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An analysis of the cost-volume relationships within the aircraft program of the Naval Air Rework Facility, Alameda, California

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THESIS

AN ANALYSIS OF THE COST-VOLUME
RELATIONSHIPS WITHIN THE AIRCRAFT PROGRAM
OF THE NAVAL AIR REWORK FACILITY,
ALAMEDA, CALIFORNIA

by

Robert Lemoine Ferriman

June 1986

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The results of this study indicate that significant cost-volume relationships exist not only with direct costs but also with many associated indirect aircraft program costs. The study further suggests that other factors, such as rate and direction of volume changes and levels of personnel strengths, may have predictable affects on aircraft rework costs.

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An Analysis of the Cost-Volume Relationships
Within the Aircraft Program of the
Naval Air Rework Facility, Alameda, California

by

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Commander, United States Navy
B.S., University of Kansas, 1969

Submitted in partial fulfillment of the
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

8

LIST OF ABBREVIATIONS

ACFT   Aircraft

D-level   Depot level

FCC   Functional Cost Catagory

FRSM   Fleet Readiness Support Meeting

G&A   General and Administrative

I-Level   Intermediate level

NALC   Naval Aviation Logistics Center

NARF   Naval Air Rework Facility

NAVAIR   Naval Air Systems Command

NESO   NAVAIR Engineering Support Office

NIF   Naval Industrial Fund

O-level   Organizational level

PRDN   Production

QTR   Quarter

SDLM   Standard Depot Level Maintenance

TAT   Turnaround Time

TMS   Type/Model/Series

WKDY   Workday

WSM   Weapon Systems Manager

I. INTRODUCTION

A. THESIS OBJECTIVE

The purpose of this research project is to explore the
effects of aircraft workload variations on costs incurred in
the aircraft rework program of the Naval Air Rework Facility
(NARF), Alameda, California. Through the examination and
analysis of quarterly historical data, specific cost-volume
relationships are formulated for the direct and indirect
costs in each of the four aircraft program segments (A-6,
P-3, S-3, A-3). These relationships are then assembled into
average cost-volume models useable as decision support aids
in selecting cost-efficient workloads and estimating aircraft
rework prices.

B. HISTORY OF THE PROBLEM

1. Unique Constraints

NARF Alameda is a very large and complex industrial
activity saddled with some highly unique, government
controlled constraints. First, as in all government
operations, it is a not-for-profit organization expected to
execute its budget to within 1% of that appropriated.
Secondly, it is driven by the monumental objective of
"service to the fleet" which means it is obligated to adapt

11

to all sorts of unexpected changes, respond to operational
necessities and emergencies, and work around the resultant
productivity inefficiencies and irreversible financial
losses. Thirdly, NARF Alameda has much less flexibility than
similar corporate industrial activities due in part to an
extremely procedure-laden civilian personnel structure,
budget restricted personnel ceilings, periodic congressional
hiring freezes, non-competitive wages for skilled labor, and
a serious labor/supervisor wage inversion problem. These
handicaps severely restrict management control of short term
production driven labor adjustments, work force stability and
productivity, and depth of supervisory experience. And
fourthly, NARF Alameda's cost structure is close to 50%
indirect (overhead), most of which is very inflexible due to
many of the aforementioned constraints.

   2. Fixed Price Constaint

       As if NARF management didn't have enough restrictions
limiting their control, the Naval Air Systems Command, who
has the overall resource allocation responsibilty for
aircraft rework, established the fixed price concept and rate
stabilization system in 1975 in an attempt to improve
uniformity of rework costs for fleet and other customers and
simplify the budget estimation process [Ref. 1:pp. 2,10,13].
The rate stabilization system leads to problems because NARF
must initiate the complicated budgeting process 18 months
prior to the budgeted fiscal year. Estimating a realistic

fixed price per type aircraft, missile or engine etc., that far in the future is difficult. Some adjustments for inflation and local labor rates are made during the budgeting process, but regardless of how the original production schedule may change to meet the actual needs of the fleet NARF is totally committed to the established fixed prices.

Workload schedules are produced using projected direct labors hours available and established labor hour norms per aircraft. Since the actual workload is constantly being changed (due to overriding considerations of constantly changing operational requirements), it's highly possible that actual per aircraft costs may vary drastically. However, this is not considered and the NARF receives the fixed price regardless. When actual production is less than scheduled, losses are explainable. When actual production is greater than scheduled, the mind-set is per aircraft costs should be less and therefore the budget variances should be positive.

Out of 103 A-6's completed over the past four years, only 22 have either broken even or been under their established fixed price. Of these 22, 18 were salvaged from red ink by severe underusages of estimated materials. This is not an attempt to imply that workload fluctuations and fixed prices are the only reasons for cost overruns in the aircraft program, but it is certainly a distinct possibility that they are major contributors.

The fixed price constraint is one of the reasons the NARF Alameda Deputy Comptroller requested this study. If the ideal situation existed where management had full control and was not subject to the personnel and other constraints, then it is conceivable that each aircraft could be processed for the agreed fixed price. Also, if NARF aircraft inductions were scheduled at a relatively constant level, then again an actual break-even (zero profit or loss) situation is conceivable. Unfortunately, the nature of the personnel and workload scheduling problems will probably never change.

3. Management Needs

The NARF Alameda Deputy Comptroller is interested in the cost-volume relationships for the various types of aircraft and how fluctuations in workloads contribute to NARF'S ills. He feels that the cost behaviors differ extensively between aircraft types and the cost of reworking any particular aircraft may be dependent on the number and mix of aircraft in production. Having knowledge of the effects of production volume on the rework costs of a particular aircraft type would be an invaluable tool in deciding the workload level, estimating per aircraft costs, and renegotiating aircraft prices under unavoidable workload changes. [Ref. 2]

C. RESEARCH QUESTIONS

1. <u>Primary</u>

Through the analysis of historical data, can a reasonably reliable relationship between aircraft workload and related costs be ascertained for the aircraft program as a whole and for each of its four segments? To answer this question, a representative measure of volume must be derived and all aircraft rework related costs identified, separated as to type of aircraft, and examined for volume related behavior.

2. <u>Subsidiary</u>

If the primary research question can be answered and relationships determined, the following subsidiary objectives will be accomplished:

  (1) Develop cost-volume models for the aircraft program and its four segments

  (2) Explore the effects of volume increases and decreases on program and segment costs.

  (3) Use break-even analysis to compare revenues and costs and to evaluate relative profitability of the four aircraft program segments.

D. SCOPE, LIMITATIONS, AND ASSUMPTIONS

1. <u>Scope</u>

The emphasis of this thesis is on matching actual quarterly costs and representative quarterly production activity measures for each of the four basic aircraft types for the period FY82-FY85 and analyzing their historical

cost-volume relationships. Although there are several models within each aircraft type, and some have very different rework requirements, all aircraft within each type are considered equivalent for the purposes of this project. A fifth aircraft type, the C-118, of which about seven were reworked in FY82, is not analyzed but is included in overall aircraft program figures.

To properly develop a predictive cost-volume model, the influence of other environmental factors on cost-volume behavior must be included. Some of these factors are discussed when evaluating the cost-volume results in Chapter IV, but due to limited data, development of specific relationships is not within the scope of this project.

2. Limitations

Availability of a sufficient number of years of all types of required data limited the study to 16 quarterly periods, well below the statistically desirably 30 data periods. This did not prevent reasonable analysis, but did restrict the level of outcome reliability and the possibility of discovering significant underlying relationships.

Indirect costs are a sizeable portion of aircraft rework costs, yet most are allocated and few are traceable to the aircraft program. No indirect costs are traceable to an aircraft type. Without the ability to identify any indirect costs by type aircraft, the possibility of observing any differential effects between aircraft types is lost.

3. Assumptions

Within the time frame of the historical data being
used, some changes have occurred at NARF Alameda. These
include minor accounting policies, redefinition of some
overhead functional cost catagories, and reorganization of
some cost centers. These changes are assumed not to affect
the results of this project.

Numerous descrepencies were discovered in direct and
indirect cost data during data collection. Ones that were
significant in nature and could not be reconciled are assumed
to be inaccurate and are removed from analysis where
appropriate. The remainder of the data is assumed to be
error free and to have been recorded using consistent
methods. It also is assumed that all costs that occurred
within a quarter were recorded in that quarter. This last
assumption may be unrealistic, but hopefully the lag in
recording costs was consistent enough over time to cancel out
any adverse effects.

E. METHODOLOGY

The princpal method of analysis used is simple linear
regression. Using matched costs and production activity
measures, regression is applied to direct labor, material and
other services costs, and indirect costs determined to
possibly exhibit variable relations with volume. Regression
of these costs are attempted with several different activity

measures in order to discover the ones most related to costs. Using cost-volume theory, specific cost-volume relationships are developed for the aircraft program and each of its four segments.

Cost and volume data were collected through the assistance of the Comptroller Division of the Management Controls Department. Hard copy Production Performance Reports, individual Job Order Summaries, Physical Completion Reports, and Cost Center Summaries were used to assemble direct costs by aircraft type, job order costs by job number, aircraft days in process, and cost center data respectively. The ICMS Dbase files[1] were used to extract and analyze pertinent indirect costs by Functonal Cost Catagory (FCC).

Interviews were conducted with NARF department heads and some division managers to acheive a better understanding of cost and workload considerations.

Literature searches were conducted through Dudley Knox library. Text books and periodical and journal articles on cost estimation techniques, indirect cost theory, cost-volume analysis and break-even analysis were consulted.

F. SUMMARY OF FINDINGS

Although the reliability of results is somewhat in question, reasonable cost-volume models are attainable and

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[1]The Indirect Cost Management System was developed for NARF Alameda by General Management Systems of Lexington Park, Md.

show some interesting differences among aircraft types. The measurements of production activity found to be the most related to segment costs and most identifiable with a meaningful measure of aircraft workload were aircraft workdays per quarter and an equivlent measure of aircraft completions per quarter. Direct labor demonstrated the most accurate variable relationship, as expected, but direct material and other direct services exhibited unexpectedly poor variable relationships. Other direct services data were so inconsistent that they were considered to be fixed costs for development of the cost-volume models. Several indirect costs were found to have partial variable relationships with volume. Finally, some inferences were made as to the effects of direction, rate and duration of quarterly volume changes as they relate to cost behavior.

G. ORGANIZATION OF STUDY

The remaining chapters lead the reader through the data analysis and model formulation accomplished by the author. First, background information on the Naval Air Rework Facility System is provided in Chapter II and a brief discussion of cost behavior, cost-volume and break-even theoretical concepts are covered in Chapter III. Next, Chapter IV describes the possible volume measurements and the type and distributions of costs associated with the aircraft program. Chapter V leads the reader step by step through the

regression analysis of the cost-volume relationships of both direct and indirect costs for all four aircraft types, and presents the resultant cost-volume models. Also included in Chapter IV is a discussion of the application of the relationships and an evaluation of the effects of other factors on cost behavior. Chapter VI compares costs with revenues through break-even analysis and demonstrates the usefulness of this technique in aiding managerial workload decisions. And lastly, Chapter VII presents some general conclusions and some specific recommendations to NARF Alameda for improvement of future analyses and their use.

II. NAVAL AIR REWORK FACILITY SYSTEM

A. THE NARF MISSION

The primary mission of NARF Alameda is to provide "service to the fleet" in the form of depot level maintenance on designated operational assets in a timely manner and at minimum cost. Depot level (D-level) maintenance is the most far-ranging of the three maintenance levels in the Department of the Navy (DON). D-level maintenance is designed to perform the more complicated and extensive repair and rework functions not within the scope of intermediate level (I-level) or organizational level (O-level) maintenance operations.

O-level and I-level organizations perform preventive and minor component replacement and repair maintenance on operational fleet equipment. NARF provides in field assistance to I-level and O-level organizations when unusual repair or damage circumstances occur. Otherwise, NARF's superior in-house facilities and technical capabilities are utilized to provide a wide range of rework and overhaul maintenance; as well as complete rebuilding and manufacturing of parts and assemblies, performing major equipment modifications, and incorporating required technical directives.

B.   D-LEVEL PROGRAMS

NARF Alameda's industrial operations are separated into five major programs; aircraft, engines, missiles, components, and other support activities.   Each of these programs comprises a varied workload mix.   The Aircraft program involves four basic types of aircraft (with several different models and series of each type): the P-3 Orion, a large four engine turbo-prop, shorebased, anti-submarine aircraft; the A-6 Intruder, a carrier based, twin jet engine, all weather attack bomber; the S-3 Viking, a carrier based, twin wing mounted turbo-fan jet, anti-submarine aircraft; and the A-3 Skywarrior, a large carrier capable, twin wing mounted jet, electronic surveilence and reserve training aircraft.   The Engine program consists of the T-56, J-52(P-8), TF-34, and 501K-17 engines as well as numerous auxilary power units. The Missile program overhauls the Sparrow, Shrike and Phoenix missile guidance and control sections.   The Component program handles hundreds of various aeronautical component systems and subassemblies (eg. landing gear, flaps, radios, radars, and engine accessories).   The Other Support program includes such activities as field repair and modification, shipboard repair of catapult systems and other equipment, fleet test equipment calibration, fleet training and technical assistance, and parts manufacturing.

C. MANAGEMENT OF DEPOT LEVEL INDUSTRIAL RESOURCES

NARF Alameda is classified as an industrial activity of the Naval Shore Establishment. All NARFs are officially designated as Naval Aviation Industrial Establishments and, along with the commercial activities contracted to do depot level maintenance, comprise the naval aviation D-level Industrial Program. [Ref. 3:p. 2-4]

NARF Alameda is directly responsible to and under the support of Commander, Naval Aviation Logistics Center (NALC), Patuxent River, Md. NALC provides and controls the NARF's operating funds, personnel ceilings, industrial equipment and tooling, material support, and management assistance. NALC is accountable to Naval Air Systems Command (NAVAIR) for the coordination, management and execution of all naval aviation D-level Industrial Programs. NAVAIR is responsible to the Chief of Naval Operations (OPNAV) for the overall planning and development of naval aviation resources to meet material support requirements for the active and reserve forces of the Navy and Marine Corps. [Ref. 3:pp. 2-5 - 2-6]

D. NARF DEPARTMENTAL ORGANIZATION

The organizational structure of NARF Alameda resembles that of a matrix organization. Top management positions are military billets that create a military chain of responsibility between the civilian department heads and the Commanding Officer in the overall execution of the various

department functions. There are seven departments in all, two under the Management Resources Director, two under Quality and Reliability Officer, and three under Production Officer.

1. Management Resources

The 2000 Management Controls Department, the head of which is also the Deputy Comptroller, is responsible for maintaining the financial management program and the management information system, and administering the Navy Industrial Fund (NIF) budgeting and accounting system. [Ref. 4:p. 3-1]

The 7000 Material Management Department is responsible for overall facility material planning and support and acts as the material policy advisor and inventory control authority [Ref. 4:p. 18-1]. This department was established beginning the 3rd quarter FY83 in an attempt to improve overall material support.

2. Quality and Reliability

The 8000 Flight Check Department is comprised of all military personnel and is charged with the administration of the military personnel programs. Operational responsibilities involve the coordination of flight check operations for all reworked aircraft. [Ref. 4:p. 18-1]

The 4000 Quality and Reliability Assurance Department is responsible for providing product quality and reliability recommendations to NESO (NAVAIR Engineering Support Office,

NARF Division 9100), discovering poor workmanship, and
ensuring the end product meets or exceeds NARF standards of
quality. Many of the divisions in this department work
closely with production divisions in verifying quality of
work and investigating Aircraft Descrepency Reports (ADRs)
and Quality Deficiency Reports (QDRs). [Ref. 4:p. 3-2]

   3.   Production

       The 5000 Production Planning and Control Department
is responsible for three basic functions: examination and
evaluation (E & E) of the material condition of installed
systems; production control of in-process products; and
workload planning and estimating. This department is one of
the most important staff functions of NARF and coordinates
meticulously with the Production Department. [Ref. 4:pp. 3-3]
For instance, the 5500 Aircraft Planning and Control Division
has branch managers and supervisors dedicated to specific
types of aircraft (A-6, P-3, etc.) who monitor the sequences
of operations, regulate and obtain needed materials, control
work in process for aircraft parts, and maintain a work
control center for each type aircraft [Ref. 5].

       The 6000 Production Engineering Department is
responsible for four basic functions; operations analysis,
methods and standards, facilities and equipment engineering,
and plant services. This department works closely with NESO
and Production Planning with respect to establishing rework
standards and workload production schedules based on their

analysis of rework task procedures and estimated labor times. It is responsible for plant layout, coordination of plant improvements, and preventive and corrective maintenance of production equipment. [Ref. 4:pp. 3-4 - 3-5]

The 9000 Production Department is responsible for the direct accomplishment of the NARF workload. All other departments within NARF exist only to assist the Production Department in producing a quality product in reasonable time and at minimum cost. The Production Department is split into six divisions; 9100 NESO, 9200 Weapon Systems Manager (WSM), 9300 Metal and Process, 9400 Avionics, 9500 Airframes, and 9600 Power Plants. [Ref. 4:p. 3-5]

Approximately 85% of all NARF direct labor is accomplished by 9300, 9400, 9500 and 9600 divisions which employs 45% of NARF's employees. The 9500 Airframes Division is the major aircraft program contributor with 74% of this programs direct labor hours.

E. FINANCIAL MANAGEMENT

1. Fiscal Planning

Fiscal planning for NARF Alameda is a very critcal and continuous process that centers around the development and execution of three budgets: the NIF A-11 Budget, which consists of the annual operational costs for the entire naval aviation D-level Industrial Program; the annual NIF Funding Budget, which further defines all NARF workloads and

operating funds and is negotiated and updated at the quarterly Fleet Readiness Support Meetings (FRSMs); and the quarterly NARF Operating Budget which is used to measure each NARF's performance.

