	190.15	2108.51	1185.53	255.34	14224.94
FRR-77	2.	4.	3.	8796.89	87.29	1923.93	1196.46	259.92	12264.48
FRR-77	2.	4.	4.	12452.75	281.38	2669.12	911.82	140.80	16455.87
FRW-2	2.	4.	1.	729.37	239.53	121.35	3215.27	78.30	4383.82
FRW-2	2.	4.	2.	5463.13	1017.28	450.96	3489.80	193.18	10614.35
FRW-2	2.	4.	3.	8042.22	4227.61	908.64	3942.42	382.59	17503.49
FRW-2	2.	4.	4.	3708.09	2702.68	370.46	3640.39	256.20	10677.81
FSA-22	4.	4.	1.	54.84	0.00	0.00	6992.65	2343.32	9390.80
FSA-22	4.	4.	2.	0.00	0.00	0.00	8506.92	2977.00	11483.93
FSA-22	4.	4.	3.	0.00	0.00	0.00	5827.71	1855.82	7683.54
FSA-22	4.	4.	4.	0.00	0.00	0.00	3883.84	1042.37	4926.21
FSA-4	4.	4.	1.	220.96	0.00	239.73	21224.61	8590.47	30275.78
FSA-4	4.	4.	2.	1231.98	1624.24	4580.25	12094.51	4769.77	24300.74
FSA-4	4.	4.	3.	0.00	0.00	0.00	2849.51	900.98	3750.49

FSA-4	4.	4.	4.	3607.55	0.00	0.00	4807.22	1720.23	10135.00
FSQ-44A	4.	4.	1.	0.00	0.00	0.00	778.24	198.95	977.19
FSQ-44A	4.	4.	2.	0.00	0.00	0.00	980.69	283.67	1264.37
FSQ-44A	4.	4.	3.	280.57	0.00	7.20	587.46	119.12	994.35
FSQ-44A	4.	4.	4.	0.00	0.00	0.00	715.08	172.52	887.60
FTA-13	3.	4.	1.	842.56	151.25	118.08	2041.36	461.42	3614.68
FTA-13	3.	4.	2.	0.00	0.00	0.00	2993.99	860.07	3854.07
FTA-13	3.	4.	3.	49.73	0.00	0.00	2492.18	650.08	3191.99
FTA-13	3.	4.	4.	368.04	0.00	39.24	1835.58	375.30	2657.89
FTA-15	3.	4.	1.	18.09	0.00	0.70	1933.40	10.73	1962.91
FTA-15	3.	4.	2.	0.00	0.00	0.00	1923.08	6.42	1929.50
FTA-15	3.	4.	3.	0.00	0.00	0.00	2058.50	63.09	2121.59
FTA-15	3.	4.	4.	0.00	0.00	0.00	2204.51	124.19	2328.69
FTA-28	3.	4.	1.	6.09	0.00	0.32	1471.52	70.89	1548.82
FTA-28	3.	4.	2.	0.00	0.00	0.00	1400.24	41.06	1441.31
FTA-28	3.	4.	3.	166.73	0.00	18.73	1403.19	42.30	1630.94
FTA-28	3.	4.	4.	13.85	0.00	2.30	1454.45	63.75	1534.34
MGC-2	3.	5.	1.	20785.38	253.18	40207.88	1808.57	123.24	63178.24
MGC-2	3.	5.	2.	16469.31	0.00	27605.56	1688.96	73.18	45837.01
MGC-2	3.	5.	3.	27350.54	0.00	12879.09	1949.38	182.16	42361.18
MGC-2	3.	5.	4.	0.00	0.00	0.00	1622.23	45.26	1667.49
MPN-13A	1.	5.	1.	137694.49	4351.53	207418.24	45599.96	10630.08	405694.30
MPN-13A	1.	5.	2.	205755.78	1054.68	87453.06	38585.74	7694.82	343544.07
MPN-13A	1.	5.	3.	44906.93	3184.96	19544.26	40393.88	8451.48	116481.50
MPN-13A	1.	5.	4.	59542.19	5058.4[illegible]	25396.27	40428.33	8465.89	138891.17
MPN-13B	1.	5.	1.	56163.61	4067.96	19527.26	7785.42	723.57	88267.83
MPN-13B	1.	5.	2.	48769.06	4601.88	19127.11	15635.04	4008.43	92141.52
MPN-13B	1.	5.	3.	74401.80	4776.06	22267.84	16983.49	4572.71	123001.91
MPN-13B	1.	5.	4.	76592.03	8188.67	29726.34	6719.51	277.52	121504.06
MPN-13C	1.	5.	1.	43160.62	5225.95	19050.26	31932.04	10194.68	109563.55
MPN-13C	1.	5.	2.	52620.10	4576.39	20915.99	33776.20	10966.41	122855.09
MPN-13C	1.	5.	3.	52616.96	3457.39	21709.12	48723.24	17221.34	143728.04
MPN-13C	1.	5.	4.	69109.75	5098.93	27141.97	35205.49	11564.53	148120.67
MPN-14F	1.	5.	1.	31206.77	3700.03	13746.62	90637.14	35242.70	174533.25
MPN-14F	1.	5.	2.	32562.45	3538.69	15777.83	26201.23	8278.03	86358.22
MPN-14F	1.	5.	3.	3[illegible]654.80	3766.38	17502.75	62390.88	23422.41	139737.23
MPN-14F	1.	5.	4.	42163.23	5337.10	22120.86	24514.54	7572.19	101707.92
MPN-14G	1.	5.	1.	589282.23	4405.01	638298.17	81591.92	9129.35	1322706.67
MPN-14G	1.	5.	2.	406703.84	3937.92	221960.28	89729.49	12534.70	734666.23
MPN-14G	1.	5.	3.	139437.13	2978.94	99[illegible]65.70	82718.30	9600.71	334300.78
MPN-14G	1.	5.	4.	60055.83	4795.31	2[illegible]740.20	76523.74	7008.45	175123.54
MPN-14H	1.	5.	1.	126278.63	4432.69	84037.66	52358.25	17145.81	284253.05
MPN-14H	1.	5.	2.	120855.43	3980.13	64434.11	45703.15	14360.83	249333.64
MPN-14H	1.	5.	3.	194361.88	3202.35	193963.18	38181.73	11213.32	440922.46
MPN-14H	1.	5.	4.	269947.32	4807.17	214130.73	44007.47	13651.24	546543.92
MPN-14J	1.	5.	1.	39490.03	4409.62	17344.40	30068.07	9896.19	101208.31
MPN-14J	1.	5.	2.	767384.90	3977.15	647833.81	38251.83	13320.87	1470768.56
MPN-14J	1.	5.	3.	47914.51	3190.80	28622.24	29044.99	9468.06	118240.60
MPN-14J	1.	5.	4.	59717.46	4757.93	24629.56	41246.69	14574.14	144925.78
MRC-107	2.	5.	1.	1957.20	15.70	328.05	16976.50	780.84	20258.29
MRC-107	2.	5.	2.	1794.00	20.49	221.72	16903.53	750.31	19690.05
MRC-107	2.	5.	3.	2114.07	25.58	369.10	16108.42	417.58	19034.75

MRC-107	2.	5.	4.	1252.03	15.88	233.56	16817.39	714.26	19033.13
MRC-108	2.	5.	1.	1474.76	16.13	187.04	9056.82	393.92	11128.67
MRC-108	2.	5.	2.	1542.24	36.83	166.09	9373.29	526.35	11644.81
MRC-108	2.	5.	3.	1485.98	33.73	250.76	9151.62	433.59	11355.69
MRC-108	2.	5.	4.	985.35	17.74	290.04	9291.26	492.03	11076.41
MRC-113	2.	5.	1.	70911.15	23259.33	5028.71	12076.81	4166.77	115442.78
MRC-113	2.	5.	2.	61330.20	62883.35	8147.28	17418.55	6402.15	156181.54
MRC-113	2.	5.	3.	128870.13	20331.18	3474.93	7082.32	2076.71	161835.28
MRC-113	2.	5.	4.	45257.97	9827.68	1670.41	6475.09	1822.60	65053.76
MRC-80A	2.	5.	1.	2411.86	0.00	1358.48	22185.23	5292.22	31247.79
MRC-80A	2.	5.	2.	3352.56	0.00	2257.78	18691.37	3830.13	28131.84
MRC-80A	2.	5.	3.	20971.79	0.00	9216.90	19710.35	4256.55	54155.58
MRC-80A	2.	5.	4.	23387.30	0.00	10230.85	24046.69	6071.19	63736.03
MRC-98A	2.	5.	1.	9867.51	26228.31	4932.46	1355.61	187.12	42571.02
MRC-98A	2.	5.	2.	3464.05	657.78	3555.71	1275.87	153.75	9107.16
MRC-98A	2.	5.	3.	2939.74	1211.17	892.05	908.45	0.00	5951.41
MRC-98A	2.	5.	4.	5240.46	6060.97	2553.13	1320.28	172.34	15347.18
MRN-20	2.	5.	1.	1545.12	490.88	368.51	2415.37	858.70	5678.59
MRN-20	2.	5.	2.	54586.21	364.79	14984.47	1602.13	518.38	72055.97
MRN-20	2.	5.	3.	18285.15	388.19	4735.12	919.69	232.80	24560.95
MRN-20	2.	5.	4.	1106.68	193.50	147.83	1182.31	342.70	2973.02
MSQ-10	4.	5.	1.	13662.45	253.18	9145.09	7082.63	1063.08	31206.42
MSQ-10	4.	5.	2.	1223.24	0.00	1847.37	5997.26	608.88	9676.75
MSQ-10	4.	5.	3.	209.56	0.00	0.00	5160.97	258.92	5629.44
MSQ-10	4.	5.	4.	0.00	0.00	0.00	5280.66	309.00	5589.66
MSQ-46	4.	5.	1.	107866.60	1159.25	26185.33	47717.34	7879.26	190807.77
MSQ-46	4.	5.	2.	14147.29	731.49	4048.62	47787.54	7908.64	74623.57
MSQ-46	4.	5.	3.	113595.51	5586.97	29705.51	28888.73	0.00	177776.72
MSQ-46	4.	5.	4.	64558.50	653.44	15112.74	29021.97	55.76	109402.41
MSQ-77	4.	5.	1.	70956.74	1271.41	18537.27	388110.32	152478.73	631354.77
MSQ-77	4.	5.	2.	168940.50	1828.71	43405.22	176978.31	64125.72	455278.45
MSQ-77	4.	5.	3.	59415.20	5081.11	17957.14	24650.30	380.58	107484.34
MSQ-77	4.	5.	4.	101003.57	4599.61	31019.53	27556.34	1596.68	165775.72

Appendix C: Computer Programs for Statistical Analysis

```
RUN NAME        C3I DISCRIMINANT ANALYSIS 1
PRINT BACK      CONTROL
VARIABLE LIST   TMS,TYPE,MODE,YR,ADMC,RIC,TPC,BMLC,BMMC,TOTAL
INPUT MEDIUM    CARD
N OF CASES      444
INPUT FORMAT    FIXED(A7,1X,F2.0,1X,F2.0,1X,F2.0,6F10.2)
IF              (TYPE EQ 1.)GROUP = 1
IF              (TYPE EQ 2.)GROUP = 2
IF              (TYPE EQ 3.)GROUP = 3
IF              (TYPE EQ 4.)GROUP = 4
COMPUTE         SET=TRUNC(UNIFORM(2.0))
VAR LABELS      TMS,TYPE MODEL SERIES NUMBER/TYPE,EQUIPMENT USE TYPE/
                MODE,EQUIPMENT USAGE MODE/YR,COSTED YR/ADMC,ADJUSTED
                DEPOT MAINT COST/RIC,REPLACEMENT INVESTMENT COST/
                TPC,TRANSPORTATION AND PACKING COST/BMLC,BASE MAINT
                LABOR COST/BMMC,BASE MAINT MATERIAL COST/TOTAL,
                TOTAL NORMALIZED LOGISTICS SUPPORT COST/
DISCRIMINANT    GROUPS = GROUP(1,4)/VARIABLES=ADMC,RIC,TPC,BMLC,
                BMMC/METHOD=MAHAL/
OPTIONS         5,7,8,10,11,12,13
STATISTICS      7
DISCRIMINANT    GROUPS = GROUP(1,4)/VARIABLES=ADMC,RIC,TPC,BMLC,
                BMMC/SELECT=SET(0)/METHOD=MAHAL/
OPTIONS         5
READ INPUT DATA
FINISH
```

```
RUN NAME          C3I DISCRIMINANT ANALYSIS 2
PRINT BACK        CONTROL
VARIABLE LIST     TMS,TYPE,MODE,YR,ADMC,RIC,TPC,BMLC,BMMC,TOTAL
INPUT MEDIUM      CARD
N OF CASES        444
INPUT FORMAT      FIXED(A7,1X,F2.0,1X,F2.0,1X,F2.0,6F10.2)
IF                (MODE EQ 1.)GROUP = 1
IF                (MODE EQ 2.)GROUP = 2
IF                (MODE EQ 3.)GROUP = 3
IF                (MODE EQ 4.)GROUP = 4
IF                (MODE EQ 5.)GROUP = 5
COMPUTE           SET=TRUNC(UNIFORM(2.0))
VAR LABELS        TMS,TYPE MODEL SERIES NUMBER/TYPE,EQUIPMENT USE TYPE/
                  MODE,EQUIPMENT USAGE MODE/YR,COSTED YR/ADMC,ADJUSTED
                  DEPOT MAINT COST/RIC,REPLACEMENT INVESTMENT COST/
                  TPC,TRANSPORTATION AND PACKING COST/BMLC,BASE MAINT
                  LABOR COST/BMMC,BASE MAINT MATERIAL COST/TOTAL,
                  TOTAL NORMALIZED LOGISTICS SUPPORT COST/
DISCRIMINANT      GROUPS = GROUP(1,5)/VARIABLES=ADMC,RIC,TPC,BMLC,
                  BMMC/METHOD=MAHAL/
OPTIONS           5,7,8,10,11,12,13
STATISTICS        7
DISCRIMINANT      GROUPS = GROUP(1,5)/VARIABLES=ADMC,RIC,TPC,BMLC,
                  BMMC/SELECT=SET(0)/METHOD=MAHAL/
OPTIONS           5
READ INPUT DATA
FINISH
```

```
RUN NAME          C3I DISCRIMINANT ANALYSIS 3
PRINT BACK        CONTROL
VARIABLE LIST     TMS,TYPE,MODE,YR,ADMC,RIC,TPC,BMLC,BMMC,TOTAL
INPUT MEDIUM      CARD
N OF CASES        444
INPUT FORMAT      FIXED(A7,1X,F2.0,1X,F2.0,1X,F2.0,6F10.2)
IF                (TYPE EQ 1. AND MODE EQ 1.)GROUP = 1
IF                (TYPE EQ 2. AND MODE EQ 1.)GROUP = 2
IF                (TYPE EQ 3. AND MODE EQ 1.)GROUP = 3
IF                (TYPE EQ 4. AND MODE EQ 1.)GROUP = 4
IF                (TYPE EQ 1. AND MODE EQ 2.)GROUP = 5
IF                (TYPE EQ 2. AND MODE EQ 2.)GROUP = 6
IF                (TYPE EQ 3. AND MODE EQ 2.)GROUP = 7
IF                (TYPE EQ 4. AND MODE EQ 2.)GROUP = 8
IF                (TYPE EQ 1. AND MODE EQ 3.)GROUP = 9
IF                (TYPE EQ 2. AND MODE EQ 3.)GROUP = 10
IF                (TYPE EQ 3. AND MODE EQ 3.)GROUP = 11
IF                (TYPE EQ 4. AND MODE EQ 3.)GROUP = 12
IF                (TYPE EQ 1. AND MODE EQ 4.)GROUP = 13
IF                (TYPE EQ 2. AND MODE EQ 4.)GROUP = 14
IF                (TYPE EQ 3. AND MODE EQ 4.)GROUP = 15
IF                (TYPE EQ 4. AND MODE EQ 4.)GROUP = 16
IF                (TYPE EQ 1. AND MODE EQ 5.)GROUP = 17
IF                (TYPE EQ 2. AND MODE EQ 5.)GROUP = 18
IF                (TYPE EQ 3. AND MODE EQ 5.)GROUP = 19
IF                (TYPE EQ 4. AND MODE EQ 5.)GROUP = 20
COMPUTE           SET=TRUNC(UNIFORM(2.0))
VAR LABELS        TMS,TYPE MODEL SERIES NUMBER/TYPE,EQUIPMENT USE TYPE/
                  MODE,EQUIPMENT USAGE MODE/YR,COSTED YR/ADMC,ADJUSTED
                  DEPOT MAINT COST/RIC,REPLACEMENT INVESTMENT COST/
                  TPC,TRANSPORTATION AND PACKING COST/BMLC,BASE MAINT
                  LABOR COST/BMMC,BASE MAINT MATERIAL COST/TOTAL,
                  TOTAL NORMALIZED LOGISTICS SUPPORT COST/
DISCRIMINANT      GROUPS = GROUP(1,20)/VARIABLES=ADMC,RIC,TPC,BMLC,
                  BMMC/METHOD=MAHAL/
OPTIONS           5,7,8,10,11,12,13
STATISTICS        7
DISCRIMINANT      GROUPS = GROUP(1,20)/VARIABLES=ADMC,RIC,TPC,BMLC,
                  BMMC/SELECT=SET(0)/METHOD=MAHAL/
OPTIONS           5
READ INPUT DATA
FINISH
```

```
RUN NAME          C3I REGRESSION A TO D
PRINT BACK        CONTROL
VARIABLE LIST     TMS,TYPE,MODE,YR,ADMC,RIC,TPC,BMLC,BMMC,TOTAL
INPUT MEDIUM      CARD
N OF CASES        444
INPUT FORMAT      FIXED(A7,1X,F2.0,1X,F2.0,1X,F2.0,6F10.2)
NEW REGRESSION    SELECT=TYPE EQ 1./DESCRIPTIVES/VARIABLES=ADMC
                  TO TOTAL/STATISTICS=
                  ALL,F/DEPENDENT=TOTAL/STEPWISE/RESIDUALS/
                  SCATTERPLOT(*RESID,*PRED),(*RESID,TOTAL)'
                  SELECT=TYPE EQ 2./DESCRIPTIVES/VARIABLES=
                  ADMC TO TOTAL/STATISTICS=ALL,F/
                  DEPENDENT=TOTAL/STEPWISE/RESIDUALS/
                  SCATTERPLOT(*RESID,*PRED),(*RESID,TOTAL)/
                  SELECT=TYPE EQ 3./DESCRIPTIVES/VARIABLES=
                  ADMC TO TOTAL/STATISTICS=ALL,F/
                  DEPENDENT=TOTAL/STEPWISE/RESIDUALS/
                  SCATTERPLOT(*RESID,*PRED),(*RESID,TOTAL)/
                  SELECT=TYPE EQ 4./DESCRIPTIVES/VARIABLES=
                  ADMC TO TOTAL/STATISTICS=ALL,F/
                  DEPENDENT=TOTAL/STEPWISE/RESIDUALS/
                  SCATTERPLOT(*RESID,*PRED),(*RESID,TOTAL)/
READ INPUT DATA
FINISH
```

Appendix D: Results of Discriminant Analysis 1

NUMBER OF CASES BY GROUP

GROUP	NUMBER OF CASES UNWEIGHTED	WEIGHTED	LABEL
1	80	80.0	
2	204	204.0	
3	104	104.0	
4	56	56.0	
TOTAL	444	444.0	

PRIOR PROBABILITY FOR EACH GROUP IS .25000

-------------- VARIABLES NOT IN THE ANALYSIS AFTER STEP 0 -------------

VARIABLE	TOLERANCE	MINIMUM TOLERANCE	F TO ENTER	D SQUARED	BETWEEN GROUPS	
ADMC	1.0000000	1.0000000	23.0611	.00896	2	3
RIC	1.0000000	1.0000000	2.6323	.00906	2	4
TPC	1.0000000	1.0000000	14.3808	.00110	2	3
BMLC	1.0000000	1.0000000	31.8861	.00040	2	3
BMMC	1.0000000	1.0000000	.3808			

* *

AT STEP 1, RIC WAS INCLUDED IN THE ANALYSIS.