The Naval Industrial Fund (NIF) is used to finance all NARF operating and inventory costs except government furnished material (GFM) and other statistical costs. The NIF is a revolving fund designed to be self-sustaining and, through reinbursements by customer's appropriated funds, approach a break-even situation by the end of the fiscal year. [Ref. 3:pp. 4-1 - 4-2]

2. Budgeting Cycle

The naval aviation D-level Industrial Program budgeting cycle begins 18 months (April X1) prior to the beginning of the budgeted fiscal year (FYX3 beginning October X2). NALC and all six NARFs meet with NAVAIR to estimate FYX3 workloads, basic costs and other requirements necessary to outline the initial framework for the FYX3 A-11 Budget. Using these projections, the NARFs spend the next couple months formulating their inputs to be submitted to NALC in June X1. NALC then assembles the entire Industrial Program A-11 Budget and submits it up the chain of command to eventually become part of the President's budget proposal to Congress. [Ref. 6]

The next step occurs at the 2nd quarter FYX2 FRSM in February X2. NALC and NARF management negotiate factors

concerning aircraft, missile and engine schedules, unit
norms, personnel ceilings, direct/indirect ratios, overtime
percentages, hourly labor rates and material unit costs [Ref.
7].   These are balanced with the NARF's projected expenses
and workload capacity estimates and funds expected to be
available through the A-11 Budget.   The results of these
negotiations become the initial set of funding rates for the
FYX3 NIF Funding Budget.   Also during this FRSM, and every
other quarterly FRSM, renegotiation on workload for the next
and remaining quarters of the current fiscal year is
accomplished and becomes the basis for developing each NARF's
next quarter Operating Budget. [Ref. 6]

During the May X2 FRSM all rates, norms, ratios and
ceilings are finalized and become stabilized from that point
on.   Now NALC can determine the fixed prices for particular
aircraft and engines etc. and publish these to its customers.
Using these norms and stabilized rates, the NARFs develop
their FYX3 annual NIF Funding and 1st quarter FYX3 Operating
Budgets. At the August X2 FRSM, final negotiation on workload
takes place to coincide with the funding and other guidelines
in the Defense Authorization Bill (which should have been
passed by this time).

At this point NARF Alameda management coordinates the
internal distribution of the NIF Funding Budget and finalizes
their 1st quarter Operating Budget.   Generally the Operating
Budget is completed and submitted to NALC prior to the

beginning of FYX3. The Operating Budget is used by NALC to evaluate NARF's performance; therefore, the execution of the Operating Budget is crucial to the NARF's overall viewed success.

The NARF financial managers cannot overemphasize the importance of the quarterly FRSM negotiations that ultimately result in the Operating budget. There are numerous variables that the NARF must thoroughly research prior to each FRSM and be prepared to defend in order to attain a workload schedule and fiscal budget that are realistic and executable. The more directions from which these variables can be examined and defended, such as cost-volume analysis, the greater possibility of success.

F. THE AIRCRAFT PROGRAM

1. Types of D-level Maintenance

Fleet, reserve and RDT&E aircraft are scheduled for D-level maintenance at periodic intervals over their service life in order to ensure that their material condition remains well within safe and acceptable limits. Naval aircraft are subjected to particularly deteriorating conditions through carrier operations and highly corrosive environments. O-level preventative maintenance is continually performed and a series of physical integrity inspections, called corrosion control inspections, are conducted to ensure satisfactory,

safe performance during the aircraft's service period (interval between successive D-level rework).

There are several reasons an aircraft is scheduled for NARF D-level maintenance. There are four major catagories that comprise almost all of NARF's in-house rework accomplished. [Ref. 3:pp. 10-1 - 10-2]

a. Standard Depot Level Maintenance

Standard Depot Level Maintenance (SDLM) is the most common rework accomplished, for each aircraft undergoes SDLM several times during its service life, scheduled at intervals (service periods) determined by flight hours, service months, and engineering studies. The extent of maintenance to be accomplished is defined by the SDLM specifications developed by the Cognizant Field Activity (CFA) for each type/model/series (TMS) of aircraft. Work done on an aircraft is limited to the airframes structure only. Rework is done on installed systems only if it's part of the structure and not removable. If at all possible, each aircraft is to leave with the exact same set of accessories and components it arrived with. Removable components needing rework, such as engines and black boxes, are replaced and routed through their own D-level program.

b. Service Life Extension

The Service Life Extension Program (SLEP) is a SDLM program that involves major replacement or restoration of aircraft structures that have reached fatigue life limits.

The A-3 is a prime example of this where extension of its
service life has been determined to be necessary in order to
meet operational and reserve training missions. This type of
D-level maintenance is extremely difficult and requires three
to four times the hours of a normal SDLM.

c.   Modification and Airframe Change

Modification (MOD) and Airframe Change (AFC)
D-level maintenances are performed as required by technical
directives (TDs) designed to alter the performance or
capabilities of an aircraft without changing its model or
series designation. This work may be accomplished by field
teams but is most often fulfilled concurrently with SDLM
rework.

d.   Conversion

Conversion (CONV) is a major alteration of the
mission of the aircraft and results in a model or series
redesignation. This is usually accomplished as a combination
SDLM/CONV depot level effort.

e.   Summary

Almost without exception, aircraft physically
inducted at NARF Alameda are scheduled for either SDLM/AFC,
SDLM/MOD, SDLM/CONV, or straight SDLM rework. Most of the
other subprograms are conducted by field teams away from the
NARF physical plant.

2. Production Processing

When an aircraft is received at NARF Alameda, it is inducted as scheduled and a job number established. From this point on direct labor hours and other costs are charged to the aircraft. Two aircraft examiners are immediately assigned to the aircraft to perform ground tests of all aircraft systems equipment and record discrepencies before defueling and moving the aircraft into the hangar. These examiners stay with the aircraft through the initial disassembly stages. They determine what technical directives are required and through the use of the SDLM specifications for that TMS, determine the tailored fixed load of specific SDLM tasks that must be performed on the aircraft. [Ref. 8]

It is seldom necessary for an aircraft to need all possible SDLM tasks achieved. Using the established norms for each SDLM task (determined NARF-wide during the A-11 budgeting process), the exact number of direct labor hours projected to complete rework is calculated. According to NARF management, the fixed load is usually less than the number of hours on which the fixed price was based [Ref. 6]. This is an accepted inconsistency, however, for it is also quite common to discover further corrosion or safety of flight rework not included in the fixed load that must be completed.

To explain further what norms are, consider the following simplified example. For the SDLM task of "fuel

cell removal" for a P-3C, the task norm is 540 direct labor hours.[2] This figure is arrived at through operational analysis and methods and standards surveys. Using an estimated efficiency index of .82 and an expected occurrance rate of this task of .68, the final weighted task norm is (540/.82) x .68 or 448 hours. Summing all the SDLM weighted tasks norms for P-3Cs will then create the overall norm for determining the fixed price at the FRSMs. To determine the fixed load for a specific P-3C, if fuel cell removal were needed, then it would be estimated to take 540/.82 or 658 hours. Summing all SDLM tasks required for this aircraft gives the actual fixed load. The fixed load is what production managers use to monitor rework progress. The norms (in direct hours and dollars) are what the financial managers use for tracking their financial position.

The physical flow of aircraft within the hangars differs some by type. The S-3s and A-6s use a semi-garage method. Aircraft are moved only once or twice during rework and once to the paint shop. The A-3s are handled garage style and remain in the same spot almost their entire rework period until painting. The P-3s travel through a moving line. They are spotted for 7-10 days then moved to the next

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[2]The example is for illustration only. All values are fictitious and have no resemblance to actual P-3C norms.

station.   The moving line method makes it easier for a
manager to observe how turnaround time is tracking, but since
any delay on one aircraft delays all those behind it,
meticulous planning of task accomplishment and material
support is absolutely critical.

The process is completed once the aircraft is painted
and it passes a series of operational flight checks by Navy
pilots and aircrewmen.   This marks the end of rework and the
aircraft is considered physically complete and ready to be
turned over to ferry crews for the return to the customer.
Financial completion (close out of the job number) may not
occur for two more months due to lagging accumulations of
costs.

III.   COST BEHAVIOR THEORY

Costs are a measurement of the value of resources and services.   Volume is a measure of activity or workload resulting from the consumption of resources and services. Anyone who has ever been a manager has at some time been concerned with costs, workload and cost efficiency.   As was stated earlier, NARF's goal is to provide quality maintenence on time and at minimum cost to its customers.

Every organization, whether private or public, profit or non-profit, in some fashion consumes its own resources or services in order to acquire other resources or services.   To achieve desired objectives, it's vital for managers to thoroughly understand in what manner their resouces are being consumed.   Recorded accounting cost data represents the means by which managers can receive this feedback.   To effectively use this data, managers need to know which costs under their control should vary in relation to changes in the volume of activities they manage and which should not.   Whether evaluating the benefits of several alternative investments, attempting to minimize costs of existing functions, or optimizing workload and product mix, cost behavior can provide invaluable insight to the manager.

This chapter will provide the reader with the basic theory on which cost-volume analysis is based. More detailed explanations will accompany the NARF Alameda cost-volume analysis discussed in later chapters.

A. TYPES OF COSTS

The total cost of operating an organization or any element of an organization--department, program, or cost center--is the sum of a variety of types and catagories of costs. Cost behavior can be described by three basic patterns: variable, fixed and mixed.

Variable costs are those that vary proportionally with some measure of volume. Examples of variable costs are direct labor, direct material and other uses of resources that are closely associated with producing the cost objective or output. True variable costs display a relatively linear relationship with volume and thus a constant cost per unit of volume. [Ref. 9:p. 361]

Fixed costs are those that do not vary at all with volume and either remain relatively constant over time or vary for reasons totally unrelated to volume. Examples of fixed costs are supervisory salaries, building depreciation, and other costs that increase during a period only because of the passage of time. Attempting to relate fixed costs to output may result in an unrealistic per unit value; for example, as the volume of output increases, the cost per unit decreases. [Ref. 9:pp. 361-362]

Mixed costs (or sometimes called semivariable costs) have both variable and fixed components. Therefore, mixed costs do vary with changes in volume, but proportionally less. Examples of mixed costs are indirect labor, equipment maintenance, and clerical services. [Ref. 10:p. 122]

Two other important catagorizations of costs are direct and indirect. Direct costs are those that are readily identifiable to the unit of output and can be either variable or fixed (normally variable). Indirect costs (commonly referred to as overhead) are those that are not traceable directly to a unit of output and are usually fixed or mixed.

B. COST-VOLUME ANALYSIS

Cost-volume analysis is a method by which one can use historical data to assist in predicting the behavior of costs in the future. By analyzing the various direct and indirect costs associated with producing a certain output, a determination can be made as to their behavior --variable, fixed or mixed-- in relation to volume. By no means is the past a perfect predictor of the future; in fact, at best it can only be a rough guess. Causal factors and conditions differ from one data collection period to the next. One cannot mathematically remove or hold perfectly constant these conditions while studying the effects on costs of only one

(in this case volume). However, as long as this fact is kept in mind, knowledge of historical cost behavior can be of some managerial value.

Collecting data on particular costs and volume measurements over equivalent time periods is the first step in cost-volume analysis. To be meaningful, the data should have been recorded under consistent procedures so as to have some assurance that the numerical values represent comparable quantities. For instance, cost data should have been collected under the same accounting rules, and volume data through standard methods of measurements. It is also important to convert cost data into time constant monetary values. Indexes such as the "Implicit Price Deflators for Gross National Product" (although not perfect) will remove most of the effects of inflation. The scatter plot is the result of graphically displaying the cost-volume data points. This provides a rough obervation of how the costs of interest vary with volume.

For a more accurate evaluation of the cost-volume relationship, regression analysis (which uses the least-squares method) can be applied to the data. As illustrated in Figure 3.1, considering the cost data as the dependent variable (y-axis) and the volume data as the independent variable (x-axis), a linear approximation of the relationship is modeled by an equation of the form:

$$Y_c = a + bX$$
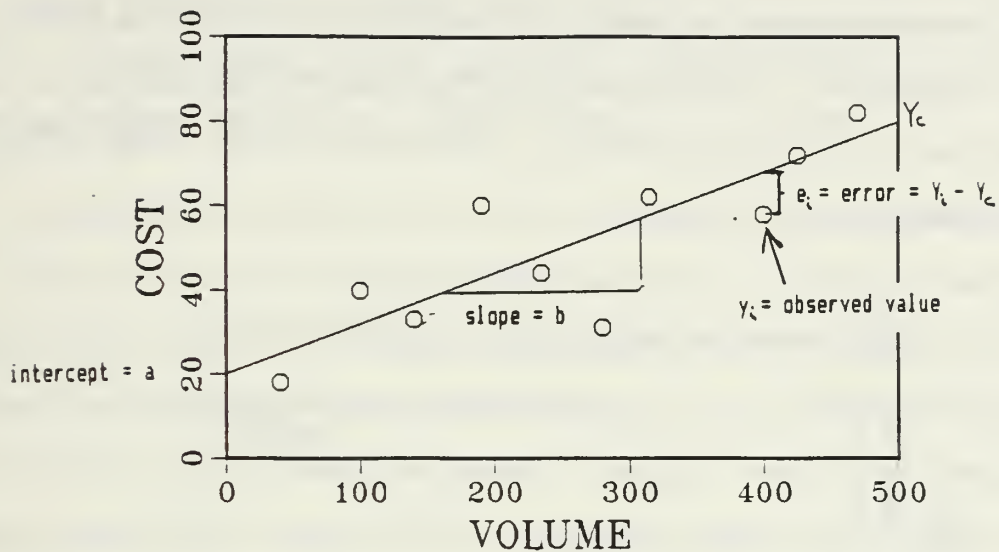
Figure 3.1   Linear Regression

The value Y_c represents the expected cost value given any

volume X. As stated earlier, it is not possible to predict

the exact cost behavior in relation to volume, so Y_c

describes only an average approximation and does not totally

"explain" the behavior of Y. The "unexplained" portion is

the difference between the actual and predicted values

$(Y - Y_c)$ and is called the error term or residual "e" giving

the equation:

$$Y = a + bX + e$$

The least-squares method used in regression analysis

minimizes the error terms and thus provides the best possible

fit of a straight line to the data. [Ref. 11: pp. 2,3]

A cost-volume curve is the results of the regression

analysis. Since all costs are either variable, fixed or

mixed, then analysis of each will result in variable and/or fixed components. Figure 3.2 shows a mixed cost with variable and fixed components. The cost-volume model would be represented similarly.
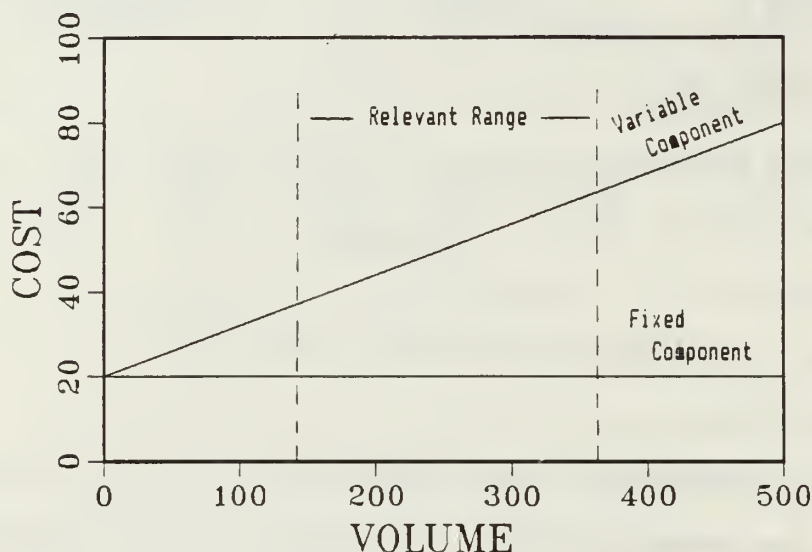
Figure 3.2   Cost-Volume Curve

The relevant range shown is the range of volumes for which the linear relationship can be considered valid. The extension of this relationship to zero volume outside of the relevant range is only for the purpose of identifying the intercept (the fixed component of cost), and does not imply a linear relationship over this range.

It must be kept in mind that the cost-volume linearity assumption, even within the relevant range, may be totally incorrect. Costs may vary by some higher order relationship or they may vary in a discontinuous manner such as a step function. However, as stated by Robert N. Anthony:

. . . the effect of these discontinuities or nonlinear cost
functions on the total costs is minor, and the assumption
that total costs vary in a linear relationship with volume
is a satisfactory working approximation . . . [for]
complicated curves are rarely used in practice. . . . [Ref.
9:p. 370]

A cost-volume model is a very simplified representation

of a series of very complex relationships. First of all, the

whole relationship is highly dependent on the choice of

volume measurement. Anthony says, ". . . a certain measure

[of volume] is selected because it most closely reflects the

conditions that cause costs to change." [Ref. 9:p. 376] The

cost-volume relationship explained by linear regression says

nothing about the causal factors of cost behavior involved.

Therefore, it is extremely important to select a

representative measure of volume--whether it be based on

resource consumption (inputs), work accomplished (outputs),

dollar values or physical units. For example, Anthony feels,

". . . overhead costs tend to vary more closely with other

input factors than with output." [Ref. 9:p. 376] It's

possible then that for different costs, different measures of

volume may be appropriate.

Product mix is another factor to consider, for cost may

vary over a period as a result of the variations in the mix

of several products being produced over that period. When

product unit costs are different, it is best to treat each

product separately and construct cost-volume curves for each.

[Ref. 9:p. 383]

Other considerations that should be investigated when evaluating the reasons for cost behavior are: (1) rate of volume change, for costs tend to exhibit larger error terms (deviations from the cost-volume curve) under rapidly changing volume; (2) direction of volume changes, for costs tend to lag behind volume changes; (3) duration of change in volume, for costs react less to temporary volume changes than to longer ones; (4) advanced knowledge of volume changes, for managers are able to anticipate required adjustments resulting in costs tending to be more in concert with volume; (5) productivity changes, for costs will vary inversely with productivity variations; and (6) management decisions, for many costs are discretionary in nature and solely dependent on a manager's judgement. [Ref. 9:pp. 383,384]

Because of all these possible real world variables, one cannot expect to estimate future costs solely by predicting the volume for a specific period of time. The cost-volume relationship is a significantly valuable analytical tool, but its application has to be moderated with common sense and a good understanding of the effects of these other factors.

C.   BREAK-EVEN ANALYSIS

The break-even point is defined as that level of volume at which the revenues received are equal to the costs incurred.

If:

V_B = Break-even volume
C_V = Variable cost per unit
C_S = Sales price per unit
C_F = Fixed costs

then:

$$V_B = C_F \ / \ (C_S - C_V)$$

Fixed costs must be matched with the varialble revenue gain
(called contribution margin) in order to break-even.
Therefore, knowing the contribution margin per unit (sales
revenue per unit less variable costs per unit) the volume of
activity needed to cover fixed costs can be determined. As
displayed in Figure 3.3, if volume is below break-even (where
costs equal revenue), then a loss will occur and if above
then a profit.

Figure 3.3 Break-even Analysis

43
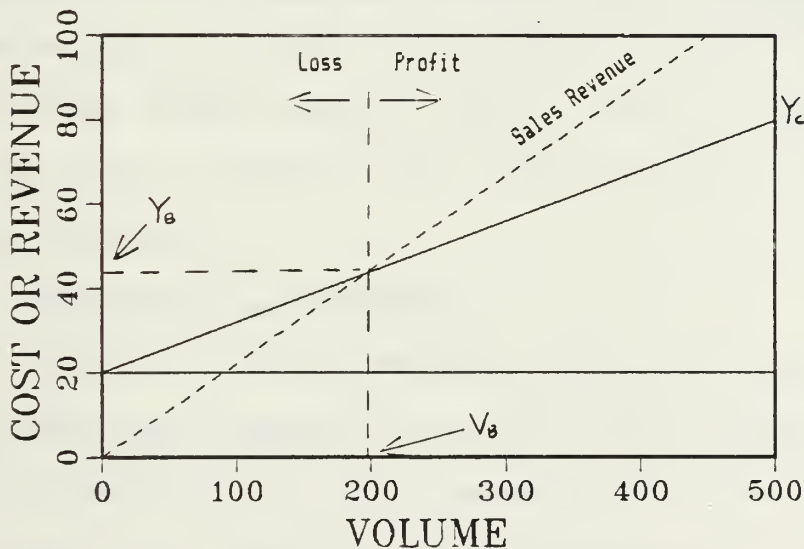
As can be seen in Figure 3.3, break-even analysis is simply an extension of cost-volume analysis: comparing the revenue-volume relationship with cost-volume. A non-profit organization such as a NARF, who has break-even as a goal, should always be striving (theoretically) for the break-even volume.

Of course, just as with costs, revenues are affected by factors other than just volume. The product mix is probably the most important to a NARF. Product mix will vary revenue through different product prices (aircraft TMS in NARF's case). Market demand and the resulting fluctuations in sales volume (rates and directions of change etc.) may affect pricing decisions. However, since NARF works on a fixed price system, variations due to market demand are removed and volume changes will not affect revenues as they do costs.

IV.   VOLUME AND COST DESCRIPTIONS

A.   VOLUME MEASUREMENT

1.   Qualities of a Volume Measurement

The first step, and possibly the most important, in
studying the cost-volume relationships of the NARF Alameda
aircraft program is determining suitable volume measurements.
Volume, the dependent variable in this situation, is not as
easily definable as one would initially suspect.   To be both
meaningful and useful to management a volume dimension should
have certain qualities such as: (1) simple to understand; (2)
easily and consistently measurable; (3) relatable to input or
output; (4) controlable by management; (5) representative of
actual production activity; (6) accurately predictable; and
(7) equivalent across product lines.   There is probably no
production activity measure that would perfectly meet all
these requirements.

2.   Possible Volume Measures

Quarterly activity measures which can possibly meet
some of these requirements for the aircraft program are
aircraft inductions, aircraft completions, direct personnel,
direct labor hours, and aircraft in production.   Combinations
of these to be considered are aircraft per quarter (an
equivalent unit based on percent completion) and hours per
aircraft (a productivity value).

45

a. Inductions and Completions

Probably the least suitable volume measures are inductions and completions. These are certainly related to input and output, but fail to accurately represent the actual quarterly production activity. An induction or completion may occur at anytime during the quarter, so no consistent measurement is possible. Being small interger values make them inappropriate for sensative analysis. Inductions and completions would have a better chance of being a valid measure on an annual basis.

b. Direct Personnel

The number of direct personnel associated with the aircraft program, primarily within the 9500 Airframes Division, is definitely related to production activity or at least production capacity. However, control is difficult, for this measurement is severely limited by the constraints involved in adjusting the workforce to meet production. There are certainly costs that vary due to personnel levels, but as a production volume measure it is not well suited.

c. Direct Labor Hours

Aircraft program direct labor hours would initially seem to be the best choice of a volume measurement. It is as closely related to input as possible, and is obviously the measure most related to direct labor costs. However, the author believes its accurate predictabilty is suspect, and management control is limited somewhat by direct personnel availability, divisional distribution and overtime

46

ceilings. Direct labor hours is the most common method of measuring a labor intensive operation, but possibly there are other equally representative measures more closely identifiable with output.

d. Workdays per Quarter

The number of aircraft in production (in-house) at any point in time is a meaningful measurement of activity being performed if all aircraft are being worked on equally. This measurement is simple, related to input and output, and through turnaround time (TAT) estimates and induction scheduling, it is also controlable. The difficulty is in how to measure it.

A single count at some point during the quarter (like the beginning or end) or an average is not a true representation of quarterly activity. Measuring the number of aircraft in-house on a daily basis and summing over the entire quarter (in other words adding up all the days each aircraft will be worked on during the quarter) gives the total number of aircraft workdays per quarter and thus a reasonable measure of production activity. And, if on the average, rework on all types of aircraft airframes can be considered comparable, then aircraft workdays for each type of aircraft can be considered equivalent.

This measurement of volume is certainly not perfect, for it may be influenced by labor related factors such as artisan availability and distribution, training,

experience and productivity from one type of aircraft to another. In all, the author believes this to be the best measure of volume available for the purposes of this project and will be used as the primary volume measurement throughout the analysis procedures.

e.   Aircraft per Quarter

Another interesting and possibly useful volume dimension is a combination of workdays and actual turnaround time into an equivalent unit computed by determining aircraft percent completion per quarter. Dividing the number of workdays an aircraft is in production during a quarter by its turnaround time (total workdays to complete the entire job) results in a rough estimate of the fraction of the rework job completed during that quarter. Summing these fractions for all aircraft of one type yields an approximation of the number of aircraft completed that quarter. For example, given three A-6's were in production 10, 30 and 50 workdays respectively during the quarter and each has a TAT of 100 workdays, then .1 + .3 + .5 or equivalent to roughly .9 (90%) of one A-6 was completed that quarter. This gives a relative measure of output between the aircraft types, and a relative assessment of activity from quarter to quarter within an aircraft type.

What makes this attractive is being in units of aircraft. It gives management an instant picture of production output and is much simpler to relate to than input

units such as hours. Also, if this aircraft per quarter
value is combined with hours per quarter, the resulting hours
per aircraft figure provides an evaluation of relative
productivity. One drawback to the aircraft per quarter
measure arises in its equivalency across aircraft types.
Since the average turnaround times for the four major
aircraft types vary so widely, some method of weighting may
have to be divised before comparison between aircraft types
is valid.

   3.   Aircraft Catagories

      Now that the primary volume measurements have been
determined, in the multi-product environment of the aircraft
program, it is important to decide which catagories of
aircraft should be used to collect volume data. Based on
budget norms for each SDLM subprogram and aircraft
type/model/series (TMS), there are over 15 unique catagories.
Considering the fact that no two aircraft have identical work
performed --there is always unique problems-- there are as
many catagories as there are aircraft. Obviously there is no
benefit in considering each aircraft separately. Likewise,
attempting to relate volume to cost for every different
model/series would be impractical in many cases, for there
are insufficient numbers of some models reworked to create a
data base.

With the aircraft program essentially involved in airframes rework only and the airframes structures of each type aircraft being fundamentally identical, influences on costs should not be expected beyond the four basic types. Another convincing reason is that quarterly cost data are only available by type, not model or series. Therefore, the conclusion must be to analyze the cost-volume relationships for the aircraft program as a whole and the four types of aircraft only.

Tables 4.1 through 4.5 display the volume measurements for FY82-FY85 for each of the four aircraft types and their relative share of the overall aircraft program. Examination of this data reveals the close similarities between the behavior of direct hours, workdays and aircraft per quarter measurements. The coefficients of correlation[3] between these three volume measurements, range from .75 and .88, illusrating marked similarities.

This suggests that the use of either of these volume dimensions in cost-volume analysis should produce somewhat similar results. However, since there are at least subtle differences, all should be considered to attain the best possible explanation of behavior.

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[3]The coefficient of correlation is a least squares method of showing similarity in behavior of two variables measured on a scale of 0 to 1, where 0 indicates no relation between the two variables and 1 indicates a perfect relation.

TABLE 4.1

AIRCRAFT PROGRAM VOLUME MEASUREMENTS

QTR	INDT	COMP	WKDYS	AC/QTR	DIRHRS	HRS/AC	TOTAL PERS	9500 PERS
821	34	33	3559	32.65	330356	10118	4949	822
822	34	38	4212	33.59	389107	11584	5099	*
823	25	27	4221	31.42	360704	11480	5227	866
824	20	38	3588	26.36	308569	11706	5066	801
831	26	24	2604	23.63	263695	11159	4737	737
832	23	23	2968	23.53	295214	12546	4811	749
833	20	25	2953	23.92	263876	11032	4678	739
834	21	26	2578	22.04	230216	10445	4570	736
841	25	19	2247	21.75	234119	10764	4516	716
842	25	19	2787	24.08	278357	11560	4415	671
843	23	29	2866	23.67	274123	11581	4345	628
844	31	22	2997	21.67	269167	12421	4337	612
851	15	18	2869	22.62	267326	11818	4311	627
852	16	23	2966	20.67	334382	16177	4413	659
853	22	20	2758	19.49	296646	15220	4624	662
854	25	21	2867	23.13	319938	13832	4627	651

TABLE 4.2
A-6 SEGMENT VOLUME MEASUREMENTS
AND SHARE OF PROGRAM

QTR	INDT	COMP	WKDYS	AC/QTR	DIRHRS	HRS/AC	INDT%	CMPT%	WKDY%	ACFT%	DHRS%
821	14	16	1285	12.53	129460	10332	41	48	36	38	38
822	14	13	1491	12.90	149520	11591	41	34	35	38	34
823	9	11	1536	12.00	147949	12329	36	41	36	38	38
824	11	13	1359	10.58	128253	12122	55	34	38	40	36
831	10	9	1146	10.00	113885	11388	38	38	44	42	40
832	6	8	1186	8.23	108335	13163	26	35	40	35	33
833	4	11	1033	7.32	97990	13387	20	44	35	31	34
834	6	7	777	6.24	79724	12776	29	27	30	28	31
841	7	4	620	5.60	60018	10717	28	21	28	26	24
842	7	5	777	6.09	78973	12968	28	26	28	25	26
843	6	10	902	7.14	89480	12532	26	34	31	30	30
844	8	6	832	6.42	95008	14799	26	27	28	30	32
851	4	5	715	6.27	83173	13265	27	28	25	28	29
852	6	8	708	5.63	110349	19600	38	35	24	27	31
853	7	5	692	5.62	98205	17474	32	25	25	29	31
854	5	5	741	6.42	100782	15698	20	24	26	28	29

TABLE 4.3
P-3 SEGMENT VOLUME MEASUREMENTS
AND SHARE OF PROGRAM

QTR	INDT	COMP	WKDYS	AC/QTR	DIRHRS	HRS/AC	INDT%	CMPT%	WKDY%	ACFT%	DHRS%
821	11	10	693	9.76	81876	8389	32	30	19	30	24
822	9	11	817	9.54	120754	12658	26	29	19	28	27
823	7	7	756	8.56	85834	10027	28	26	18	27	22
824	4	9	534	6.08	63424	10432	20	24	15	23	18
831	7	6	409	6.55	55818	8522	27	25	16	28	20
832	8	7	553	7.70	61688	8011	35	30	19	33	19
833	9	8	598	8.02	61738	7573	45	32	20	34	21
834	8	8	625	7.88	66092	8157	38	31	24	36	25
841	10	7	622	8.19	78932	9585	40	37	28	38	31
842	9	9	877	10.19	98477	9534	36	47	31	42	32
843	7	10	697	8.84	94099	10320	30	34	24	37	31
844	9	9	604	7.01	88049	13336	29	41	20	32	31
851	5	6	532	6.93	83153	11999	33	33	19	31	29
852	5	7	526	6.37	99053	15550	31	30	18	31	28
853	10	6	543	6.52	80044	12277	45	30	20	33	25
854	8	7	719	7.97	91418	11470	32	33	25	34	27

TABLE 4.4
S-3 SEGMENT VOLUME MEASUREMENTS
AND SHARE OF PROGRAM

QTR	INDT	COMP	WKDYS	AC/QTR	DIRHRS	HRS/AC	INDT%	CMPT%	WKDY%	ACFT%	DHRS%
821	7	4	778	6.30	50290	7982	21	12	22	19	15
822	9	11	1055	7.35	74126	10085	26	29	25	22	17
823	6	5	1129	7.04	65741	9338	24	19	27	22	17
824	3	9	1050	6.26	50355	11483	15	24	29	24	20
831	7	6	712	4.81	46071	9015	27	25	27	20	15
832	5	5	785	4.83	58853	12185	22	22	26	21	18
833	4	4	815	5.37	48817	9091	20	16	28	22	17
834	3	7	633	4.41	26476	8178	14	27	25	20	14
841	6	5	551	4.62	38033	8232	24	26	25	21	15
842	6	2	696	4.99	42584	8534	24	11	25	21	14
843	9	5	875	5.54	43771	7901	39	17	31	23	15
844	10	5	1245	6.75	53834	7975	32	23	42	31	18
851	5	7	1258	7.59	65755	8820	33	39	44	34	23
852	4	7	1285	6.67	78171	11720	25	30	43	32	22
853	4	7	1079	5.39	67905	12598	18	35	39	28	21
854	8	5	1012	6.31	72851	11545	32	24	35	27	21

TABLE 4.5
A-3 SEGEMENT VOLUME MEASUREMENTS
AND SHARE OF PROGRAM

QTR	INDT	COMP	WKDYS	AC/QTR	DIRHRS	HRS/AC	INDT%	CMPT%	WKDY%	ACFT%	DHRS%
821	1	2	625	2.74	49559	16601	3	6	18	8	13
822	1	2	680	2.84	26475	17567	3	5	16	8	11
823	3	4	609	2.72	43587	16675	12	15	14	9	12
824	2	4	508	2.60	53499	20463	10	11	14	10	15
831	2	3	337	2.27	47539	20942	8	13	13	10	17
832	4	3	444	2.77	63338	23949	17	13	15	12	20
833	3	2	507	3.21	55331	17237	15	8	17	13	19
834	4	4	543	3.51	57924	16503	19	15	21	16	22
841	2	3	454	3.34	57136	17107	8	16	20	15	23
842	3	3	437	2.81	58323	20755	12	16	16	12	19
843	1	4	392	2.15	46773	21755	4	14	14	9	16
844	4	2	316	1.49	32276	21662	13	9	11	7	11
851	1	0	364	1.83	35245	19260	7	0	13	8	12
852	1	1	447	2.00	46809	23404	6	4	15	10	13
853	1	2	444	1.96	50492	25761	5	10	16	10	16
854	4	4	395	2.43	54887	22587	16	19	14	11	16

B. COST DISTRIBUTION

1. Job Order Accounting System

In order to properly evaluate the validity of any cost-volume relationships in the aircraft program, it is important to understand where the related costs originate. NARF Alameda uses a job order system to accumulate costs to an end product and overhead function. Through this system historical costs can be traced to either cost centers, programs or products depending on whether they are direct or indirect costs.

a. Direct Job Orders

In the case of the aircraft program, all aircraft are assigned a direct job order number when inducted. From then until physical completion all direct costs in the catagories of labor, material and other services are charged to this job number, as well as allocations for overhead expenses based on predetermined overhead rates per direct labor hour. This method allows NARF to accumulate direct costs to specific programs, subprograms and products. [Ref. 12: pp. 16,17]

b. Indirect Job Orders

Indirect job orders are NARF-wide accounts used to collect labor, material and other services costs that are not readily identifiable with any product. This system accumulates indirect costs to specific cost centers and functional class code catagories (type of indirect cost i.e.,

supervision, training etc.). Indirect costs are not traceable to a specific product or even a specific program. Actual G&A overhead expenses are allocated to the six NARF programs quarterly using direct hours as the basis. [Ref. 12:pp. 16,17]

All indirect costs are classified as either production (PRDN) or general and administrative (G&A). Production expenses include all indirect costs incurred by production cost centers (divisions of the production department) and those G&A expenses transferred from G&A cost centers. General and administrative expenses are similarly indirect costs incurred by G&A cost centers (all non-production divisions) less the transferred expenses. [Ref. 12:p. 17]

e. Summary

The available information on cost distribution through NARF's accounting system is: (1) direct and indirect regular labor costs, overtime labor costs, material costs, and other services costs for each of the eleven G&A cost centers and six PRDN cost centers; (2) direct labor costs, direct material costs, and other direct services costs for each major program, subprogram, and type aircraft; and (3) indirect costs by type (G&A OR PRDN), cost center, and functional class code (FCC).