		DEGREES OF FREEDOM			SIGNIF.	BETWEEN GROUPS	
WILKS LAMBDA	.9823691	1	3	440.0			
EQUIVALENT F	2.632275		3	440.0	.0495		
MINIMUM D SQUARED	.9062243E-02					2	4
EQUIVALENT F	.3981810		1	440.0	.5284		

---------------- VARIABLES IN THE ANALYSIS AFTER STEP 1 ----------------

VARIABLE	TOLERANCE	F TO REMOVE	D SQUARED	BETWEEN GROUPS
RIC	1.0000000	2.6323		

------------- VARIABLES NOT IN THE ANALYSIS AFTER STEP 1 -------------

VARIABLE	TOLERANCE	MINIMUM TOLERANCE	F TO ENTER	D SQUARED	BETWEEN GROUPS	
ADMC	.9773817	.9773817	22.2521	.05854	3	4
TPC	.9944606	.9944606	13.8345	.02878	2	4
BMLC	.9822383	.9822383	31.3652	.05419	1	4
BMMC	.9998202	.9998202	.3894			

* *

AT STEP 2, ADMC WAS INCLUDED IN THE ANALYSIS.

		DEGREES OF FREEDOM			SIGNIF.	BETWEEN GROUPS	
WILKS LAMBDA	.8527034	2	3	440.0			
EQUIVALENT F	12.13564		6	878.0	.0000		
MINIMUM D SQUARED	.5853537E-01					3	4
EQUIVALENT F	1.062922		2	439.0	.3463		

--------------- VARIABLES IN THE ANALYSIS AFTER STEP 2 ---------------

VARIABLE	TOLERANCE	F TO REMOVE	D SQUARED	BETWEEN GROUPS
ADMC	.9773817	22.2521		
RIC	.9773817	1.9607		

------------- VARIABLES NOT IN THE ANALYSIS AFTER STEP 2 -------------

VARIABLE	TOLERANCE	MINIMUM TOLERANCE	F TO ENTER	D SQUARED	BETWEEN GROUPS	
TPC	.1509729	.1483801	3.6215	.09149	3	4
BMLC	.9275731	.9229868	22.0117	.08979	2	3
BMMC	.9998119	.9772210	.3622			

* *

AT STEP 3, TPC WAS INCLUDED IN THE ANALYSIS.

		DEGREES OF FREEDOM			SIGNIF.	BETWEEN GROUPS	
WILKS LAMBDA	.8320645	3	3	440.0			
APPROXIMATE F	9.295060		9	1066.1	.0000		
MINIMUM D SQUARED	.9148843E-01					3	4
EQUIVALENT F	1.105014		3	438.0	.3468		

---------------- VARIABLES IN THE ANALYSIS AFTER STEP 3 ----------------

VARIABLE	TOLERANCE	F TO REMOVE	D SQUARED	BETWEEN GROUPS
ADMC	.1483801	11.4848		
RIC	.9511369	2.3270		
TPC	.1509729	3.6215		

-------------- VARIABLES NOT IN THE ANALYSIS AFTER STEP 3 --------------

VARIABLE	TOLERANCE	MINIMUM TOLERANCE	F TO ENTER	D SQUARED	BETWEEN GROUPS	
BMLC	.9016875	.1395213	19.6625	.12364	2	3
BMMC	.9997744	.1483733	.3431			

* *

AT STEP 4, BMLC WAS INCLUDED IN THE ANALYSIS.

		DEGREES OF FREEDOM			SIGNIF.	BETWEEN GROUPS	
WILKS LAMBDA	.7331076	4	3	440.0			
APPROXIMATE F	11.99912		12	1156.5	.0000		
MINIMUM D SQUARED	.1236418					2	3
EQUIVALENT F	2.114690		4	437.0	.0781		

--------------- VARIABLES IN THE ANALYSIS AFTER STEP 4 ---------------

VARIABLE	TOLERANCE	F TO REMOVE	D SQUARED	BETWEEN GROUPS
ADMC	.1395213	5.5565		
RIC	.9461521	2.5323		
TPC	.1467597	1.5659		
BMLC	.9016875	19.6625		

------------- VARIABLES NOT IN THE ANALYSIS AFTER STEP 4 -------------

VARIABLE	TOLERANCE	MINIMUM TOLERANCE	F TO ENTER	D SQUARED	BETWEEN GROUPS
BMMC	.9997048	.1395185	.3130		

SUMMARY TABLE

STEP	ACTION ENTERED	ACTION REMOVED	VARS IN	WILKS LAMBDA	SIG.	MINIMUM D SQUARED	SIG.	BETWEEN GROUPS	
1	RIC		1	.982369	.0495	.00906	.5284	2	4
2	ADMC		2	.852703	.0000	.05854	.3463	3	4
3	TPC		3	.832064	.0000	.09149	.3468	3	4
4	BMLC		4	.733108	.0000	.12364	.0781	2	3

CLASSIFICATION FUNCTION COEFFICIENTS
(FISHER*S LINEAR DISCRIMINANT FUNCTIONS)

GROUP =	1	2	3	4
ADMC	.3362295E-04	.4748435E-05	.1561205E-04	.1500828E-04
RIC	.1308613E-04	.3973996E-04	-.1459264E-04	-.7539876E-05
TPC	-.2095272E-04	-.5633935E-05	-.1606941E-04	-.1694940E-04
BMLC	.3667893E-04	.9177807E-05	.8914080E-05	.4733396E-04
(CONSTANT)	-2.693502	-1.466415	-1.487085	-2.331774

CANONICAL DISCRIMINANT FUNCTIONS

FUNC TION	EIGEN VALUE	PCT OF VARIANCE	CUM PCT	CANON CORREL	AFTER FUNCTION	WILKS LAMBDA	CHI-SQUARED	DF	SIG
					0	.733	136.293	12	.000
1*	.285	82.35	82.35	.47	1	.942	26.321	6	.000
2*	.044	12.61	94.96	.20	2	.983	7.589	2	.022
3*	.017	5.04	100.00	.13					

STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

	FUNC 1	FUNC 2	FUNC 3
ADMC	.93580	.94461	-1.36710
RIC	-.09126	.16418	.93829
TPC	-.44398	-.08621	1.28910
BMLC	.70058	-.73364	.19503

CANONICAL DISCRIMINANT FUNCTIONS EVALUATED AT GROUP MEANS (GROUP CENTROIDS)

GROUP	FUNC 1	FUNC 2	FUNC 3
1	.83739	.47988	.03168
2	-.27565	-.25756	.12677
3	-.13848	-.26232	-.19696
4	.06507	.73989	-.14127

TEST OF EQUALITY OF GROUP COVARIANCE MATRICES USING BOX*S M

THE RANKS AND NATURAL LOGARITHMS OF DETERMINANTS PRINTED ARE THOSE OF THE GROUP COVARIANCE MATRICES.

GROUP LABEL	RANK	LOG DETERMINANT
1	4	79.780552
2	4	70.553588
3	4	66.710983
4	4	74.679328
POOLED WITHIN-GROUPS COVARIANCE MATRIX	4	78.984903

BOX*S M	APPROXIMATE F	DEGREES OF FREEDOM		SIGNIFICANCE
3149.7	102.81	30,	179656.4	0

CLASSIFICATION RESULTS -

ACTUAL GROUP	NO. OF CASES	PREDICTED GROUP MEMBERSHIP 1	2	3	4
GROUP 1	80	34	8	10	28
		42.5	10.0	12.5	35.0
GROUP 2	204	2	132	60	10
		1.0	64.7	29.4	4.9
GROUP 3	104	6	73	20	5
		5.8	70.2	19.2	4.8
GROUP 4	56	7	20	20	9
		12.5	35.7	35.7	16.1

PERCENT OF GROUPED CASES CORRECTLY CLASSIFIED - 43.92

Appendix E: Results of Discriminant Analysis 2

NUMBER OF CASES BY GROUP

GROUP	NUMBER OF CASES UNWEIGHTED	WEIGHTED	LABEL
1	104	104.0	
2	16	16.0	
3	124	124.0	
4	132	132.0	
5	68	68.0	
TOTAL	444	444.0	

PRIOR PROBABILITY FOR EACH GROUP IS .20000

-------------- VARIABLES NOT IN THE ANALYSIS AFTER STEP 0 --------------

VARIABLE	TOLERANCE	MINIMUM TOLERANCE	F TO ENTER	D SQUARED	BETWEEN GROUPS	
ADMC	1.0000000	1.0000000	24.0319	.00230	1	2
RIC	1.0000000	1.0000000	6.5075	.00003	1	2
TPC	1.0000000	1.0000000	13.8022	.00019	1	2
BMLC	1.0000000	1.0000000	9.9877	.02626	3	4
BMMC	1.0000000	1.0000000	.6384			

* *

AT STEP 1, BMLC WAS INCLUDED IN THE ANALYSIS.

		DEGREES OF FREEDOM			SIGNIF.	BETWEEN GROUPS	
WILKS LAMBDA	.9165869	1	4	439.0			
EQUIVALENT F	9.987693		4	439.0	.0000		
MINIMUM D SQUARED	.2626160E-01					3	4
EQUIVALENT F	1.679101		1	439.0	.1957		

---------------- VARIABLES IN THE ANALYSIS AFTER STEP 1 ----------------

VARIABLE	TOLERANCE	F TO REMOVE	D SQUARED	BETWEEN GROUPS
BMLC	1.0000000	9.9877		

-------------- VARIABLES NOT IN THE ANALYSIS AFTER STEP 1 --------------

VARIABLE	TOLERANCE	MINIMUM TOLERANCE	F TO ENTER	D SQUARED	BETWEEN GROUPS	
ADMC	.9327579	.9327579	17.0675	.03043	1	2
RIC	.9922603	.9922603	5.0320	.03053	1	2
TPC	.9715549	.9715549	10.2042	.02667	3	4
BMMC	.9991569	.9991569	.6694			

* *

AT STEP 2, RIC WAS INCLUDED IN THE ANALYSIS.

		DEGREES OF FREEDOM			SIGNIF.	BETWEEN GROUPS	
WILKS LAMBDA	.8763162	2	4	439.0			
EQUIVALENT F	7.472482		8	876.0	.0000		
MINIMUM D SQUARED	.3052644E-01					1	2
EQUIVALENT F	.2111678		2	438.0	.8097		

--------------- VARIABLES IN THE ANALYSIS AFTER STEP 2 ---------------

VARIABLE	TOLERANCE	F TO REMOVE	D SQUARED	BETWEEN GROUPS
RIC	.9922603	5.0320		
BMLC	.9922603	8.4606		

-------------- VARIABLES NOT IN THE ANALYSIS AFTER STEP 2 --------------

VARIABLE	TOLERANCE	MINIMUM TOLERANCE	F TO ENTER	D SQUARED	BETWEEN GROUPS	
ADMC	.9291393	.9283023	15.5545	.03054	1	2
TPC	.9715065	.9644442	9.7287	.03078	1	2
BMMC	.9991445	.9914478	.6631			

* *

AT STEP 3, TPC WAS INCLUDED IN THE ANALYSIS.