2. Direct Costs

The aircraft program, being one of six major programs at NARF, represents an average of approximately 21% of NARF's

total dollars spent each quarter (including overhead), 29% of the direct labor costs, 10% of the direct material costs, and 10% of the other direct services costs. Examination of the "before transfer" cost center expenditures, as recorded from quarterly cost center summaries, shows that eight of the eleven G&A cost centers have recorded direct aircraft program costs within the 16 quarter period under study. Of these, the 5000 Production Planning and Control Department, with 8% of the total, is the only G&A cost center that is significantly involved in the aircraft program. The remaining G&A cost centers together account for only about 1%. Of the six PRDN cost centers, all but 9100 NAVAIR Engineering Support Office and 9200 Weapons Systems Manager accumulated aircraft program direct costs accounting for the remaining 91%.

The breakdown of percentages of direct costs by cost center and cost catagory appears below in Table 4.6. The original data for the 16 quarter period contain many unexplainable large variations and negative values (especially in the material and other catagories). As a result, to provide a more meaningful illustration of the direct cost distribution, the data was trimmed of all values not within two standard deviations of the means before percentages were calculated.

TABLE 4.6

PERCENT OF AIRCRAFT PROGRAM DIRECT COSTS
BY COST CENTER

CC	LABOR % (range)	MATERIAL % (range)	OTHER % (range)	TOTAL % (range)
9500	75 (66-86)	71 (63-89)	73 (43-91)	74 (66-84)
9300	14 (10-16)	20 (13-28)	>1 (0-1)	15 (12-21)
500	7 (6-10)	4 (1-8)	24 (11-51)	8 (5-12)
9400	2 (1-3)	3 (1-6)	>1 (0-1)	2 (1-3)
9600	1 (0-1)	3 (1-6)	0 (0)	1 (1-2)
Other	1	1	1	1

3. Indirect Costs

NARF's total indirect costs are approximately 22%
production expenses and 78% general expenses on the average
over the 16 quarter period. Trimming the data of outliers as
was done with the direct cost, percentages by cost center
were calculated to illustrate the breakdown among G&A cost
centers and PRDN cost centers. Results are shown in Table
4.7.

The majority of G&A expenses are incurred by the
2500, 5000, 6000 and 6500 cost centers. This is no real
surprize for 5000 Production Planning and Control and 6000
Production Engineering (which includes the 6500 Plant
Services Division), are the two largest and most production
support intensive departments who would be expected to have
potentially volume related indirect costs. The 2500 division
of the Management Controls Department, however, is not
directly associated with production and simply accumulates
material and other services overhead expenses otherwise

unidentifiable with any other cost center. This division
would not be expected to have costs directly related to
production volume.

Since the 5000, 6000 and 6500 cost centers make such
a significant impact on NARF overhead costs and are
production oriented, they are the main focus of attention in
the analysis of aircraft program volume related indirect
expenses.

TABLE 4.7

PERCENT OF AIRCRAFT PROGRAM INDIRECT COSTS
BY COST CENTER

CC	LABOR % (range)	MATERIAL % (range)	OTHER % (range)	TOTAL % (range)
G&A COST CENTERS				
0000	2 (1-3)	>1 (0-2)	1 (0-7)	2 (1-3)
1000	6 (3-12)	1 (0-6)	1 (0-2)	3 (1-5)
2000	4 (3-6	1 (0-2)	>1 (0-1)	3 (2-5)
2500	4 (0-7)	51 (36-71)	92 (87-96)	40 (29-52)
4000	9 (8-13)	1 (0-3)	0 (0-1)	5 (3-7)
5000	36 (29-42)	4 (0-9)	1 (0-3)	19 (14-25)
6000	20 (14-35)	17 (7-26)	3 (1-8)	13 (9-15)
6500	17 (13-28)	27 (12-53)	1 (1-2)	14 (9-18)
7000	8 (4-10)	4 (3-10)	0 (0)	3 (1-6)
8000	0 (0-1)	1 (1-5)	0 (0)	0 (0-1)
9000	2 (1-5)	0 (0-1)	0 (0)	>1 (0-2)
PRDN COST CENTERS				
9100	>1 (0-1)	0 (0-1)	2 (1-5)	>1 (0-1)
9200	11 (7-13)	2 (0-4)	23 (10-36)	9 (5-11)
9300	21 (19-23)	35 (26-47)	27 (14-34)	24 (21-30)
9400	29 (25-34)	22 (14-39)	25 (14-34)	27 (18-34)
9500	24 (17-30)	12 (6-20)	5 (2-9)	20 (15-25)
9600	15 (12-18)	27 (15-37)	18 (10-27)	18 (12-23)

V. COST-VOLUME ANALYSIS

This chapter presents the cost-volume regression analysis results of aircraft program costs, both direct and pertinent associated NARF indirect, versus the volume measures discussed in Chapter IV. Also presented are the computations involved in constructing cost-volume curves for the aircraft program and its four segments.

The purpose of using regression analysis in this project is to determine the most accruate and reliable cost-volume relationship possible. Simple (one explanatory variable) and multiple (more than one) regression are explored using current and lagged volume data. When using current data, regression is attempted between costs and volumes of the same quarter. With lagged data, regression is performed by comparing costs of one quarter with volume data from one to three quarters earlier. This latter technique is called distributed lag. Since aircraft are in rework over several quarters in some cases, the activity of previous quarters may have an influence on current costs. All regression analysis for this project was performed using MINITAB Version 5.1 on the NPS IBM 3033 mainframe computer.

As discussed in Chapter III, regression analysis is a mathematical technique using the least squares method to

61

determine the closest fitting linear relationship possible between the dependent and independent variables. Regression also provides a numerical evaluation of the significance of the calculated relationship but in no way an explanation of the actual causes of cost behaviors.

The simplest to understand of the regression output values is r^2 (r-squared), the coefficient of determination. It is the square of r, the coefficient of correlation, and represents the percent of the dependent variable's variation that is explained by the change in the independent variable.

In evaluating any regression results, verifying the basic assumptions of the regression model is imperative. This is accomplished through analyzing the residuals (the error terms). Assumptions of the regression model are: (1) linear relationship between variables; (2) normally distributed residuals with a mean of zero; (3) finite variance for all residuals; and (4) independence between residuals. [Ref. 11:pp. 24-26]

Before analysis is even performed it is known that the assumption of independence among residuals is violated. This is due to the time related trend in cost measurement referred to as inflation. To remove this trend, the Implicit Gross National Product Price Deflator for government goods and services was applied to all costs. Table 5.1 shows the conversion factors used to create constant 1982 dollar values.

62

TABLE 5.1

IMPLICIT GNP PRICE DEFLATOR
GOVERNMENT GOODS AND SERVICES[*]

QTR	FACTOR	QTR	FACTOR	QTR	FACTOR	QTR	FACTOR
821	100.0	831	102.7	841	106.6	851	110.1
822	100.1	832	103.7	842	107.4	852	110.6
823	100.2	833	104.5	843	107.6	853	110.9
824	102.0	834	105.3	844	108.6	854	111.2

Source: [Ref. 11:p. 387]

A. DIRECT COSTS

In order to obtain the most accurate description of cost
behaviors, the costs must be studied in their least
aggregated state. For the direct costs of the aircraft
program this is direct labor, direct material and other
direct services for each of the four aircraft program
segments.

1. Direct Labor

Of all the costs associated with a production
operation, direct labor would be expected to exhibit the most
significant variable cost behavior. The regression results
has shown this to be true when comparing labor to the other
direct costs, but the results from one aircraft type to
another are inconsistent. Definite variable cost
relationships were found between direct labor costs and the

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[*]All costs displayed in all tables and figures contained in
this thesis have been converted to 1982 constant dollar
values using the convertion factors in Table 5.1.

63

volume measurements of direct labor hours, workdays and aircraft per quarter.

Regression with direct hours resulted in an r^2 of 98% or greater and a slope value of 16.0 to 16.5. Except for revealing the average 1982 constant dollar wage rate and that no major discrepencies exist between labor hours and costs recorded, the direct labor hours versus direct labor costs relationship discloses no new information. Table 5.2 displays the regression results for workdays and aircraft volume measurements, where r^2 is the coefficient of determination, "a" is the constant term, and "b" is the slope term of the regression equation $Y = a + bx$.

TABLE 5.2

REGRESSION RESULTS
DIRECT LABOR COST ORIGINAL DATA

(dollars in thousands)

Workdays as volume

Acft Segment	r-sq'd	Constant "a"	Slope "b"
A-6	80.5%	$501.6	$1.185/wkdy
P-3	44.7	363.4	1.541
S-3	61.2	133.7	.817
A-3	0.4	837.4	-.101

Aircraft as volume

A-6	76.8%	$588.5	$134.4/acft
P-3	21.2	532.5	102.0
S-3	54.5	-143.0	176.6
A-3	29.5	369.8	165.3

The outcome of regression with workdays as the independent variable was excellent for the A-6 segment, satisfactory for the P-3 and S-3 segments, and terrible for the A-3 segment. Using aircraft per quarter as the volume variable, the outcome was excellent for the A-6 segment, satisfactory for the S-3 and A-3 segments, and poor for the P-3 segment.

Attempts were made to find better results from any of the current or lagged volume variables. Occassionally direct personnel and aircraft inductions demonstrated some variable relationships with direct labor costs; however, all were much less significant than workdays or aircraft per quarter. It is interesting though that this happened at all, for both personnel and inductions are considered very weak volume measurements. Multiple regression was tried using personnel or inductions as a second variable with workdays or aircraft per quarter, but no significant additional variance explanation occurred.

Inspection of the associated residuals with the workday and aircraft per quarter regressions didn't reveal any violations of the basic regression assumptions. To ensure what relationships existed were in fact linear, cost and volume variables were transformed to their logarithmic equivalents. Regression of these transformations produced only slight improvements in a couple cases, but nothing significant enough to warrant the added confusion of using logarithmic measurements.

Some of the direct labor data is suspected to be unreliable due to unreconcilable negatives discovered during collection. Inspection of the scatter graphs of direct labor costs versus workdays and aircraft per quarter, identify some data that can be classified as outliers. Figures 5.1 through 5.4 display these scatter graphs and the data considered doubtful. Removal of these data points from regression analysis dramatically improves the level of explanation of cost variance and produces much higher confidence level relationships. There is no way of verifying the validity of this rational. However, without trimming the data, the results are unacceptable. Table 5.3 below gives the regression results using the trimmed data.

TABLE 5.3

REGRESSION RESULTS
DIRECT LABOR COST TRIMMED DATA

(dollars in thousands)

Workdays as volume

Acft Segment	r-sq'd	Constant "a"	Slope "b"
A-6	96.5%	$166.0	$1.442/wkdy
P-3	62.1	174.2	1.789
S-3	56.6	247.1	.714
A-3	50.7	170.4	1.472