		DEGREES OF FREEDOM			SIGNIF.	BETWEEN GROUPS	
WILKS LAMBDA	.8046614	3	4	439.0			
APPROXIMATE F	8.250805		12	1156.5	.0000		
MINIMUM D SQUARED	.3078005E-01					1	2
EQUIVALENT F	.1416241		3	437.0	.9350		

---------------- VARIABLES IN THE ANALYSIS AFTER STEP 3 ----------------

VARIABLE	TOLERANCE	F TO REMOVE	D SQUARED	BETWEEN GROUPS
RIC	.9922109	4.5879		
TPC	.9715065	9.7287		
BMLC	.9644442	5.5504		

-------------- VARIABLES NOT IN THE ANALYSIS AFTER STEP 3 --------------

VARIABLE	TOLERANCE	MINIMUM TOLERANCE	F TO ENTER	D SQUARED	BETWEEN GROUPS	
ADMC	.1402524	.1402524	9.5732	.03296	1	2
BMMC	.9991445	.9636766	.6606			

* *

AT STEP 4, ADMC WAS INCLUDED IN THE ANALYSIS.

		DEGREES OF FREEDOM			SIGNIF.	BETWEEN GROUPS	
WILKS LAMBDA	.7396960	4	4	439.0			
APPROXIMATE F	8.639569		16	1332.6	.0000		
MINIMUM D SQUARED	.3295601E-01					1	2
EQUIVALENT F	.1134668		4	436.0	.9778		

---------------- VARIABLES IN THE ANALYSIS AFTER STEP 4 ----------------

VARIABLE	TOLERANCE	F TO REMOVE	D SQUARED	BETWEEN GROUPS
ADMC	.1402524	9.5732		
RIC	.9720849	3.3206		
TPC	.1466477	4.0382		
BMLC	.8993778	2.1529		

-------------- VARIABLES NOT IN THE ANALYSIS AFTER STEP 4 --------------

VARIABLE	TOLERANCE	MINIMUM TOLERANCE	F TO ENTER	D SQUARED	BETWEEN GROUPS
BMMC	.9986170	.1401784	.7035		

SUMMARY TABLE

STEP	ACTION ENTERED	ACTION REMOVED	VARS IN	WILKS LAMBDA	SIG.	MINIMUM D SQUARED	SIG.	BETWEEN GROUPS	
1	BMLC		1	.916587	.0000	.02626	.1957	3	4
2	RIC		2	.876316	.0000	.03053	.8097	1	2
3	TPC		3	.804661	.0000	.03078	.9350	1	2
4	ADMC		4	.739696	.0000	.03296	.9778	1	2

CLASSIFICATION FUNCTION COEFFICIENTS
(FISHER*S LINEAR DISCRIMINANT FUNCTIONS)

GROUP =	1	2	3	4
ADMC	.1288757E-05	-.1080039E-05	.2438070E-04	.4123038E-05
RIC	-.1793083E-05	.1180386E-05	-.1781162E-06	.3799431E-04
TPC	-.2023332E-05	.7982350E-06	-.2549311E-04	-.4877553E-05
BMLC	.9145236E-05	.3318822E-05	.1875867E-04	.1652708E-04
(CONSTANT)	-1.644191	-1.613487	-1.950649	-1.767528

CLASSIFICATION FUNCTION COEFFICIENTS
(FISHER*S LINEAR DISCRIMINANT FUNCTIONS)

GROUP = 5

ADMC	.4612015E-04
RIC	.9129760E-04
TPC	-.2917843E-04
BMLC	.2538502E-04
(CONSTANT)	-3.280929

CANONICAL DISCRIMINANT FUNCTIONS

FUNC TION	EIGEN VALUE	PCT OF VARIANCE	CUM PCT	CANON CORREL	AFTER FUNCTION	WILKS LAMBDA	CHI-SQUARED	DF	SIG
					0	.740	132.215	16	.000
1*	.305	89.54	89.54	.48	1	.965	15.460	9	.079
2*	.026	7.63	97.17	.16	2	.990	4.210	4	.378
3*	.009	2.77	99.94	.10	3	1.000	.093	1	.760
4*	.000	.06	100.00	.01					

STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

	FUNC 1	FUNC 2	FUNC 3	FUNC 4
ADMC	1.46592	-1.62378	-.81292	-1.29753
RIC	.27681	.61107	.56539	-.50893
TPC	-.77709	2.00468	.14363	1.47507
BMLC	.25827	-.23498	.68897	.71783
RIC	-.00014	.02057	1.01403*	-.00566
BMLC	-.00365	.10481	-.04351	1.04833*

CANONICAL DISCRIMINANT FUNCTIONS EVALUATED AT GROUP MEANS (GROUP CENTROIDS)

GROUP	FUNC 1	FUNC 2	FUNC 3	FUNC 4
1	-.26412	.29852	-.15791	-.23096
2	-.29456	.36837	-.14345	-.39509
3	-.06440	-.19413	-.13704	.07997
4	-.18893	.18649	.07039	-.01029
5	.95744	-.55126	.38851	.32034

TEST OF EQUALITY OF GROUP COVARIANCE MATRICES USING BOX*S M

THE RANKS AND NATURAL LOGARITHMS OF DETERMINANTS PRINTED ARE THOSE OF THE GROUP COVARIANCE MATRICES.

GROUP LABEL	RANK	LOG DETERMINANT
1	4	60.315348
2	4	30.305328
3	4	72.638882
4	4	71.988202
5	4	84.245125
POOLED WITHIN-GROUPS COVARIANCE MATRIX	4	79.002951

BOX*S M	APPROXIMATE F	DEGREES OF FREEDOM		SIGNIFICANCE
4005.8	96.169	40,	18661.7	0

CLASSIFICATION RESULTS -

ACTUAL GROUP		NO. OF CASES	PREDICTED GROUP MEMBERSHIP 1	2	3	4
GROUP	1	104	29	57	5	13
			27.9	54.8	4.8	12.5
GROUP	2	16	0	16	0	0
			0	100.0	0	0
GROUP	3	124	31	37	29	13
			25.0	29.8	23.4	10.5
GROUP	4	132	33	49	17	25
			25.0	37.1	12.9	18.9
GROUP	5	68	7	8	7	8
			10.3	11.8	10.3	11.8

ACTUAL GROUP		NO. OF CASES	PREDICTED GROUP MEMBERSHIP 5
GROUP	1	104	0
			0
GROUP	2	16	0
			0
GROUP	3	124	14
			11.3
GROUP	4	132	8
			6.1
GROUP	5	68	38
			55.9

PERCENT OF GROUPED CASES CORRECTLY CLASSIFIED - 30.86

Appendix F: Results of Discriminant Analysis 3

NUMBER OF CASES BY GROUP

GROUP	NUMBER OF CASES UNWEIGHTED	WEIGHTED	LABEL
1	16	16.0	
2	76	76.0	
3	8	8.0	
4	4	4.0	
6	16	16.0	
9	12	12.0	
10	36	36.0	
11	48	48.0	
12	28	28.0	
13	24	24.0	
14	52	52.0	
15	44	44.0	
16	12	12.0	
17	28	28.0	
18	24	24.0	
19	4	4.0	
20	12	12.0	
TOTAL	444	444.0	

PRIOR PROBABILITY FOR EACH GROUP IS .05882

-------------- VARIABLES NOT IN THE ANALYSIS AFTER STEP 0 --------------

VARIABLE	TOLERANCE	MINIMUM TOLERANCE	F TO ENTER	D SQUARED	BETWEEN GROUPS	
ADMC	1.0000000	1.0000000	13.4753	.00000	4	15
RIC	1.0000000	1.0000000	2.6438	.00000	6	19
TPC	1.0000000	1.0000000	9.1477	.00000	4	6
BMLC	1.0000000	1.0000000	10.9220	.00000	15	16
EMMC	1.0000000	1.0000000	.6985			

* *

AT STEP 1, BMLC WAS INCLUDED IN THE ANALYSIS.

		DEGREES OF FREEDOM			SIGNIF.	BETWEEN GROUPS	
WILKS LAMBDA	.7095941	1	16	427.0			
EQUIVALENT F	10.92203		16	427.0	.0000		
MINIMUM D SQUARED	.2769562E-05					15	16
EQUIVALENT F	.2611302E-04		1	427.0	.9959		

--------------- VARIABLES IN THE ANALYSIS AFTER STEP 1 ---------------

VARIABLE	TOLERANCE	F TO REMOVE	D SQUARED	BETWEEN GROUPS
BMLC	1.0000000	10.9220		

------------- VARIABLES NOT IN THE ANALYSIS AFTER STEP 1 -------------

VARIABLE	TOLERANCE	MINIMUM TOLERANCE	F TO ENTER	D SQUARED	BETWEEN GROUPS	
ADMC	.9645819	.9645819	10.1159	.00001	15	16
RIC	.9888398	.9888398	2.3691	.00009	3	6
TPC	.9860702	.9860702	7.5808	.00001	3	6
BMMC	.9997496	.9997496	.6887			

* *

AT STEP 2, RIC WAS INCLUDED IN THE ANALYSIS.

		DEGREES OF FREEDOM			SIGNIF.	BETWEEN GROUPS	
WILKS LAMBDA	.6516140	2	16	427.0			
EQUIVALENT F	6.358323		32	852.0	.0000		
MINIMUM D SQUARED	.8515044E-04					3	6
EQUIVALENT F	.2265361E-03		2	426.0	.9998		

--------------- VARIABLES IN THE ANALYSIS AFTER STEP 2 ---------------

VARIABLE	TOLERANCE	F TO REMOVE	D SQUARED	BETWEEN GROUPS
RIC	.9888398	2.3691		
BMLC	.9888398	10.5521		

-------------- VARIABLES NOT IN THE ANALYSIS AFTER STEP 2 -------------

VARIABLE	TOLERANCE	MINIMUM TOLERANCE	F TO ENTER	D SQUARED	BETWEEN GROUPS	
ADMC	.9588803	.9568083	9.7384	.00020	3	6
TPC	.9858319	.9755848	7.4404	.00009	3	6
BMMC	.9997366	.9886066	.6859			

* *

AT STEP 3, ADMC WAS INCLUDED IN THE ANALYSIS.

		DEGREES OF FREEDOM			SIGNIF.	BETWEEN GROUPS	
WILKS LAMBDA	.4768069	3	16	427.0			
APPROXIMATE F	7.451180		48	1264.8	.0000		
MINIMUM D SQUARED	.1967369E-03					3	6
EQUIVALENT F	.3481163E-03		3	425.0	1.0000		

--------------- VARIABLES IN THE ANALYSIS AFTER STEP 3 ---------------

VARIABLE	TOLERANCE	F TO REMOVE	D SQUARED	BETWEEN GROUPS
ADMC	.9588803	9.7384		
RIC	.9829948	2.0843		
BMLC	.9568083	7.7406		

-------------- VARIABLES NOT IN THE ANALYSIS AFTER STEP 3 -------------

VARIABLE	TOLERANCE	MINIMUM TOLERANCE	F TO ENTER	D SQUARED	BETWEEN GROUPS	
TPC	.1562804	.1520078	4.2589	.00070	3	6
BMMC	.9997319	.9566012	.6831			

* *

AT STEP 4, TPC WAS INCLUDED IN THE ANALYSIS.

		DEGREES OF FREEDOM			SIGNIF.	BETWEEN GROUPS	
WILKS LAMBDA	.4107873	4	16	427.0			
APPROXIMATE F	6.626704		64	1662.2	.0000		
MINIMUM D SQUARED	.6975216E-03					3	6
EQUIVALENT F	.9234947E-03		4	424.0	1.0000		

---------------- VARIABLES IN THE ANALYSIS AFTER STEP 4 ----------------

VARIABLE	TOLERANCE	F TO REMOVE	D SQUARED	BETWEEN GROUPS
ADMC	.1520078	6.3377		
RIC	.9645729	2.0532		
TPC	.1562804	4.2589		
BMLC	.9416945	6.8377		

-------------- VARIABLES NOT IN THE ANALYSIS AFTER STEP 4 --------------

VARIABLE	TOLERANCE	MINIMUM TOLERANCE	F TO ENTER	D SQUARED	BETWEEN GROUPS
BMMC	.9997295	.1520071	.6793		

SUMMARY TABLE

STEP	ACTION ENTERED	REMOVED	VARS IN	WILKS LAMBDA	SIG.	MINIMUM D SQUARED	SIG.	BETWEEN GROUPS	
1	BMLC		1	.709594	.0000	.00000	.9959	15	16
2	RIC		2	.651614	.0000	.00009	.9998	3	6
3	ADMC		3	.476807	.0000	.00020	1.0000	3	6
4	TPC		4	.410787	.0000	.00070	1.0000	3	6

CLASSIFICATION FUNCTION COEFFICIENTS
(FISHER*S LINEAR DISCRIMINANT FUNCTIONS)

GROUP =	1	2	3	4
ADMC	-.5140819E-06	.3480244E-05	.4573610E-06	-.9487480E-06
RIC	-.7128213E-05	-.3423058E-05	-.1593853E-05	-.2647999E-05
TPC	-.3235127E-07	-.4043622E-05	-.7221071E-06	.4900351E-06
BMLC	.2109035E-04	.1030902E-04	.3728468E-05	.7231625E-05
(CONSTANT)	-2.972036	-2.872041	-2.837747	-2.849104

CLASSIFICATION FUNCTION COEFFICIENTS
(FISHER*S LINEAR DISCRIMINANT FUNCTIONS)

GROUP =	6	9	10	11
ADMC	-.8647223E-06	.1005989E-03	.2414048E-05	.4489748E-04
RIC	.6566609E-06	-.2041720E-04	.1077743E-04	-.2635721E-04
TPC	.6177599E-06	-.1036995E-03	-.1923101E-05	-.4477144E-04
BMLC	.3986396E-05	.1919295E-04	.1423645E-04	.1334729E-04
(CONSTANT)	-2.838070	-4.994625	-2.908668	-3.314781

CLASSIFICATION FUNCTION COEFFICIENTS
(FISHER*S LINEAR DISCRIMINANT FUNCTIONS)

GROUP =	12	13	14	15
ADMC	.8639638E-05	.2377707E-04	.7471420E-05	-.1492459E-05
RIC	.8784476E-05	.1755987E-04	.8156635E-04	-.3055838E-05
TPC	-.8839892E-05	-.2316496E-04	-.7917636E-05	.9230644E-06
BMLC	.6158868E-04	.6620663E-04	.1171896E-04	.9369176E-05
(CONSTANT)	-4.125553	-4.541563	-3.030213	-2.859799

CLASSIFICATION FUNCTION COEFFICIENTS
(FISHER*S LINEAR DISCRIMINANT FUNCTIONS)

GROUP =	16	17	18	19
ADMC	-.2438748E-05	.7316092E-04	.3272036E-04	-.1388818E-04
RIC	.1254646E-05	.5903660E-04	.1724841E-03	.6596167E-05
TPC	.2088388E-05	-.2240589E-04	-.3335976E-04	.2553534E-04
BMLC	.9440385E-05	.4465976E-04	.6558861E-05	.2527208E-05
(CONSTANT)	-2.860409	-7.861065	-3.678021	-2.981063

CLASSIFICATION FUNCTION COEFFICIENTS
(FISHER*S LINEAR DISCRIMINANT FUNCTIONS)

GROUP =	20
ADMC	.9271462E-04
RIC	-.4265211E-04
TPC	-.9336187E-04
BMLC	.8968155E-04
(CONSTANT)	-7.761588

CANONICAL DISCRIMINANT FUNCTIONS

FUNC TION	EIGEN VALUE	PCT OF VARIANCE	CUM PCT	CANON CORREL	AFTER FUNCTION	WILKS LAMBDA	CHI-SQUARED	DF	SIG
					0	.411	384.787	64	0
1*	.701	64.60	64.60	.64	1	.699	155.017	45	.000
2*	.194	17.87	82.47	.40	2	.834	78.348	28	.000
3*	.120	11.09	93.56	.33	3	.935	29.214	13	.006
4*	.070	6.44	100.00	.26					

STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

	FUNC 1	FUNC 2	FUNC 3	FUNC 4
ADMC	1.37524	-.00730	-2.09157	-.55913
RIC	.02932	.25732	-.04986	.98345
TPC	-.74712	.76705	2.27266	.29533
BMLC	.50022	-.71511	.53391	.12350

CANONICAL DISCRIMINANT FUNCTIONS EVALUATED AT GROUP MEANS (GROUP CENTROIDS)

GROUP	FUNC 1	FUNC 2	FUNC 3	FUNC 4
1	-.26984	-.03618	.36362	-.15890
2	-.28907	-.29882	.32045	-.14310
3	-.31873	-.46416	.39842	-.13877
4	-.32128	-.37880	.41261	-.14307
6	-.32359	-.45823	.42057	-.12660
9	.17804	.00224	-1.51824	-.18257
10	-.23104	-.19830	.32617	-.06131
11	-.02510	-.19452	-.43404	-.24917
12	-.04022	.98082	.05729	-.03789
13	.09924	1.11107	-.23773	.02217
14	-.22627	-.23387	.17820	.33852
15	-.32068	-.32637	.41533	-.14420
16	-.31511	-.32416	.43127	-.12041
17	2.37941	.61638	-.68424	.25571
18	-.08100	-.31120	-.34496	.86015
19	.09181	-.50796	.76508	-.10344
20	.50333	1.73524	-1.55550	-.26579

TEST OF EQUALITY OF GROUP COVARIANCE MATRICES USING BOX*S M

THE RANKS AND NATURAL LOGARITHMS OF DETERMINANTS PRINTED ARE THOSE OF THE GROUP COVARIANCE MATRICES.

GROUP LABEL	RANK	LOG DETERMINANT
1	4	58.592693
2	4	58.733371
3	4	34.392314
4	< 4	(TOO FEW CASES TO BE NON-SINGULAR)
6	4	30.305328
9	4	69.720042
10	4	66.792521
11	4	67.447426
12	4	72.615618
13	4	73.340697
14	4	67.654663
15	4	41.945163
16	4	50.387283
17	4	79.192313
18	4	73.676361
19	< 4	(TOO FEW CASES TO BE NON-SINGULAR)
20	4	74.946447
POOLED WITHIN-GROUPS COVARIANCE MATRIX	4	78.525649

SINCE SOME COVARIANCE MATRICES ARE SINGULAR, THE USUAL PROCEDURE WILL NOT WORK. THE NON-SINGULAR GROUPS WILL BE TESTED AGAINST THEIR OWN POOLED WITHIN-GROUPS COVARIANCE MATRIX. THE LOG OF ITS DETERMINANT IS 78.582253

BOX*S M	APPROXIMATE F	DEGREES OF FREEDOM		SIGNIFICANCE
6716.3	43.667	140,	21655.5	0

CLASSIFICATION RESULTS -

ACTUAL GROUP		NO. OF CASES	PREDICTED GROUP MEMBERSHIP 1	2	3	4
GROUP	1	16	1	7	0	0
			6.3	43.8	0	0
GROUP	2	76	10	6	38	1
			13.2	7.9	50.0	1.3
GROUP	3	8	0	0	4	0
			0	0	50.0	0
GROUP	4	4	0	0	0	4
			0	0	0	100.0
GROUP	6	16	0	0	0	0
			0	0	0	0
GROUP	9	12	0	3	0	0
			0	25.0	0	0
GROUP	10	36	11	1	8	4
			30.6	2.8	22.2	11.1
GROUP	11	48	2	7	6	1
			4.2	14.6	12.[illegible]	2.1
GROUP	12	28	2	3	8	0
			7.1	10.7	28.6	0
GROUP	13	24	1	0	0	0
			4.2	0	0	0
GROUP	14	52	10	10	8	2
			19.2	19.2	15.4	3.8
GROUP	15	44	8	0	8	0
			18.2	0	18.2	0
GROUP	16	12	1	1	4	1
			8.3	8.3	33.3	8.3
GROUP	17	28	0	0	0	0
			0	0	0	0
GROUP	18	24	6	3	3	0
			25.0	12.5	12.5	0

GROUP	19	4	0	0	0	0
			0	0	0	0
GROUP	20	12	0	1	0	0
			0	8.3	0	0

ACTUAL GROUP		NO. OF CASES	PREDICTED GROUP MEMBERSHIP 6	9	10	11
GROUP	1	16	0	0	1	0
			0	0	6.3	0
GROUP	2	76	6	0	5	5
			7.9	0	6.6	6.6
GROUP	3	8	4	0	0	0
			50.0	0	0	0
GROUP	4	4	0	0	0	0
			0	0	0	0
GROUP	6	16	16	0	0	0
			100.0	0	0	0