Aircraft as volume

A-6	89.7%	$322.5	$158.7/acft
P-3	36.8	230.6	136.0
S-3	46.5	24.9	151.0
A-3	69.3	334.5	189.3
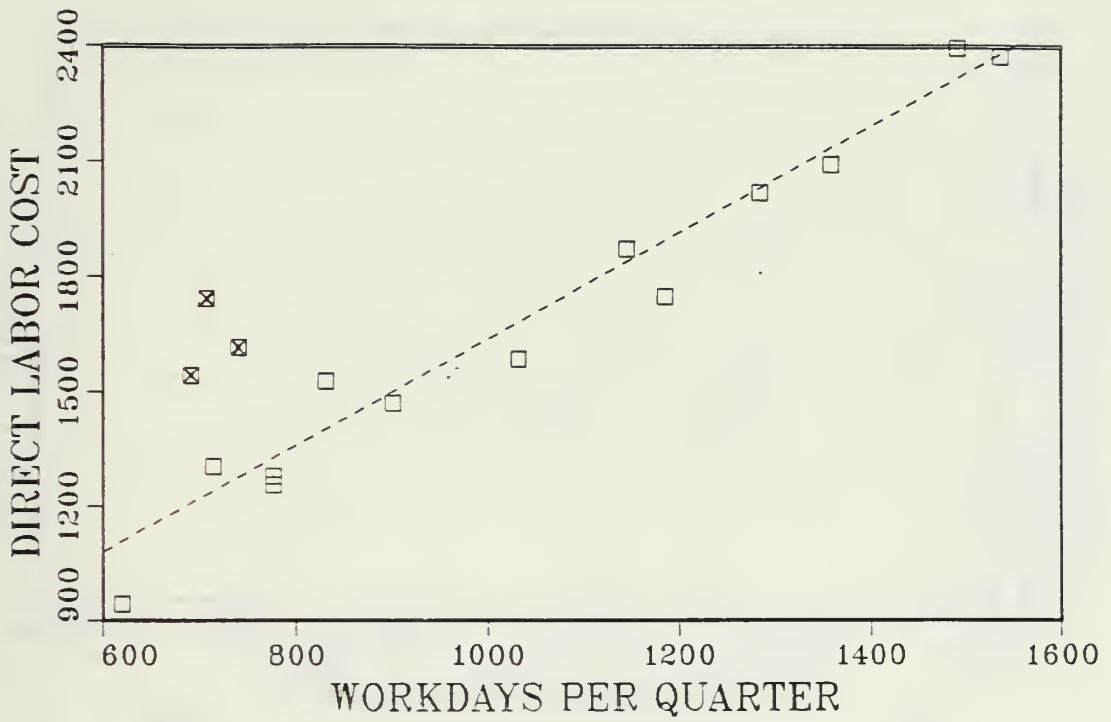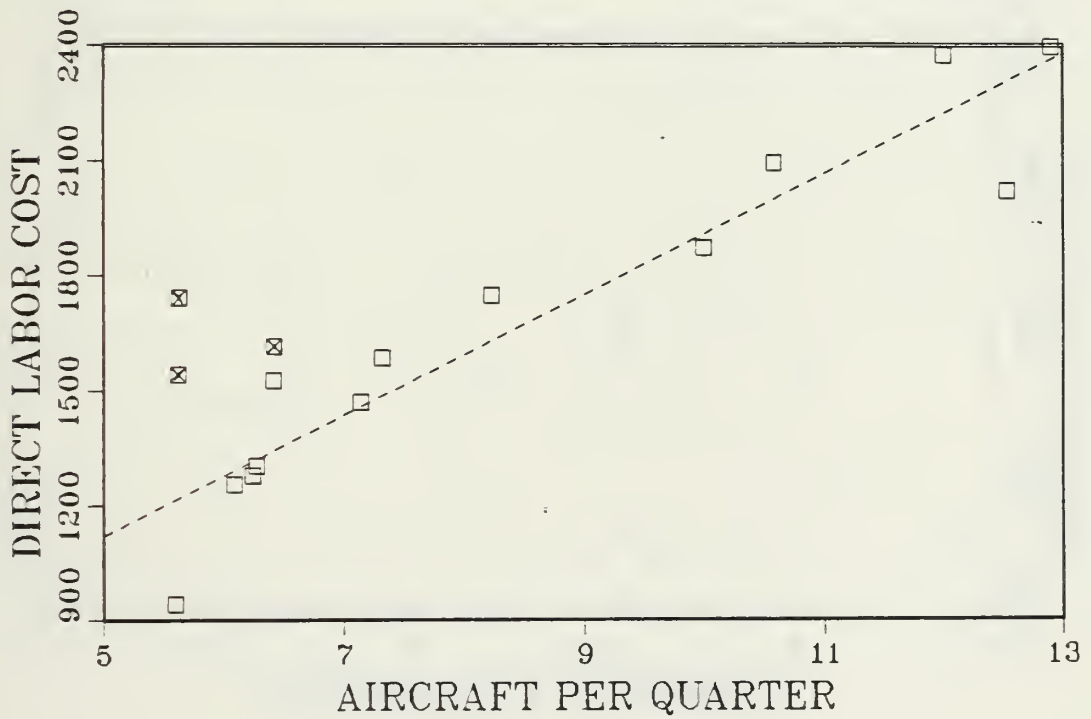
Figure 5.1   A-6 Segment Direct Labor Cost
Scatter Graphs
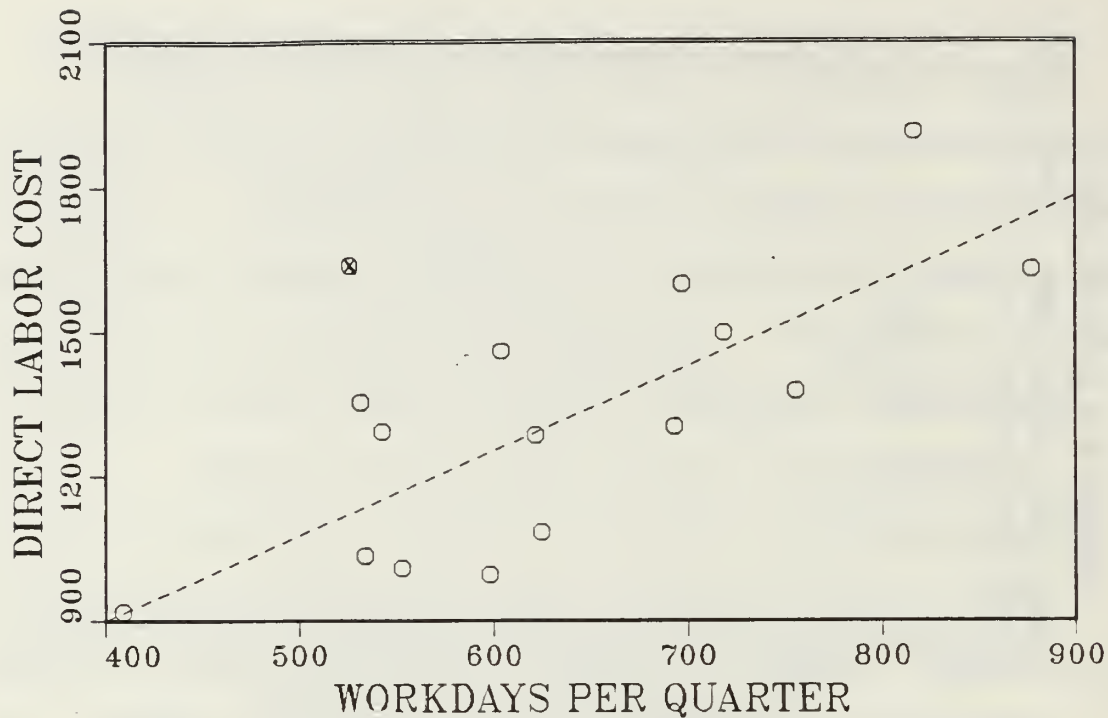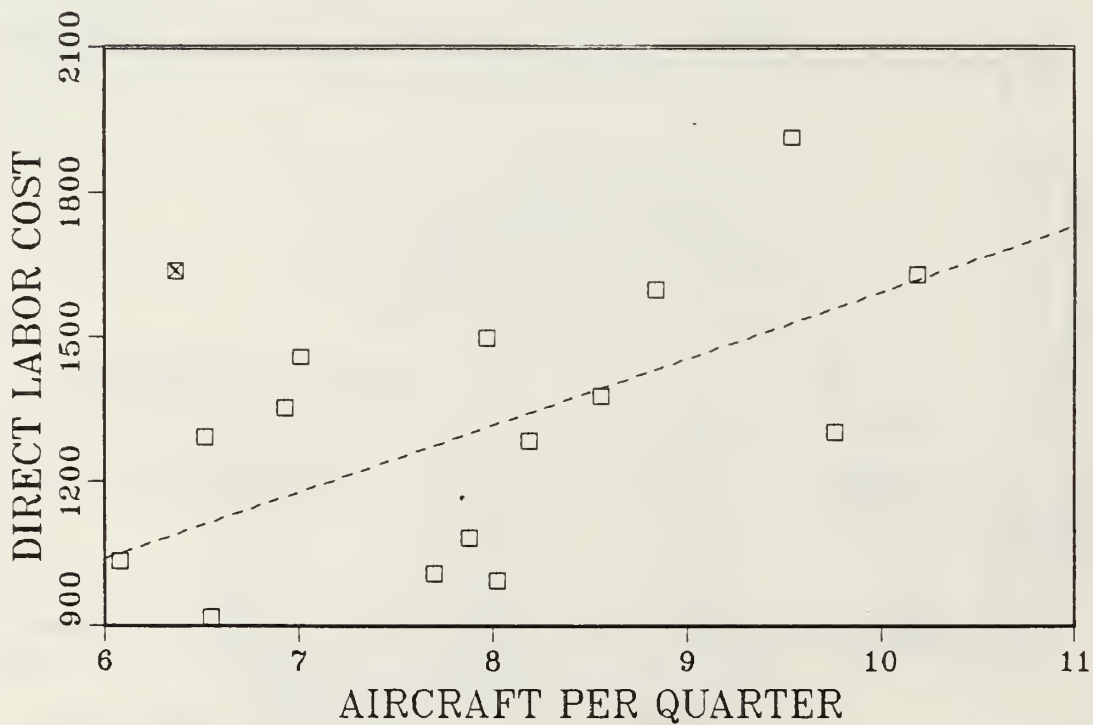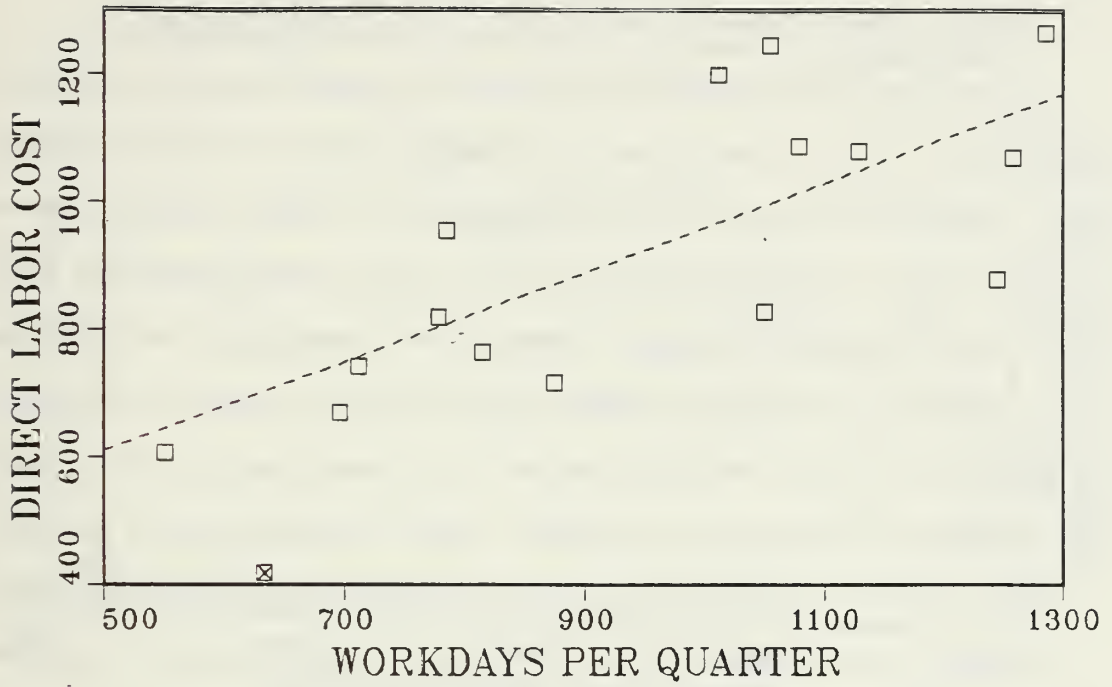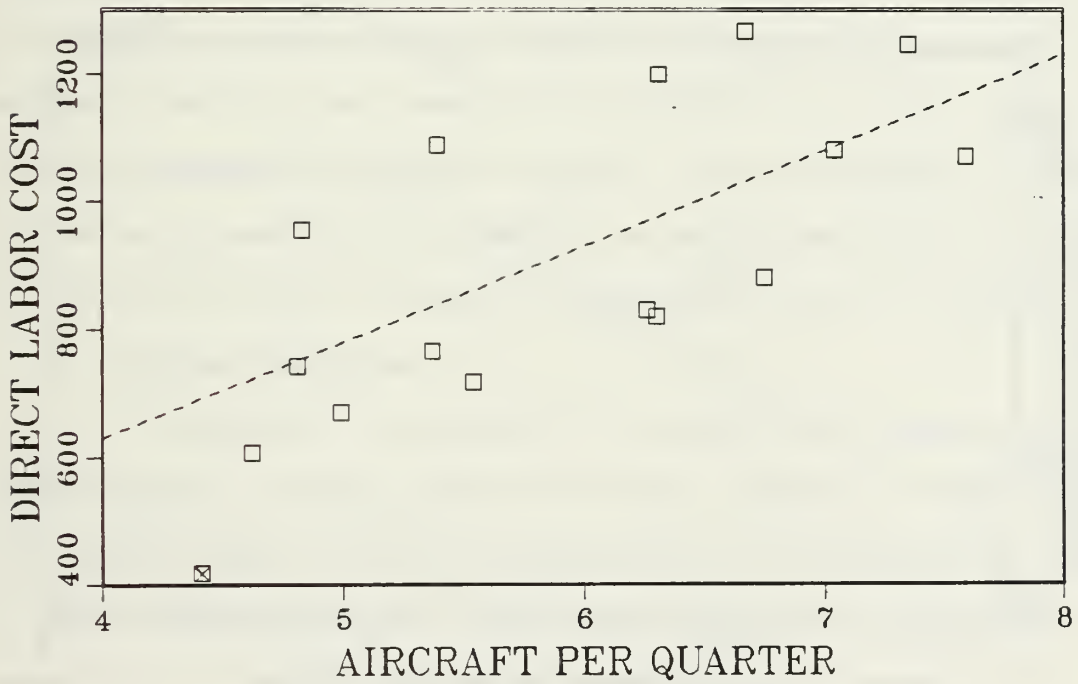
Figure 5.3   S-3 Segment Direct Labor Cost
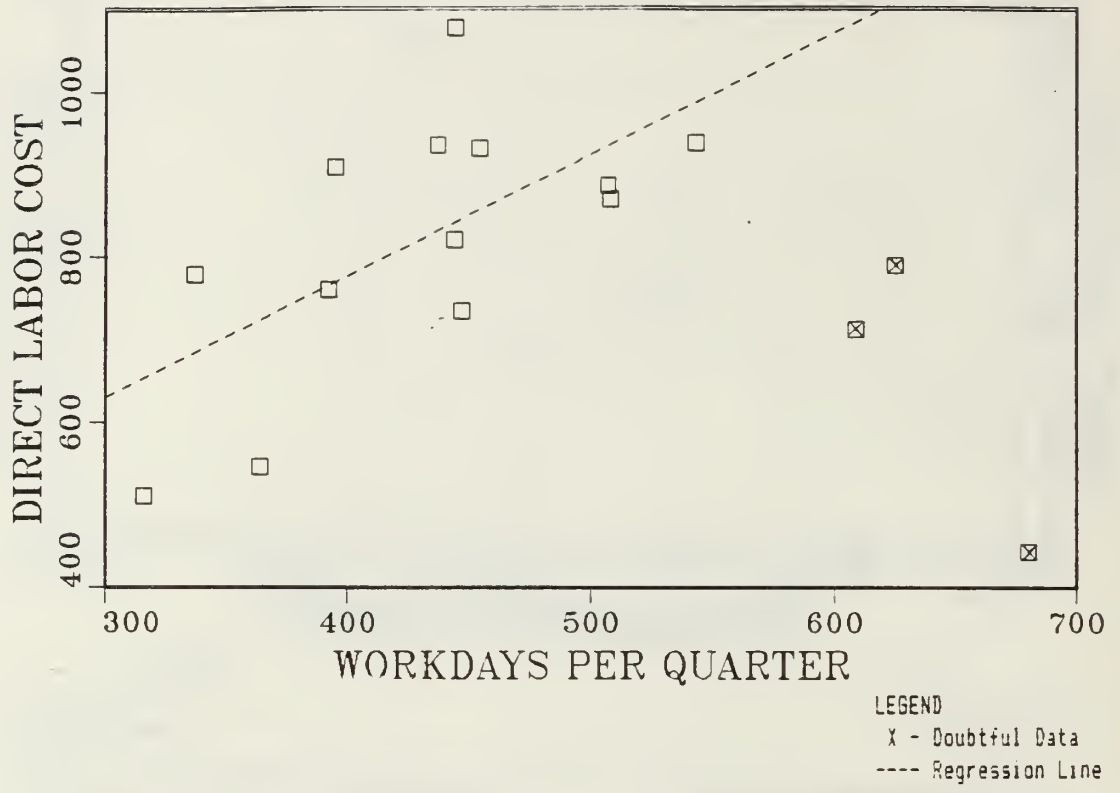Scatter Graphs
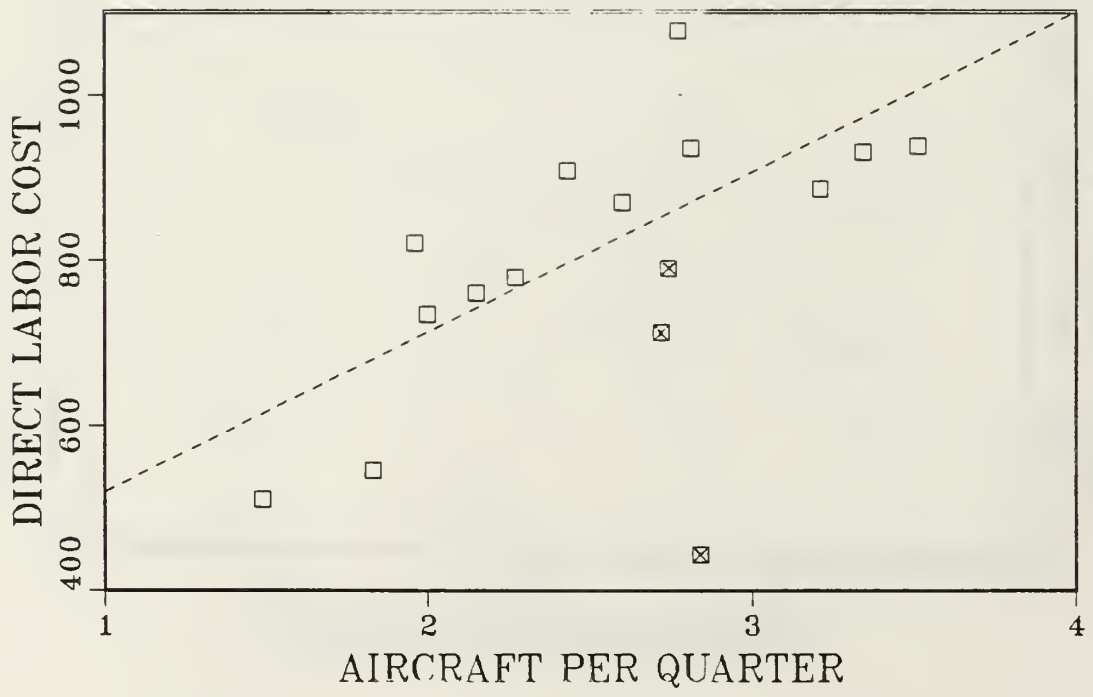
Figure 5.4   A-3 Segment Direct Labor Cost
             Scatter Graphs

Interpretation of the direct labor costs versus workdays and aircraft per quarter regression results is greatly aided through graphing (see Figure 5.5). Although direct labor costs are expected to be purely variable, the data indicate they are a mixed cost. However, the fixed portion is relativey small when compared to the total quarterly labor cost and thus approximates a variable cost. Also this is the result of extending the linear relation outside the relevant range. Below the relevant range the relation may be different or even nonlinear. Within the relavant range, the relation is considered valid and the slope "b" actually describes the incremental cost of direct labor for each additional workday or aircraft per quarter. For example, these results indicate P-3s have the highest per workday cost but the lowest per aircraft cost within the relevant range of historical data. This difference between volume measurements can possibly be evaluated as the result of the significantly shorter turnaround time for P-3s.

2. Direct Material

Throughout the rework of an aircraft, materials of various kinds are used during the many stages of SDLM. As with labor, each aircraft accumulates varying material costs at more irregular rates. Since all aircraft in-house are undergoing different stages of rework simultaneously, a relatively constant average direct material cost rate per unit of volume would be expected during a quarter.
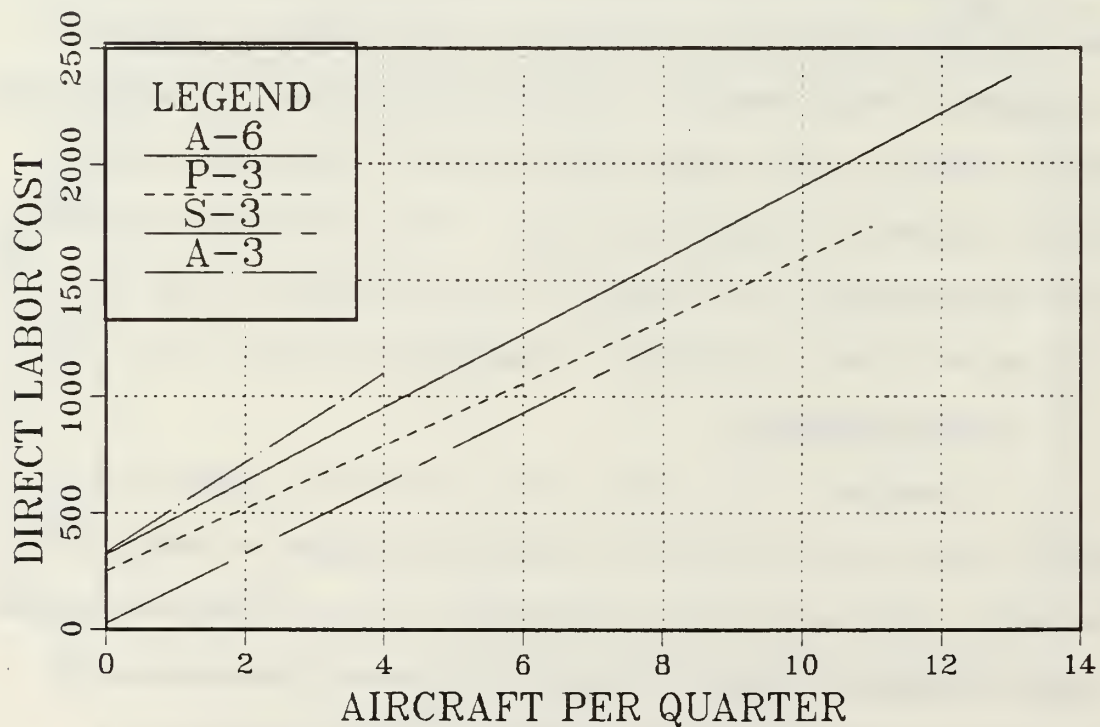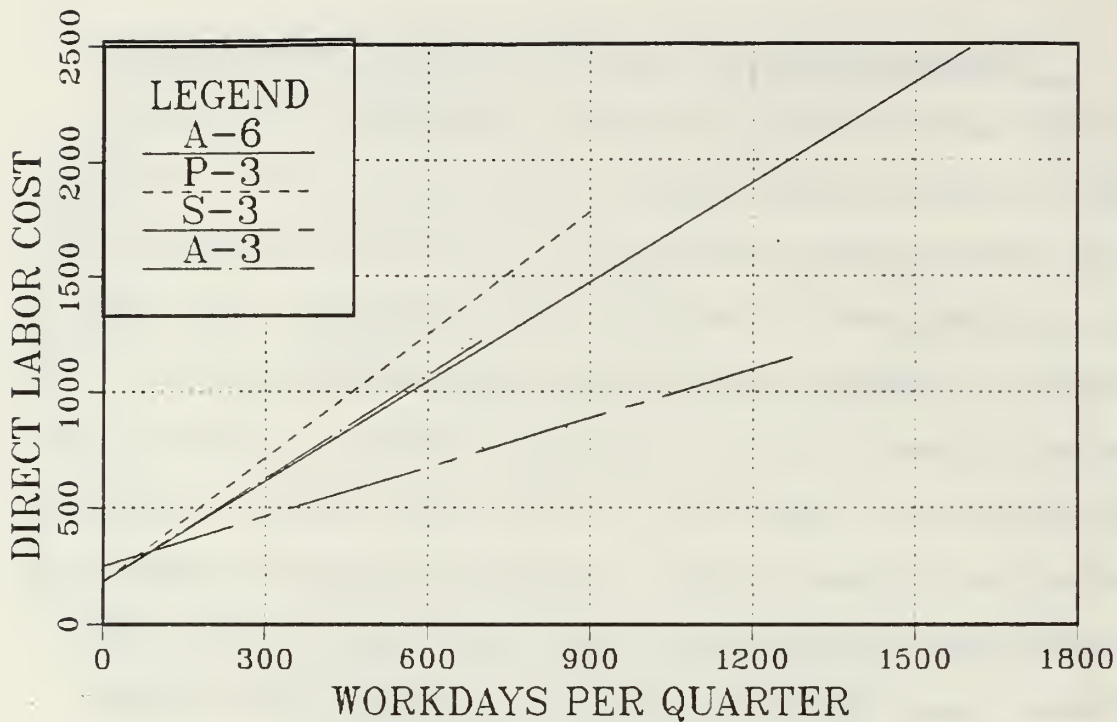
71

Figure 5.5   Graph of Direct Labor Cost
Regression Results

Unfortunately, this cannot be reliably demonstrated through the regression analysis of the available direct material cost data. The data is very erratic and even negative in some quarters. Without removal of suspected outliers or bad data, r^2 results were all less than 2%. Even after data trimming, the A-6 segment is the only one that produces a regression confidence level of 95% or better (indicated by a T-ratio of 2.0 or greater). The trimmed direct material regression results is shown in Table 5.4. As can be seen by the scatter graphs in Figures 5.6 through 5.9, variable relationships are apparent, but the variances are very large.