ACTUAL GROUP		NO. OF CASES	PREDICTED GROUP MEMBERSHIP 6	9	10	11
GROUP	9	12	0	7	1	0
			0	58.3	8.3	0
GROUP	10	36	2	0	2	3
			5.6	0	5.6	8.3
GROUP	11	48	7	5	1	8
			14.6	10.4	2.1	16.7
GROUP	12	28	0	0	4	3
			0	0	14.3	10.7
GROUP	13	24	0	3	0	2
			0	12.5	0	8.3
GROUP	14	52	2	0	3	5
			3.8	0	5.8	9.6

GROUP	15	44	20	0	0	0
			45.5	0	0	0
GROUP	16	12	1	0	1	0
			8.3	0	8.3	0
GROUP	17	28	0	7	0	1
			0	25.0	0	3.6
GROUP	18	24	1	2	0	3
			4.2	8.3	0	12.5
GROUP	19	4	1	0	0	1
			25.0	0	0	25.0
GROUP	20	12	0	5	0	0
			0	41.7	0	0

ACTUAL GROUP		NO. OF CASES	PREDICTED GROUP MEMBERSHIP 12	13	14	15
GROUP	1	16	3	0	0	4
			18.8	0	0	25.0
GROUP	2	76	2	0	1	2
			2.6	0	1.3	2.6
GROUP	3	8	0	0	0	0
			0	0	0	0
GROUP	4	4	0	0	0	0
			0	0	0	0
GROUP	6	16	0	0	0	0
			0	0	0	0
GROUP	9	12	1	0	0	0
			8.3	0	0	0
GROUP	10	36	0	0	1	0
			0	0	2.8	0
GROUP	11	48	2	1	0	3
			4.2	2.1	0	6.3
GROUP	12	28	0	3	0	0
			0	10.7	0	0

GROUP	13	24	10	4	1	0
			41.7	16.7	4.2	0
GROUP	14	52	1	0	4	4
			1.9	0	7.7	7.7

ACTUAL GROUP		NO. OF CASES	PREDICTED GROUP MEMBERSHIP 12	13	14	15
GROUP	15	44	0	0	0	6
			0	0	0	13.6
GROUP	16	12	0	0	0	3
			0	0	0	25.0
GROUP	17	28	0	8	0	0
			0	28.6	0	0
GROUP	18	24	0	0	1	1
			0	0	4.2	4.2
GROUP	19	4	0	0	0	0
			0	0	0	0
GROUP	20	12	1	0	0	2
			8.3	0	0	16.7

ACTUAL GROUP		NO. OF CASES	PREDICTED GROUP MEMBERSHIP 16	17	18	19
GROUP	1	16	0	0	0	0
			0	0	0	0
GROUP	2	76	0	0	0	0
			0	0	0	0
GROUP	3	8	0	0	0	0
			0	0	0	0
GROUP	4	4	0	0	0	0
			0	0	0	0
GROUP	6	16	0	0	0	0
			0	0	0	0
GROUP	9	12	0	0	0	0
			0	0	0	0
GROUP	10	36	1	0	1	2

			2.8	0	2.8	5.6
GROUP	11	48	1	0	0	0
			2.1	0	0	0
GROUP	12	28	0	0	0	0
			0	0	0	0
GROUP	13	24	0	0	1	0
			0	0	4.2	0
GROUP	14	52	0	0	3	0
			0	0	5.8	0
GROUP	15	44	2	0	0	0
			4.5	0	0	0
GROUP	16	12	0	0	0	0
			0	0	0	0
GROUP	17	28	0	8	2	1
			0	28.6	7.1	3.6
GROUP	18	24	0	0	4	0
			0	0	16.7	0
GROUP	19	4	0	0	0	2
			0	0	0	50.0
GROUP	20	12	1	0	0	0
			8.3	0	0	0

ACTUAL GROUP		NO. OF CASES	PREDICTED GROUP MEMBERSHIP 20
GROUP	1	16	0
			0
GROUP	2	76	0
			0
GROUP	3	8	0
			0
GROUP	4	4	0
			0

GROUP	6	16	0 0
GROUP	9	12	0 0
GROUP	10	36	0 0
GROUP	11	48	4 8.3
GROUP	12	28	5 17.9
GROUP	13	24	2 8.3
GROUP	14	52	0 0
GROUP	15	44	0 0
GROUP	16	12	0 0
GROUP	17	28	1 3.6
GROUP	18	24	0 0
GROUP	19	4	0 0
GROUP	20	12	2 16.7

PERCENT OF GROUPED CASES CORRECTLY CLASSIFIED - 17.57

Appendix G: Results of Regression A

SELECTING ONLY CASES FOR WHICH TYPE EQ 1.000

	MEAN	STD DEV	LABEL
ADMC	63861.357	118703.901	
RIC	2383.605	2618.694	
TPC	39894.352	107793.356	
BMLC	34676.874	24360.067	
BMMC	7904.845	8387.523	
TOTAL	148792.727	235355.850	

N OF CASES = 80

CORRELATION

	ADMC	RIC	TPC	BMLC	BMMC	TOTAL
ADMC	1.000	.282	.957	.306	.154	.983
RIC	.282	1.000	.230	.230	.197	.289
TPC	.957	.230	1.000	.288	.144	.978
BMLC	.306	.230	.288	1.000	.858	.422
BMMC	.154	.197	.144	.858	1.000	.270
TOTAL	.983	.289	.978	.422	.270	1.000

* *

VARIABLE(S) ENTERED ON STEP NUMBER
1.. ADMC

MULTIPLE R	.98282		
R SQUARE	.96593	R SQUARE CHANGE	.96593
ADJUSTED R SQUARE	.96550	F CHANGE	2211.64054
STANDARD ERROR	43717.45692	SIGNIF F CHANGE	0

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE
REGRESSION	1	4226922867778.03125	.42269E+13
RESIDUAL	78	149074851107.48437	1911216039.83954

F = 2211.64054 SIGNIF F = 0

CONDITION NUMBER BOUNDS$ 1.000, 1.000

VAR-COVAR MATRIX OF REGRESSION COEFFICIENTS (B)
BELOW DIAGONAL$ COVARIANCE ABOVE$ CORRELATION

	ADMC
ADMC	.00172

---------------------- VARIABLES IN THE EQUATION ----------------------

VARIABLE	B	SE B	95 CONFDNCE INTRVL B		BETA
ADMC	1.94865	.04144	1.86616	2.03114	.98282
(CONSTANT)	24349.35727	5558.08523	13284.05949	35414.65504	

---------------------- VARIABLES IN THE EQUATION ----------------------

VARIABLE	SE BETA	CORREL	PART COR	PARTIAL	TOLERANCE	F	SIG F
ADMC	.02090	.98282	.98282	.98282	1.00000	2211.641	.0000
(CONSTANT)						19.192	.0000

DURBIN-WATSON TEST = 1.99999

OUTLIERS - STANDARDIZED RESIDUAL
- SELECTED CASES

SEQNUM	SUBFILE	*ZRESID
7	NONAME	8.01853
5	NONAME	2.29525
167	NONAME	-.43658
4	NONAME	-.43417
2	NONAME	-.43414
3	NONAME	-.43413
1	NONAME	-.43397
9	NONAME	-.42915
168	NONAME	-.42841
10	NONAME	-.42793

```
HISTOGRAM                      - SELECTED CASES
STANDARDIZED RESIDUAL
 N EXP N     ( * = 1 CASES,     . % = NORMAL CURVE)
 1   .06   OUT *
 0   .12  3.00
 0   .31  2.66
 1   .71  2.33 %
 0  1.46  2.00 .
 0  2.67  1.66   .
 0  4.39  1.33    .
 0  6.45  1.00      .
 0  8.50  0.66        .
 6 10.02  0.33 ******   .
38 10.59  0.00 **********%***************************
34 10.02 -0.33 *********%************************
 0  8.50 -0.66        .
 0  6.45 -1.00      .
 0  4.39 -1.33    .
 0  2.67 -1.66   .
 0  1.46 -2.00 .
 0   .71 -2.33 .
 0   .31 -2.66
 0   .12 -3.00
 0   .06   OUT
```

```
NORMAL PROBABILITY (P-P) PLOT - SELECTED CASES
STANDARDIZED RESIDUAL
  1.00 +---------+---------+------*************
       I                          **         . I
       I                       ***         .   I
       I                      *          .     I
       I                     *         .       I
   .75 +                             .         +
       I                    *      .           I
 O     I                         .             I
 B     I                       .               I
 S     I                  *  .                 I
 E .50 +                   .                   +
 R     I                 .                     I
 V     I               .*                      I
 E     I             .                         I
 D     I           .                           I
   .25 +         .                             +
       I       .     ***                       I
       I     .                                 I
       I   .                                   I
       I .                                     I
       +*************-----+---------+---------+ EXPECTED
                .25       .5       .75      1.0
```

```
STANDARDIZED SCATTERPLOT        - SELECTED CASES
ACROSS - *PRED       DOWN - *RESID
OUT ++-----+-----+ . --+-----+-----+-----++
  3 +                                    +   SYMBOLS%
    I                                    I
    I              .                     I      MAX N
  2 +                                    +
    I                                    I   .     4.
    I                                    I   %     8.
  1 +                                    +   *    16.
    I                                    I
    I                ...    .         .
  0 +              .%**.  .  .     .     .
    I             .**.      .
    I                                    I
 -1 +                                    +
    I                                    I
    I                                    I
 -2 +                                    +
    I                                    I
    I                                    I
 -3 +                                    +
OUT ++-----+-----+-----+-----+-----+-----++
    -3    -2    -1     0     1     2     3 OUT
```

```
STANDARDIZED SCATTERPLOT        - SELECTED CASES
ACROSS - TOTAL       DOWN - *RESID
OUT ++-----+-----+- . -+-----+-----+-----++
  3 +                                    +   SYMBOLS%
    I                                    I
    I              .                     I      MAX N
  2 +                                    +
    I                                    I   .     4.
    I                                    I   %     8.
  1 +                                    +   *    16.
    I                                    I
    I                ...    .         .
  0 +              .%**.  .  .     .     .
    I             .**.      .
    I                                    I
 -1 +                                    +
    I                                    I
    I                                    I
 -2 +                                    +
    I                                    I
    I                                    I
 -3 +                                    +
OUT ++-----+-----+-----+-----+-----+-----++
    -_    -2    -1     0     1     2     3 OUT
```