TABLE 5.4

REGRESSION RESULTS
DIRECT MATERIAL COST TRIMMED DATA

(dollars in thousands)

Workdays as volume

Acft Segment	r-sq'd	Constant "a"	Slope "b"
A-6	41.2%	$307.6	$.475/wkdy
P-3	19.0	158.6	.604
S-3	16.1	140.3	.305
A-3	17.5	140.6	.622

Aircraft as volume

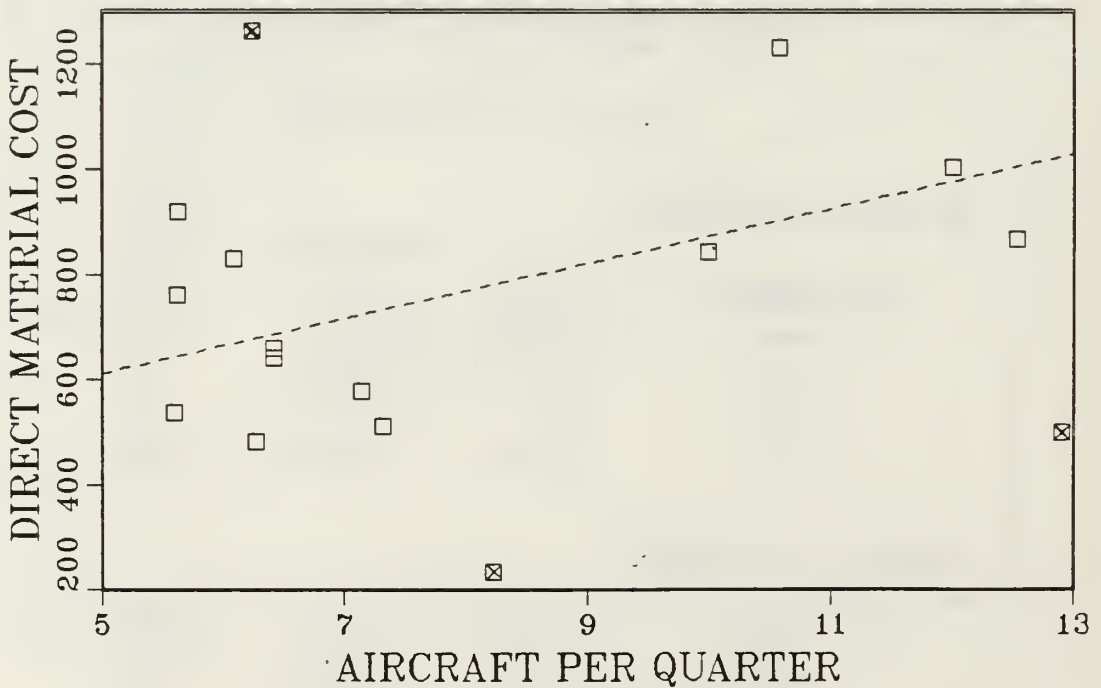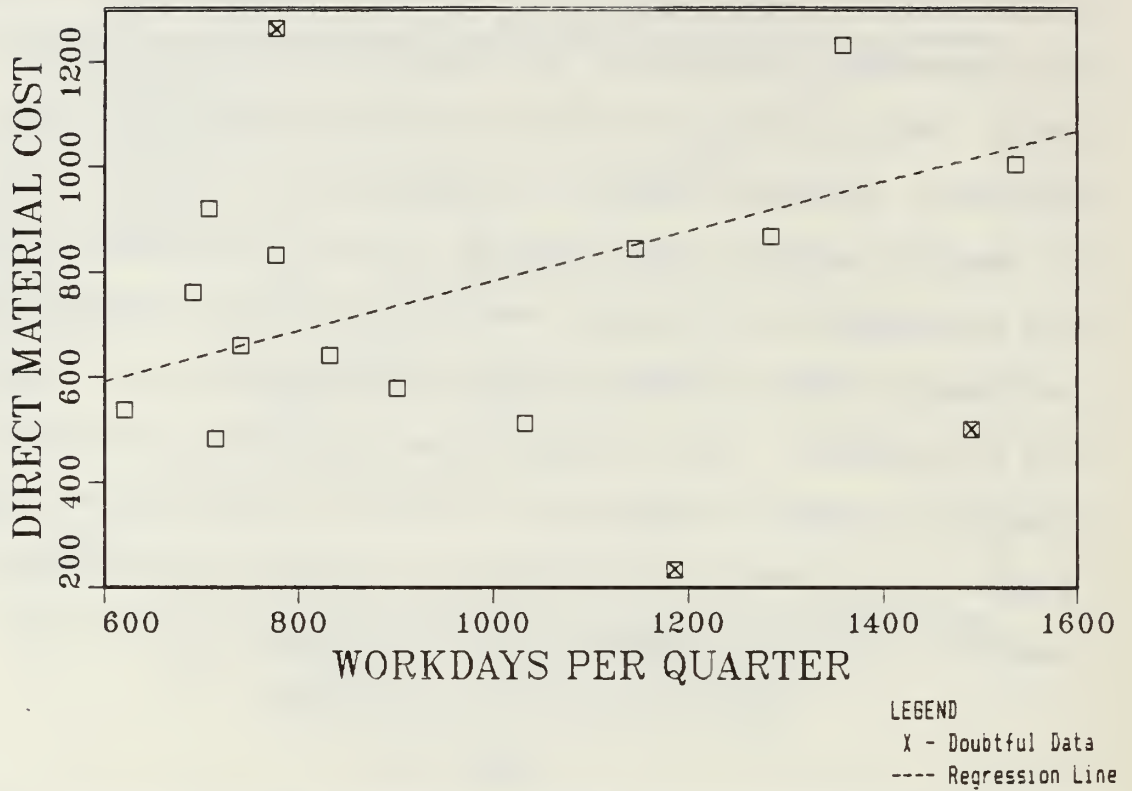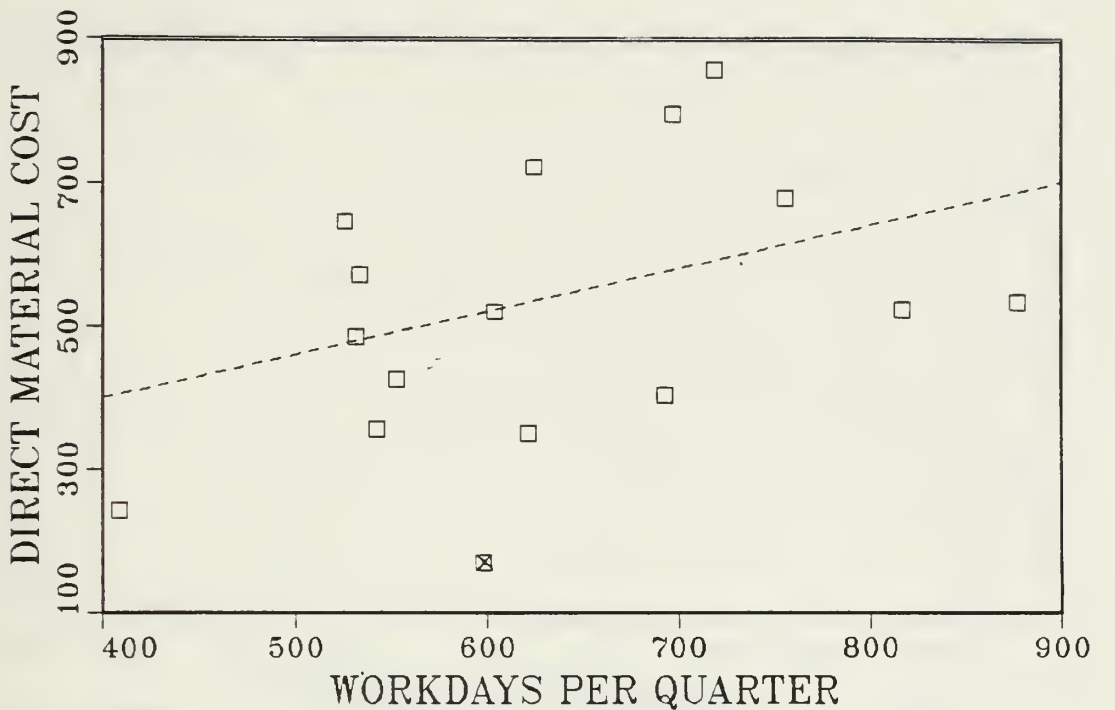| Acft Segment	r-sq'd	Constant "a"	Slope "b"
A-6	36.5%	$350.3	$52.3/acft
P-3	2.9	364.1	22.5
S-3	0.6	343.4	14.6
A-3	1.0	365.5	25.2

Figure 5.6   A-6 Segment Direct Material Cost
Scatter Graphs

74

LEGEND
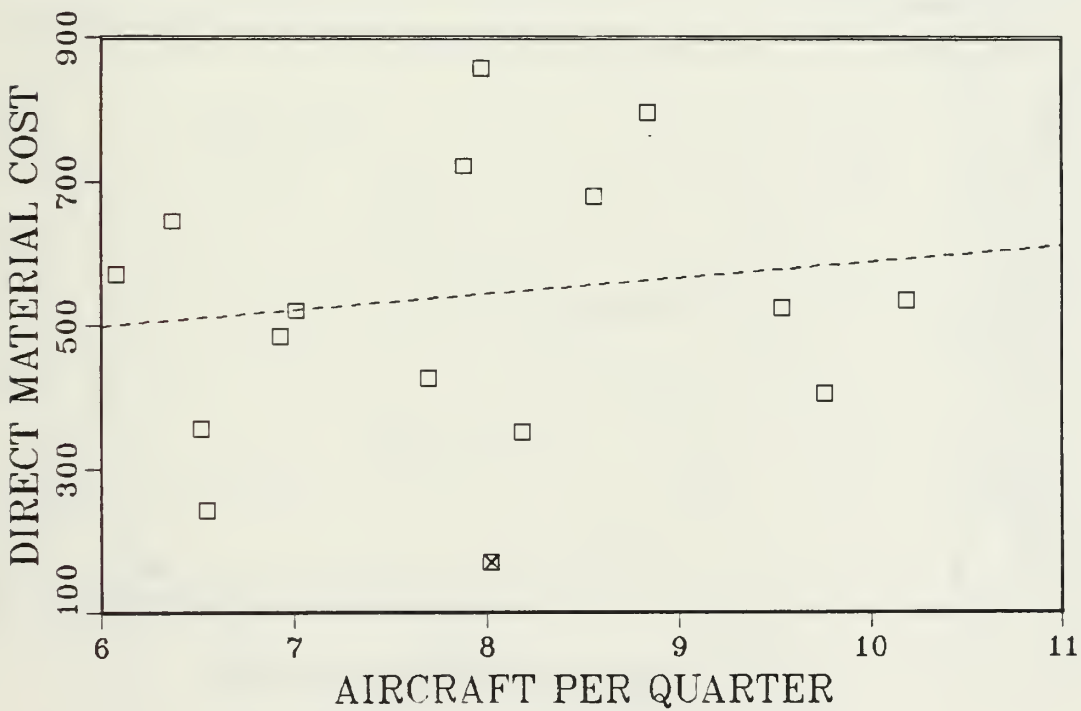X - Doubtful Data
---- Regression Line

Figure 5.7   P-3 Segment Direct Material Cost
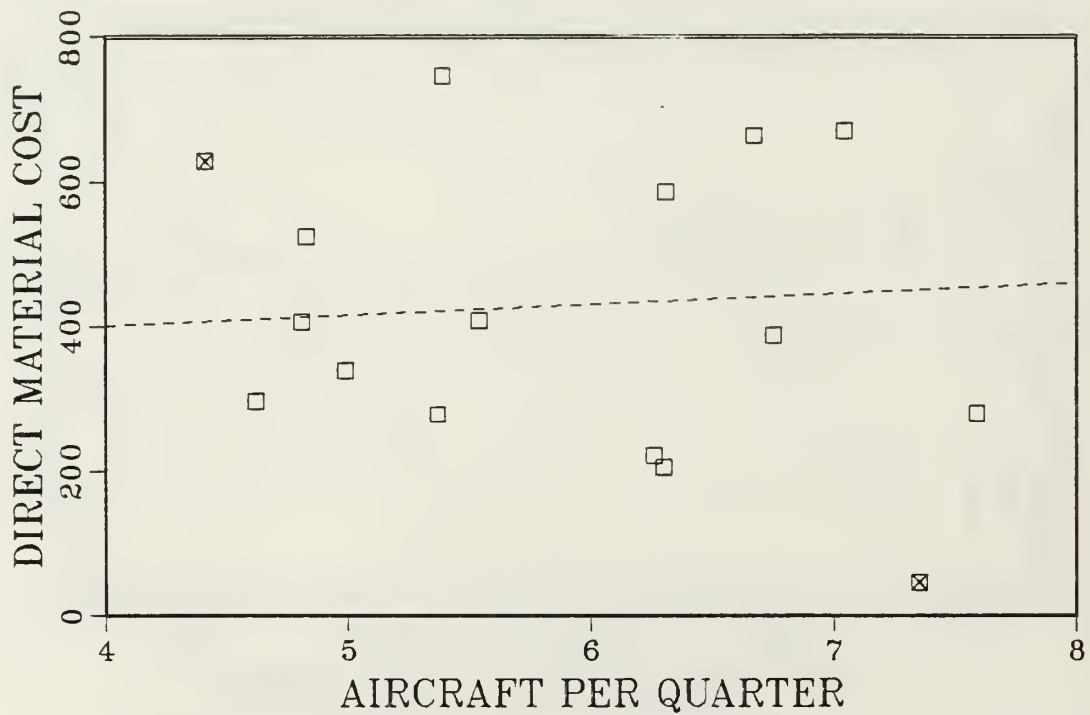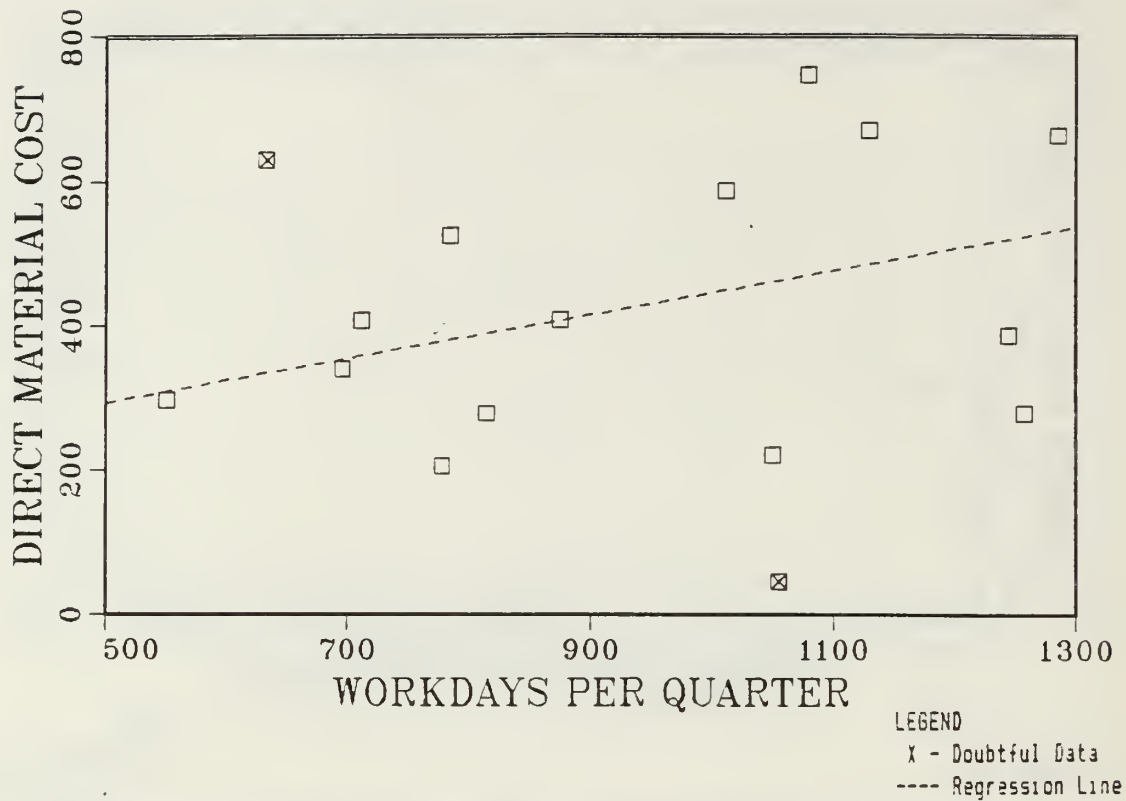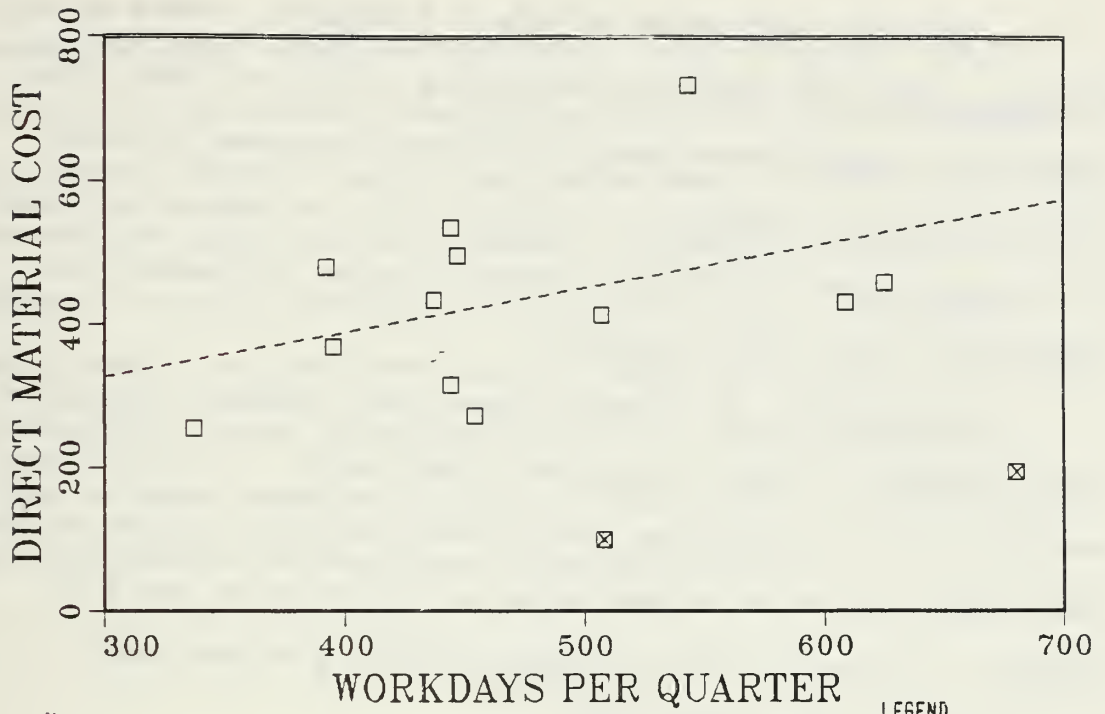   Scatter Graphs