Appendix H: Results of Regression B

SELECTING ONLY CASES FOR WHICH TYPE EQ 2.000

	MEAN	STD DEV	LABEL
ADMC	6164.243	12966.546	
RIC	1657.854	8324.817	
TPC	1525.944	3294.608	
BMLC	8028.563	8261.336	
BMMC	246422.748	3500611.921	
TOTAL	18698.030	24726.650	

N OF CASES = 204

CORRELATION

	ADMC	RIC	TPC	BMLC	BMMC	TOTAL
ADMC	1.000	.472	.465	.145	-.033	.810
RIC	.472	1.000	.412	.310	-.014	.752
TPC	.465	.412	1.000	.239	-.033	.606
BMLC	.145	.310	.239	1.000	-.068	.603
BMMC	-.033	-.014	-.033	-.068	1.000	-.053
TOTAL	.810	.752	.606	.603	-.053	1.000

* *

VARIABLE(S) ENTERED ON STEP NUMBER
1.. ADMC

MULTIPLE R	.80958		
R SQUARE	.65542	R SQUARE CHANGE	.65542
ADJUSTED R SQUARE	.65371	F CHANGE	384.21719
STANDARD ERROR	14550.70462	SIGNIF F CHANGE	0

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE
REGRESSION	1	81347617997.52979	.81348E+11
RESIDUAL	202	42768046988.03979	211723004.89129

F = 384.21719 SIGNIF F = 0

CONDITION NUMBER BOUNDS$ 1.000, 1.000

VAR-COVAR MATRIX OF REGRESSION COEFFICIENTS (B)
BELOW DIAGONAL$ COVARIANCE ABOVE$ CORRELATION

	ADMC
ADMC	.00620

---------------------- VARIABLES IN THE EQUATION ----------------------

VARIABLE	B	SE B	95 CONFDNCE	INTRVL B	BETA
ADMC	1.54383	.07876	1.38853	1.69913	.80958
(CONSTANT)	9181.47308	1128.52582	6956.27138	11406.67478	

---------------------- VARIABLES IN THE EQUATION ----------------------

VARIABLE	SE BETA	CORREL	PART COR	PARTIAL	TOLERANCE	F	SIG F
ADMC	.04130	.80958	.80958	.80958	1.00000	384.217	.0000
(CONSTANT)						66.191	.0000

DURBIN-WATSON TEST = 1.17522

OUTLIERS - STANDARDIZED RESIDUAL
- SELECTED CASES

SEQNUM	SUBFILE	*ZRESID
51	NONAME	6.03477
50	NONAME	4.14566
302	NONAME	3.83660
52	NONAME	3.64687
318	NONAME	-3.48239
319	NONAME	-2.95963
49	NONAME	2.84583
418	NONAME	2.70923
317	NONAME	-2.45724
188	NONAME	-2.10918

```
HISTOGRAM                   - SELECTED CASES
STANDARDIZED RESIDUAL
 N EXP N      ( * = 2 CASES,    . % = NORMAL CURVE)
 4    .16   OUT **
 1    .31  3.00 *
 1    .80  2.66 *
 0   1.82  2.33 .
 0   3.72  2.00  .
 1   6.82  1.66 * .
 0  11.19  1.33      .
14  16.45  1.00 *******.
 7  21.67  0.66 ****       .
27  25.56  0.33 *************%*
89  27.00  0.00 *************%*******************************
26  25.56 -0.33 *************%
 8  21.67 -0.66 ****       .
 8  16.45 -1.00 ****    .
 6  11.19 -1.33 ***   .
 6   6.82 -1.66 **%
 3   3.72 -2.00 *%
 1   1.82 -2.33 %
 0    .80 -2.66
 1    .31 -3.00 *
 1    .16   OUT *
```

```
NORMAL PROBABILITY (P-P) PLOT - SELECTED CASES
STANDARDIZED RESIDUAL
   1.00 +---------+---------+---------+---------*
        |                                 ******|
        |                             ****  .   |
        |                        *****    .     |
        |                      **       .       |
    .75 +                             .         +
        |                           .           |
 O      |                     *   .             |
 B      |                       .               |
 S      |                    *.                 |
 E  .50 +                    .                  +
 R      |                  .*                   |
 V      |                 . *                   |
 E      |               .  *                    |
 D      |             .                         |
    .25 +           .    **                     +
        |         .  **                         |
        |        .******                        |
        |     .***                              |
        |****                                   |
        +------  --+---------+---------+---------+ EXPECTED
                 .25        .5        .75       1.0
```

```
STANDARDIZED SCATTERPLOT         - SELECTED CASES
ACROSS - *PRED       DOWN - *RESID
OUT ++-----+-----+-----+- .. + . --+-----++
  3 +                .                     SYMBOLS%
    I                                .
    I                                         MAX N
  2 +                                +
    I               .                I    .    13.
    I                                I    %    26.
  1 +             . .......     .         *    52.
    I             . ..  .. .         .
    I           .. ....    .  .
  0 +          .*..... .  .  .
    I           ... .  ...    .      .
    I             ....
 -1 +              . ..  . .
    I                ..              .
    I                ..  .
 -2 +                 .              +
    I                             .  I
    I                                I
 -3 +                        .       +
OUT ++-----+-----+-----+-----+--- . -----++
   -3    -2    -1     0     1     2     3 OUT
```

```
STANDARDIZED SCATTERPLOT         - SELECTED CASES
ACROSS - TOTAL       DOWN - *RESID
OUT ++-----+-----+-----+-- ... - . +-----++
  3 +                .                     SYMBOLS%
    I                                .
    I                                         MAX N
  2 +                                +
    I               .                I    .    12.
    I                                I    %    24.
  1 +             ...... ..     .         *    51.
    I             .. . .. .          .
    I           .. ....    .  .
  0 +          .*..... .  .  .
    I           ... . ....    .      .
    I             . ..
 -1 +             . . . .  .
    I               . ..             .
    I               ...  .
 -2 +               .                +
    I                             .  I
    I                                I
 -3 +                        .       +
OUT ++-----+-----+-----+-----+-- . +-----++
     -3    -2    -1     0     1     2     3 OUT
```

Appendix I: Results of Regression C

SELECTING ONLY CASES FOR WHICH TYPE EQ 3.000

	MEAN	STD DEV	LABEL
ADMC	11267.491	24248.220	
RIC	106.243	375.955	
TPC	3055.384	6468.692	
BMLC	8561.855	12667.144	
BMMC	949.070	1624.675	
TOTAL	23585.562	39482.251	

N OF CASES = 104

CORRELATION

	ADMC	RIC	TPC	BMLC	BMMC	TOTAL
ADMC	1.000	.535	.680	.662	.786	.963
RIC	.535	1.000	.401	.640	.491	.632
TPC	.680	.401	1.000	.400	.420	.723
BMLC	.662	.640	.400	1.000	.732	.807
BMMC	.786	.491	.420	.732	1.000	.814
TOTAL	.963	.632	.723	.807	.814	1.000

* *

VARIABLE(S) ENTERED ON STEP NUMBER

1.. ADMC

MULTIPLE R	.96306		
R SQUARE	.92748	R SQUARE CHANGE	.92748
ADJUSTED R SQUARE	.92677	F CHANGE	1304.56879
STANDARD ERROR	10684.15131	SIGNIF F CHANGE	0

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE
REGRESSION	1	148917948704.49902	.14892E+12
RESIDUAL	102	11643411090.34869	114151089.12107

F = 1304.56879 SIGNIF F = 0

CONDITION NUMBER BOUNDS$ 1.000, 1.000

VAR-COVAR MATRIX OF REGRESSION COEFFICIENTS (B)
BELOW DIAGONAL$ COVARIANCE ABOVE$ CORRELATION

	ADMC
ADMC	.00188

---------------------- VARIABLES IN THE EQUATION ----------------------

VARIABLE	B	SE B	95 CONFDNCE INTRVL B		BETA
ADMC	1.56810	.04342	1.48199	1.65422	.96306
(CONSTANT)	5916.95722	1156.24555	3623.54964	8210.36480	

---------------------- VARIABLES IN THE EQUATION ----------------------

VARIABLE	SE BETA	CORREL	PART COR	PARTIAL	TOLERANCE	F	SIG F
ADMC	.02666	.96306	.96306	.96306	1.00000	1304.569	.0000
(CONSTANT)						26.188	.0000

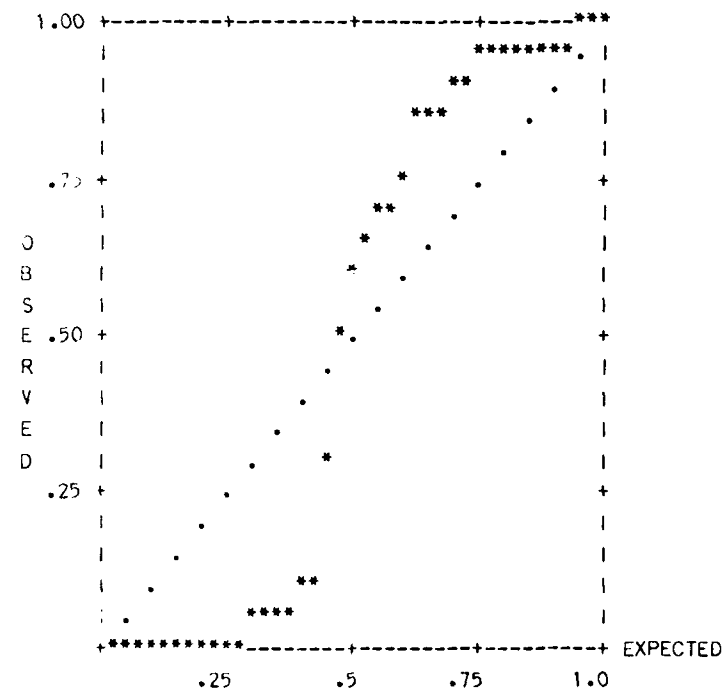
DURBIN-WATSON TEST = 1.45486

OUTLIERS - STANDARDIZED RESIDUAL
- SELECTED CASES

SEQNUM	SUBFILE	*ZRESID
239	NONAME	-9.01068
242	NONAME	1.89129
241	NONAME	1.55438
140	NONAME	1.52102
146	NONAME	1.32851
275	NONAME	.90528
237	NONAME	.82640
273	NONAME	.75402
240	NONAME	.66204
147	NONAME	.62248

```
HISTOGRAM                    - SELECTED CASES
STANDARDIZED RESIDUAL
 N EXP N      ( * = 1 CASES,     . % = NORMAL CURVE)
 0    .08   OUT
 0    .16  3.00
 0    .41  2.66
 0    .93  2.33 .
 1   1.90  2.00 *.
 2   3.48  1.66 **.
 1   5.71  1.33 *     .
 1   8.39  1.00 *       .
 9  11.05  0.66 ********* .
16  13.03  0.33 *************%***
62  13.77  0.00 *************%************************************************
 9  13.03 -0.33 *********   .
 2  11.05 -0.66 **        .
 0   8.39 -1.00         .
 0   5.71 -1.33       .
 0   3.48 -1.66    .
 0   1.90 -2.00   .
 0    .93 -2.33 .
 0    .41 -2.66
 0    .16 -3.00
 1    .08   OUT *
```