Figure 5.8   S-3 Segment Direct Material Cost
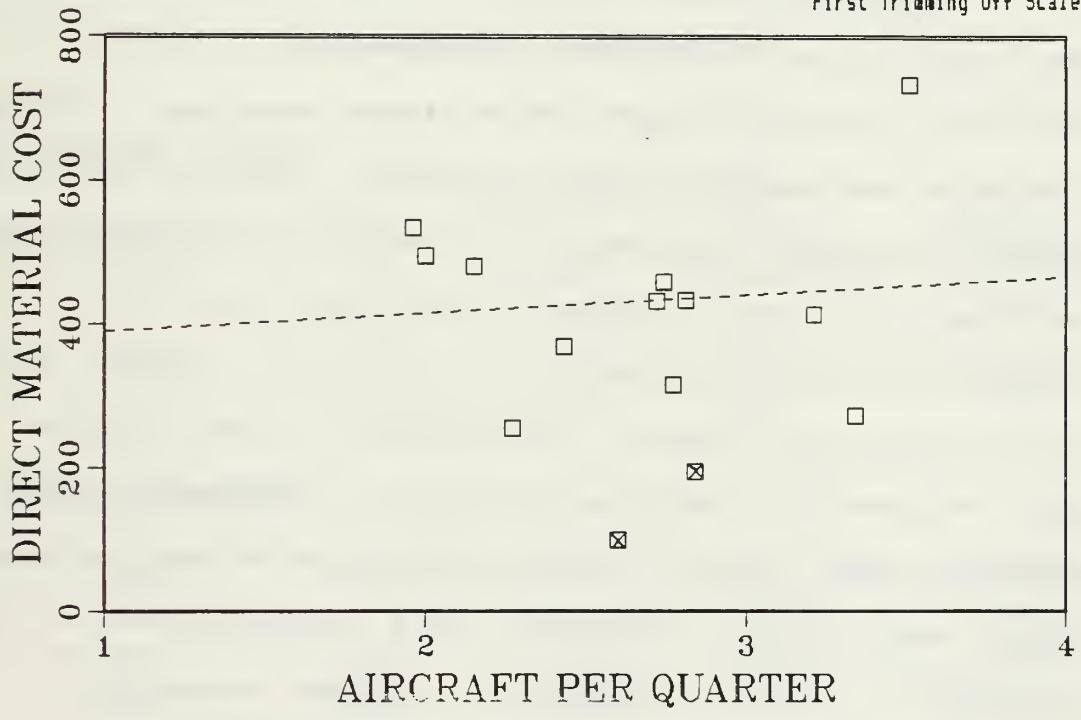   Scatter Graphs

Figure 5.9 A-3 Segment Direct Material Cost
Scatter Graphs

With the exception of the A-3 segment, where direct material costs per workday indicating close to fixed, the regression results show some consistency between aircraft types. Further trimming of the A-3 data, as shown in Figure 5.9, brought the A-3 direct material costs to comparable values with the other aircraft.

In contrast to direct labor, the constant terms for direct material costs are quite significant. In fact, the results not only indicate that direct material may be a mixed cost, but also, with slope terms as low as with the S-3 segment, it comes close to approximating a fixed cost.

3. Other Direct Services

Training, travel and other non-labor, non-material costs that can be specifically identified with direct job orders are classified under other direct services. Although this is termed a direct cost, a constant input of these costs to each job is not expected. This is a highly unpredictable cost, especially on a quarterly basis. As evident by the quarterly data, it is also very difficult to properly record in the accounting system. The presence of such frequent negatives possibly indicates transfer or reclassification adjustments for incorrect entries made one or two quarters later. Regression of these cost data produced wide variances and little, if any, relationship to volume measurements.

Again, the data were trimmed of obvious outliers. Considering the magnitude of other direct services costs in

comparison with labor and material (less than 1%) the
reliability of the regression results is of little impact on
the overall direct costs. As can be seen in Table 5.5, the
A-6 and S-3 data show an inverse incremental cost per unit
volume. Is this possible? It's more likely that other
direct services cost behavior is closer to fixed. Since the
reliabilty of this data over the short term is doubtful,
using the mean quarterly cost per type aircraft over the 16
quarter period is considered more descriptive.

TABLE 5.5

REGRESSION RESULTS
OTHER DIRECT SERVICES COSTS TRIMMED DATA

(dollars in thousands)

Workdays as volume

Acft Segment	r-sq'd	Constant "a"	Slope "b"	16 Qtr Means
A-6	6.3%	$ 25.7	$-.019/wkdy	$.018/wkdy
P-3	0.6	6.9	.011	.022
S-3	5.5	8.1	-.005	.010
A-3	3.3	-0.6	.003	.007

Aircraft as volume

	r-sq'd	Constant "a"	Slope "b"	16 Qtr Means
A-6	10.3%	$30.5	$-3.1/acft	$1.860/acft
P-3	0.1	11.1	0.3	1.860
S-3	13.5	13.7	-1.6	1.670
A-3	38.0	-3.8	1.8	1.180

B.   INDIRECT COSTS

Analyzing the aircraft program indirect costs is a more formidable task than is direct costs. First of all, it is difficult to identify, with reasonable assurance, the indirect costs associated with the aircraft program. Secondly, the indirect costs vary for a variety of reasons, making it complicated to isolate the effects of volume. Thirdly, indirect costs are more discretionary in nature. They can increase or decrease drastically within a single catagory from one fiscal period to another depending on managerial budgetary priorities. And fourthly, accounting procedures change and functional cost catagories are redefined periodically thus affecting long run consistency of measurement.

Since it is impossible to remove all the effects of the many influencing factors, any cost-volume relationships discovered are of relatively low reliability. Unless a very large number of observations are available (30 or more), it's possible that not only inaccurate but totally incorrect relationships may result. This is the main reason why the analysis of indirect cost behavior must be tempered with knowledge of the operations involved. All results must be scrutinized to ensure they are sensable and reflect, with reasonable assurance, the relationship described. In other words, if roof repair costs vary with the number of aircraft in process, a closer look at the data is needed.

Keeping this latter point in mind, the author chose for indirect cost analysis all 9500 Airframes Division production expenses and all general and production expenses transferred to 9500 from other cost centers. The Airframes Division essentially is the aircraft program. It charges from 85% to 90% of all its direct costs to the aircraft program and accounts for a quarterly average of 74% of all aircraft program direct costs. The expenses transferred to 9500 are NARF management's assessment of those G&A and production expenses that are identifiable with the aircraft program. Therefore, it is reasonable to expect to observe some relationship between these aircraft program associated indirect costs and the aircraft volume measuresments.

The aircraft program indirect costs were analyzed as an aggregate of labor, material and other costs for each occurring Functional Classification Code (FCC). Since very few of the FCCs contain significant amounts of material or other costs, it would not be beneficial to analyze costs by other than the total for each cost center FCC.

The titles of the 20 different G&A and production transferred expenses and the 28 types of Airframes Division expenses analyzed are listed in Table 5.6. The Airframes Division has actually charged expenses to 39 different FCCs over the 16 quarter period, but some that are very similar in nature were grouped together for analysis.

TABLE 5.6
FUNCTIONAL COST CLASSIFICATION CATAGORIES
AIRCRAFT PROGRAM ASSOCIATED

Airframes Division FCCs

FCC		FCC	
AA	Administration	MA	Shop Supervision
AD	Personnel Services	MB	Work Delays
DA	Management Programs	MC	Experimental Work
EA	Weapons Engineering	MD	Pre-Expended Bin Mat'l
EC	Technical Services	ME	Parts Backrobbing
FA	Quality Management	MF	Parts Cannibalization
GA	Production Control	MG	Clean-up
GC,D	Workload/Mat'l Mgmt.	MJ	Shop General
JC	Methods Development	NA,B,C	Training
KB	Preventative Maint.	PA,B	Travel
KC	Corrective Maint.	QA-E	Employee Time Allowed
KD	Minor Equipment	TB,D	Defective Work
KE	Tool Room Operations	ZA,C,G	Facilities Maintenance
LA	Equipment Calibration		

Transferred-in FCCs by Cost Center (CC)

CC	FCC		CC	FCC	
4000	FB	Verification	6500	ZA	Facilities Maint.
5000	GA	Production Cont'l	9200	EA	Weapons Engineering
5000	KD	Minor Equipment	9300	KB	Preventative Maint.
6000	KD	Minor Equipment	9300	KC	Corrective Maint.
6000	LA	Equip. Calib.	9300	KD	Minor Equipment
6500	AF	Safety Services	9300	TD	Defective Work
6500	KB	Prevent. Maint.	9400	KC	Corrective Maint.
6500	KC	Corective Maint.	9400	KD	Minor Equipment
6500	KD	Minor Equipment	9400	LA	Equip. Calibration
6500	KE	Tool Room Ops.	9400	TD	Defective Work

Source: [Ref. 10:pp. 64-83]

The same regression procedures were used as with direct costs to obtain the best possible cost-volume relationships. Data were plotted and closely examined to identify outliers that should be eliminated. Even though the use of direct hours as the volume measure showed slightly better relationships in a few cases, workdays and aircraft per quarter measurements are considered the better choices and most desirable choices with respect to matching up indirect with direct cost regression results. Distributed lag was attempted, but no significant outcomes surfaced. The final regression results of the transferred costs and the Airframes Division indirect costs are presented in Table 5.7 and 5.8.

The regression results showed only 16 of the 48 workday and 16 of the 48 aircraft per quarter relationships attempted were significant, having an r^2 of greater than 20% and a T-ratio above the 95% confidence level of 2.0 (T-ratios not shown). Of each 16, four were eliminated because the variable component of cost was close to zero or the cost's variable behavior could not be justified (such as being negative). In addition, the Airframes Division's shop general (MJ) costs, with an r^2 of less than 20%, was added because the low confidence results were considered valid. For comparison purposes and for later use when tabulating the results, the means for each fixed cost FCC are also displayed in Tables 5.7 and 5.8.

TABLE 5.7

REGRESSION RESULTS
AIRFRAMES DIVISION INDIRECT COSTS

(thousands)

	Workdays as Volume		Aircraft as Volume	
Mixed Costs				
	Constant	Slope	Constant	Slope
FCC	"a"	"b"	"a"	"b"
MA	$269.7	$.078/wkdy	$281.0	$ 9.30/acft
ME	-216.5	.101	-209.9	12.26
MG	7.7	.013	3.3	1.84
MJ	108.3	.036	69.1	6.03
NA,C	-4.4	.062	-32.6	8.71
QA-E	9.0	.024	14.1	2.76
TB,D,G	-52.7	.034	-83.1	5.59
Total				
Mixed	121.1	.348	41.9	46.48
Fixed Costs				
FCC	Mean Cost		Mean Cost	
AA	$160.9		$160.9	
AD	5.0		5.0	
DA	6.5		6.5	
EA-JC	0.8		0.8	
KB	5.8		5.8	
KC	4.1		4.1	
KD	8.2		8.2	
KE	184.7		184.7	
LA	1.2		1.2	
MB	21.7		21.7	
MC	0.1		0.1	
MD	0.5		0.5	
MF	0.7		0.7	
PA,B	6.1		6.1	
ZA,C,G	12.3		12.3	
Total				
Fixed	418.6		418.6	
Overall				
Total	$539.7	$.348/wkdy	$460.5	$46.48/acft

TABLE 5.8

REGRESSION RESULTS
INDIRECT COSTS TRANSFERRED TO AIRFRAMES DIVISION

(thousands)

		Workdays as Volume		Aircraft as Volume	
Mixed Costs					
		Constant	Slope	Constant	Slope
CC	FCC	"a"	"b"	"a"	"b"
4000	FB	$106.4	$.033/wkdy	$ 74.4	$ 5.44/acft
5000	GA	239.4	.070	179.8	11.07
6000	KD	−23.2	.012	−22.0	1.47
6000	LA	−3.4	.009	−4.9	1.16
6500	KE	7.6	.011	8.3	1.41
9300	KC	20.5	.015	129.2	2.16
Total					
Mixed		347.3	.150	254.8	22.71
Fixed Costs					
CC	FCC	Mean Cost		Mean Cost	
5000	KD	$ 0.7		$ 0.7	
6500	AF	2.0		2.0	
6500	KB	12.9		12.9	
6500	KC	56.5		56.5	
6500	KD	89.8		89.8	
6500	ZA	1.3		1.3	
9200	EA	66.2		66.2	
9300	KB	11.9		11.9	
9300	KD	31.5		31.5	
9300	TD	0.9		0.9	
9400	KC	0.3		0.3	
9400	KD	1.0		1.0	
9400	LA	18.3		18.3	
9400	TD	0.3		0.3	
Total					
Fixed		293.7		293.7	
Overall					
Total		$641.0	$.150/wkdy	$548.5	$22.7/acft

C. COST-VOLUME CURVES

Now that the regression analysis of the direct and indirect costs with respect to the volume measurements have been completed, the 16 quarter historical cost-volume curves can be constructed for each of the four aircraft types and the aircraft program as a whole.

1. Fixed Components

The fixed components of each curve will consist of the sums of the fixed portions of direct labor, direct material, other direct services and all indirect costs. In the case of direct labor and material, the fixed portion is simply the intercept value "a" of the regression results. The other direct services costs are considered totally fixed; therefore, the 16 quarter mean is used. For the indirect costs, the fixed portion is the sum of the intercept values of the mixed costs and the means of the fixed costs of the 9500 division's production (PRDN) expenses and transferred-in expenses, plus the 16 quarter mean of the remaining NARF G&A expenses.

Percent of direct labor hours is used to allocate remaining G&A to the aircraft program. An allocation factor based on the applicable volume measure is used to distribute the aircraft program fixed indirect costs between the four aircraft segments.

2. Variable Components

The variable components of each curve will consist of the sums of the weighted averages of the slope values "b"

(weighted by % workdays or aircraft per quarter as applicable) of direct labor, direct material, and the slopes of the indirect mixed costs. The variable portion of the four aircraft segments' mixed costs must be assumed to be equal to the Airframes Division variable value, for there is no way to determine otherwise. Tables 5.9 through 5.13 show the breakdown of the fixed and variable components of each cost-volume curve. Table 5.14 summarizes the fixed and variable components of each segment and Figure 5.10 shows the graphs of the resultant total cost-volume relationships.