NORMAL PROBABILITY (P-P) PLOT - SELECTED CASES
STANDARDIZED RESIDUAL



```
STANDARDIZED SCATTERPLOT          - SELECTED CASES
ACROSS - *PRED        DOWN - *RESID
OUT ++-----+-----+-----+-----+-----+-----++
  3 +                                      +   SYMBOLS%
    |                                      |
    |                                              MAX N
  2 +                                      .
    |              .            .          .     .   12.
    |             .                        |     %   24.
  1 +            .                         +     *   51.
    |            ...  ...    .   .   .
    |           . .. ..  .                 .
  0 +           *... ... .                 .
    |           ..   ..
    |                      .               .
 -1 +
    |                                      |
    |                                      |
 -2 +                                      +
    |                                      |
    |                                      |
 -3 +                                      +
OUT ++-----+-----+-----+-----+-- . +-----++
   -3    -2    -1     0     1     2     3 OUT
```

```
STANDARDIZED SCATTERPLOT          - SELECTED CASES
ACROSS - TOTAL        DOWN - *RESID
OUT ++-----+-----+-----+-----+-----+-----++
  3 +                                      +   SYMBOLS%
    |                                      |
    |                                              MAX N
  2 +                                      .
    |               .           .                .   12.
    |              .                       |     %   24.
  1 +            .                         +     *   51.
    |            .. . ...    .   .   .
    |           . ..  .  .                 .
  0 +           *... ....                  .
    |           ..   ..
    |                      .               .
 -1 +
    |                                      |
    |                                      |
 -2 +                                      +
    |                                      |
    |                                      |
 -3 +                                      +
OUT ++-----+-----+-----+--- . -----+-----++
   -3    -2    -1     0     1     2     3 OUT
```

Appendix J: Results of Regression D

SELECTING ONLY CASES FOR WHICH TYPE EQ 4.000

	MEAN	STD DEV	LABEL
ADMC	21793.270	35855.640	
RIC	1102.133	2592.872	
TPC	7645.150	11743.079	
BMLC	35952.398	65957.163	
BMMC	6030.962	21713.561	
TOTAL	72524.439	117068.869	

N OF CASES = 56

CORRELATION

	ADMC	RIC	TPC	BMLC	BMMC	TOTAL
ADMC	1.000	.595	.897	.507	.409	.771
RIC	.595	1.000	.756	.359	.069	.495
TPC	.897	.756	1.000	.556	.318	.764
BMLC	.507	.359	.556	1.000	.821	.935
BMMC	.409	.069	.318	.821	1.000	.807
TOTAL	.771	.495	.764	.935	.807	1.000

* *

VARIABLE(S) ENTERED ON STEP NUMBER
1.. BMLC

MULTIPLE R	.93466		
R SQUARE	.87359	R SQUARE CHANGE	.87359
ADJUSTED R SQUARE	.87125	F CHANGE	373.17698
STANDARD ERROR	42006.72737	SIGNIF F CHANGE	0

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE
REGRESSION	1	658495089066.59766	.65850E+12
RESIDUAL	54	95286517782.82373	1764565144.12636

F = 373.17698 SIGNIF F = 0

CONDITION NUMBER BOUNDS% 1.000, 1.000

VAR-COVAR MATRIX OF REGRESSION COEFFICIENTS (B)
BELOW DIAGONAL% COVARIANCE ABOVE% CORRELATION

	BMLC
BMLC	.00737

---------------------- VARIABLES IN THE EQUATION ----------------------

VARIABLE	B	SE B	95 CONFDNCE INTRVL B		BETA
BMLC	1.65895	.08588	1.48678	1.83112	.93466
(CONSTANT)	12881.25504	6406.44921	37.09762	25725.41247	

------------------------ VARIABLES IN THE EQUATION ------------------------

VARIABLE	SE BETA	CORREL	PART COR	PARTIAL	TOLERANCE	F	SIG F
BMLC	.04838	.93466	.93466	.93466	1.00000	373.177	.0000
(CONSTANT)						4.043	.0494

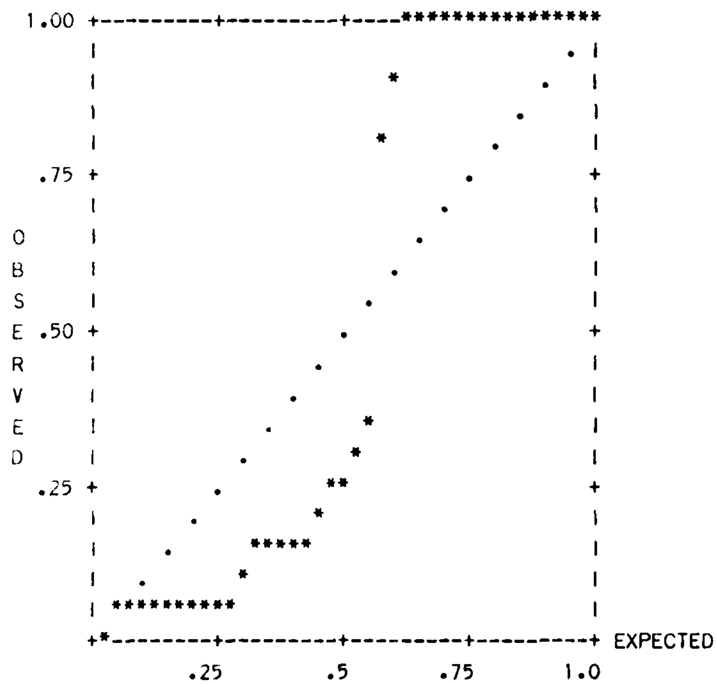
DURBIN-WATSON TEST = 2.00000

OUTLIERS - STANDARDIZED RESIDUAL
- SELECTED CASES

SEQNUM	SUBFILE	*ZRESID
225	NONAME	4.92056
224	NONAME	-4.05967
443	NONAME	-1.69270
439	NONAME	-1.64185
444	NONAME	-1.23799
223	NONAME	-.59391
358	NONAME	-.51697
209	NONAME	-.49703
228	NONAME	-.35837
226	NONAME	.27495

```
HISTOGRAM                    - SELECTED CASES
 STANDARDIZED RESIDUAL
  N EXP N       ( * = 1 CASES,     . % = NORMAL CURVE)
  1   .04   OUT *
  0   .09  3.00
  0   .22  2.66
  0   .50  2.33
  0  1.02  2.00 .
  0  1.87  1.66  .
  0  3.07  1.33   .
  0  4.52  1.00     .
  0  5.95  0.66      .
 14  7.02  0.33 ******%*******
 32  7.41  0.00 ******%*************************
  3  7.02 -0.33 ***    .
  2  5.95 -0.66 **    .
  0  4.52 -1.00      .
  1  3.07 -1.33 * .
  2  1.87 -1.66 *%
  0  1.02 -2.00 .
  0   .50 -2.33
  0   .22 -2.66
  0   .09 -3.00
  1   .04   OUT *
```

NORMAL PROBABILITY (P-P) PLOT - SELECTED CASES
STANDARDIZED RESIDUAL



```
STANDARDIZED SCATTERPLOT          - SELECTED CASES
ACROSS - *PRED        DOWN - *RESID
OUT ++-----+-----+-----+-----+---- . ----++
  3 +                                     +   SYMBOLS%
    |                                     |
    |                                     |     MAX N
  2 +                                     +
    |                                     |   .     4.
    |                                     |   %     8.
  1 +                                     +   *    17.
    |
    |               ...  ... .            .
  0 +              %*...   .              .
    |                 .     .
    |                .        .           |
 -1 +                                     +
    |                       .             |
    |                    .  .             |
 -2 +                                     +
    |                                     |
    |                                     |
 -3 +                                     +
OUT ++-----+-----+-----+-----+ . --+-----++
    -3    -2    -1     0     1     2     3 OUT
```

```
STANDARDIZED SCATTERPLOT          - SELECTED CASES
ACROSS - TOTAL        DOWN - *RESID
OUT ++-----+-----+-----+-----+---- . ----++
  3 +                                     +   SYMBOLS%
    |                                     |
    |                                     |     MAX N
  2 +                                     +
    |                                     |   .     4.
    |                                     |   %     8.
  1 +                                     +   *    17.
    |
    |               ...  ... .            .
  0 +              %*...   .              .
    |                 .     .
    |                .        .           |
 -1 +                                     +
    |                       .             |
    |                    .  .             |
 -2 +                                     +
    |                                     |
    |                                     |
 -3 +                                     +
OUT ++-----+-----+-----+-----+ . --+-----++
    -3    -2    -1     0     1     2     3 OUT
```

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Abstract

This thesis researched the problems with life cycle costing of command, control, communications, and intelligence systems (C^3I). As operating and support costs skyrocket it is imperative that the military design systems for reliability and maintainability to slow escalating costs. However, the cost drivers are unknown and no life cycle cost model exists specifically for C^3I systems. This thesis used actual cost data categorized by type of equipment (radar, radio, wire, special/combination) and by usage mode (ground, portable, transportable, fixed, and mobile). A discriminant analysis showed that the four groups in the type category were significantly differnet based on cost data, and, likewise, that the five mode groups differed significantly. Next a regression was performed, and the resultant correlation table indicated which variable was the cost driver for each group. The simple regression yielded the regression coefficients and y-intercept for the regression equations. These equations are the cost estimating relationships for C^3I systems, based on the cost drivers identified by this thesis.

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