3. Evaluation of Results

Comparing the final cost-volume relationships of each segment, it can be seen that the P-3 segment has the highest per workday variable cost rate, the A-3 and A-6 segments being next highest and the S-3 segment being significantly lower. This follows the observed behavior of direct labor costs, as would be expected since they are the major contributor to the variable component. For the per aircraft variable cost rates this pattern is not the same. Here, the P-3 segment dropped to the lowest while the others remained in the same relative ranking, as again was the case with direct labor. This can possibly be explained, at least in part, by the fact that on the average the P-3 segment has considerably shorter turnaround times (TAT) than the other segments --averaging about 85 workdays compared to 130, 170 and 250 for the A-6, S-3 and A-3 segments respectively.

TABLE 5.9

AIRCRAFT PROGRAM
COST-VOLUME RELATIONSHIPS

(thousands)

	Workdays as Volume		Aircraft as Volume	
Fixed Component				
Direct				
Labor	757.8		912.5	
Material	747.0		1423.3	
Other	43.7	$1548.5	43.7	$2379.5
Indirect				
9500 Prdn	539.7		460.5	
Trans G&A	641.0		541.9	
Other G&A	6388.3	$7569.0	6388.3	$7390.7
Total Fixed		$9117.5		$9770.2
Variable Component				
Direct				
Labor	1.275		151.3	
Material	.465	$1.740/wkdy	30.2	$181.5/acft
Indirect				
9500 Prdn	.349		46.5	
Trans G&A	.151	$ .500/wkdy	22.7	$ 69.2/acft
Total Variable		$2.240/wkdy		$250.7/acft

Cost-Volume Curves:

$$Cost = 9117 + 2.24 \times Wkdys$$

$$Cost = 9770 + 250.7 \times Acft$$

TABLE 5.10

A-6 SEGMENT
COST-VOLUME RELATIONSHIPS

(thousands)

	Workdays as Volume		Aircraft as Volume	
Fixed Component				
Direct				
Labor	166.0		322.5	
Material	307.6		350.3	
Other	17.0	$ 490.6	17.0	$ 689.8
Indirect				
Allocation				
31.8% Wkdys		$2406.9		
32.1% Acft				$2372.4
Total Fixed		$2897.5		$3062.2
Variable Component				
Direct				
Labor	1.442		158.7	
Material	.475	$1.917/wkdy	52.3	$211.0/acft
Indirect				
9500 Prdn	.349		46.5	
Trans G&A	.151	$ .500/wkdy	22.7	$ 69.2/acft
Total Variable		$2.417/wkdy		$280.2/acft

Cost-Volume Curves:

$$Cost = 2898 + 2.42 \times Wkdys$$

$$Cost = 3062 + 280 \times Acft$$

TABLE 5.11

P-3 SEGMENT
COST-VOLUME RELATIONSHIPS

(thousands)

	Workdays as Volume		Aircraft as Volume	
Fixed Component				
Direct				
Labor	174.2		230.6	
Material	158.6		364.1	
Other	14.1	$ 346.9	14.1	$ 608.8
Indirect				
Allocation				
20.9% Wkdys		$1581.9		
32.3% Acft				$2387.2
Total Fixed		$1928.8		$2996.0
Variable Component				
Direct				
Labor	1.789		136.0	
Material	.604	$2.393/wkdy	22.5	$158.5/acft
Indirect				
9500 Prdn	.349		46.5	
Trans G&A	.151	$ .500/wkdy	22.7	$ 69.2/acft
Total Variable		$2.893/wkdy		$227.7/acft

Cost-Volume Curves:

Cost = 1929 + 2.89 x Wkdys

Cost = 2996 + 228 x Acft

TABLE 5.12

S-3 SEGMENT
COST-VOLUME RELATIONSHIPS

(thousands)

	Workdays as Volume		Aircraft as Volume	
Fixed Component				
Direct				
Labor	247.1		24.9	
Material	140.3		343.5	
Other	9.1	$ 396.5	9.1	$ 377.5
Indirect				
Allocation				
30.2% Wkdys		$2285.8		
24.2% Acft				$1788.6
Total Fixed		$2682.3		$2166.0
Variable Component				
Direct				
Labor	.714		151.0	
Material	.305	$1.019/wkdy	14.6	$165.6/acft
Indirect				
9500 Prdn	.349		46.5	
Trans G&A	.151	$ .500/wkdy	22.7	$ 69.2/acft
Total Variable		$1.519/wkdy		$234.8/acft

Cost-Volume Curves:

Cost = 2682 + 1.52 x Wkdys

Cost = 2166 + 235 x Acft

TABLE 5.13

A-3 SEGMENT
COST-VOLUME RELATIONSHIPS

(thousands)

	Workdays as Volume		Aircraft as Volume	
Fixed Component				
Direct				
Labor	170.4		334.5	
Material	140.6		365.5	
Other	3.5	$ 314.5	3.5	$ 703.5
Indirect				
Allocation				
15.4% Wkdys		$1165.6		
10.5% Acft				$ 776.0
Total Fixed		$1480.1		$1479.5
Variable Component				
Direct				
Labor	1.472		189.3	
Material	.622	$2.094/wkdy	25.2	$214.5/acft
Indirect				
9500 Prdn	.349		46.5	
Trans G&A	.151	$ .500/wkdy	22.7	$ 69.2/acft
Total Variable		$2.594/wkdy		$283.7/acft

Cost-Volume Curves:

$$Cost = 1480 + 2.59 \times Wkdys$$

$$Cost = 1480 + 284 \times Acft$$

92

However, ranking by average turnaround times does not hold up in comparing the A-6, S-3 and A-3 segments per aircraft variable cost rates. The A-3 segment is the highest, which matches, but the A-6 segment's per aircraft variable cost component is almost equal to the A-3 segment's (yet TAT is about half) and $46,000 per aircraft higher than the S-3 segment. It is obvious then that there must be other factors (such as relative productivities or production methods) involved in explaining the different variable costs per aircraft between segments.

TABLE 5.14

SUMMARY OF
COST-VOLUME RELATIONSHIPS

(thousands)

Workdays as volume

Acft Segment	Fixed Component	Variable Component
A-6	$2898	$2.42/wkdy
P-3	1929	2.89
S-3	2682	1.52
A-3	1480	2.59
Acft Prog	9117	2.24

Aircraft as volume

A-6	$3062	$280/acft
P-3	2996	228
S-3	2166	235
A-3	1480	284
Acft Prog	9770	251
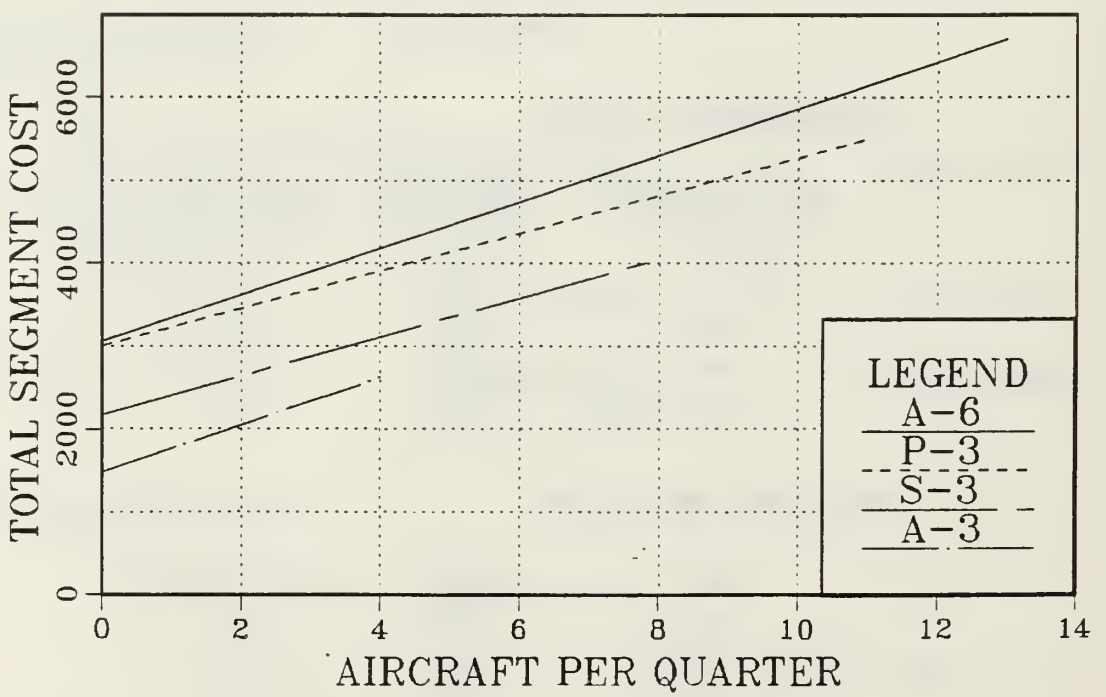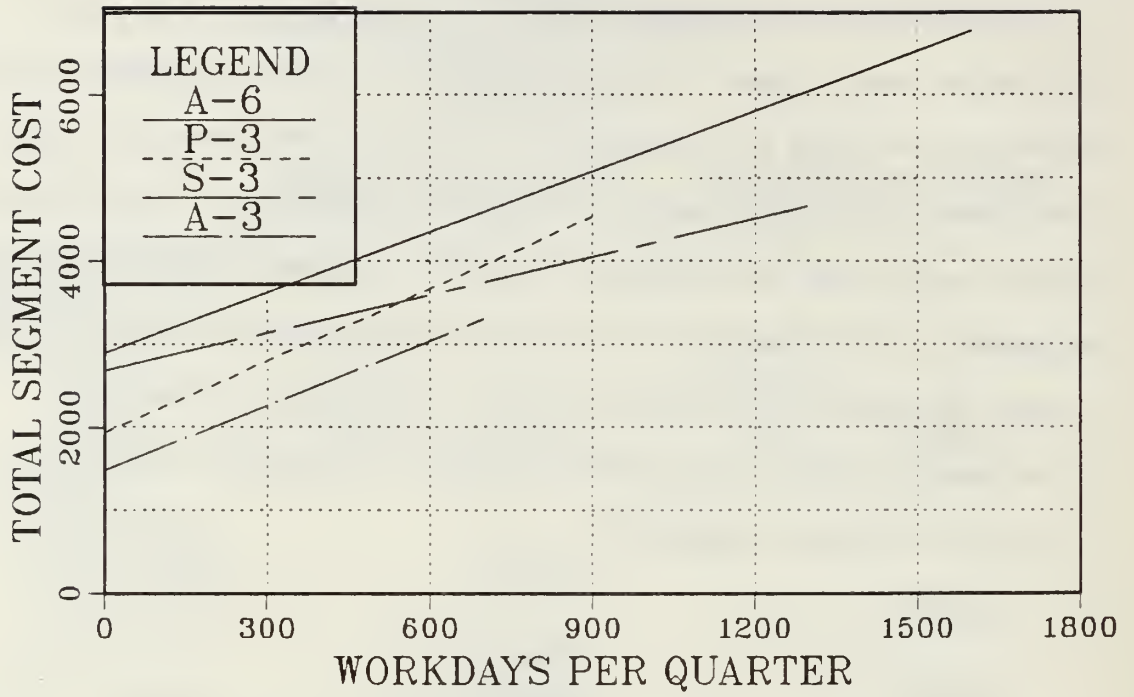
Figure 5.10   Total Segment Cost-Volume Curves.

D. COST-VOLUME APPLICATION

In order to properly use the cost-volume relationship derived through regression analysis, there are several preliminary steps that must be accomplished in order to attain the volume measurements to be used and logically predict the related costs.

1. Volume

It's extremely important that volume estimates be as accurate as possible. The induction and completion dates of all aircraft expected to be in-house during the quarter of interest are all the information needed to calculate the volume measurements, both workdays per quarter and aircraft per quarter. From aircraft job completion reports reviewed by the author, actual TATs were rarely equal to or below scheduled. Every effort should be made to ensure that TAT estimates are realistic and take into account probable delays. Then once calculated, applying the volume values to the cost-volume relationships will yield an estimate of the average overall aircraft program or segment costs (in 1982 dollars).

2. Evaluation of Errors

Since the predicted cost at any given volume is only an estimate of the average costs using only 16 quarters of data (of sometimes questionable accuracy), an understanding of the cost distribution about the resultant regression line is important. A standard error of estimate (SEE) was

computed as part of the regression analysis for each variable
cost component of the final cost-volume relationship.
Assumming the cost-volume data are normally distributed about
the regression line, which was confirmed through observation
of the residuals (error terms) being randomly distributed
around zero, there's approximately a 67% probability of the
variable costs being within plus or minus one SEE of the
predicted average value at any volume within the revelant
range. This is not the total possible error involved,
however, for the SEEs are those resulting from regression of
costs contributing only to the variable component of the
cost-volume relationships. The majority of the fixed
component costs were computed using the 16 quarter means of
the individual costs which all have an associated standard
deviation. Therefore, the variable component and the fixed
component have errors of distribution associated with the
estimation of the aircraft program or segment costs.

Table 5.15 lists the results of summing the variable
and fixed error terms for each cost-volume expression. These
summed errors probably overestimate the value of the standard
error of estimate for the resultant cost-volume curves, for
summing errors is not mathenatically valid. However, knowing
the range of the possible error in estimation is definitely
important, for then management can at least evaluate the
extremes, worst and best cases, for decision purposes.
Further knowledge of circumstances and factors that may

TABLE 5.15

ERRORS OF ESTIMATE
OF THE COST-VOLUME MODELS

(thousands)

Workdays as Volume

ACFT Segment	Dir Labor SEE	Dir Mat'l SEE	Indirect SEE	Total SEE	Fixed St.Dev.
A-6	$ 87	$175	$19	$ 282	$ 639
P-3	177	163	18	359	420
S-3	148	170	12	330	607
A-3	107	165	8	280	309
AC PROG	371	724	22	1116	2011

Aircraft as Volume

ACFT Segment	Dir Labor SEE	Dir Mat'l SEE	Indirect SEE	Total SEE	Fixed St.Dev.
A-6	$118	$182	$19	$ 319	$ 645
P-3	229	178	18	427	649
S-3	164	185	12	362	486
A-3	85	165	8	257	211
AC PROG	525	714	22	1261	2011

factors that may influence program costs can narrow this cost range and guide management toward a higher confidence estimate.

Productivity has a definite influence on costs. For instance, in FY85, it can be seen from the volume data displayed in Tables 4.1 through 4.5 that the measurement hours/aircraft (a very rough productivity dimension) jumped significantly in the A-6, P-3 and A-3 segments indicating a productivity drop. The reason for this is not known, but aircraft and workday variable costs for that period have high

"positive" error terms (actual costs were above the regression line). Estimation of training levels or recent actual productivity trends may predict whether to expect above or below average productivity and thus costs below or above the cost-volume curve.

Direct or indirect personnel levels can certainly adversely or positively affect productivity and program costs. Workload changes from quarter to quarter can easily cause an over or under-staffing, for personnel adjustments always require long range planning. As can be seen by the graphs in Figure 5.11, the personnel level bottomed out at the end of FY84 beginning of FY85 (quarter 12 and 13 of the 16 quarter period), and has been climbing in FY85. Since volume has not significantly increased, over staffing may have occurred and contributed to higher costs. Knowledge of such a situation gives the manager confidence in believing costs will tend above the average cost-volume relationship.

Volume changes from quarter to quarter are inevitable and certainly can be expected to push costs above or below average. Not only does a change in volume influence costs, but also the direction, duration and rate of the volume change. To determine whether any pattern of influence could be observed over the 16 quarter period, the quarterly changes in the two volume measurements, workdays and aircraft, were compared to the residuals of each segment's direct labor cost regression results. Figures 5.12 through 5.15 display the
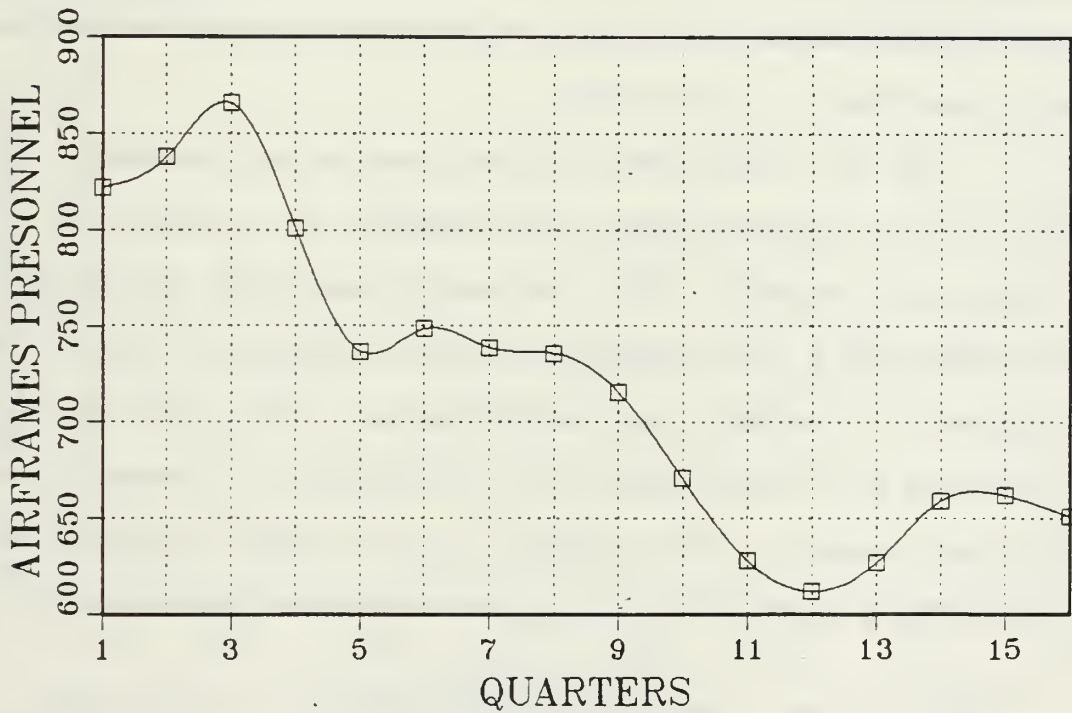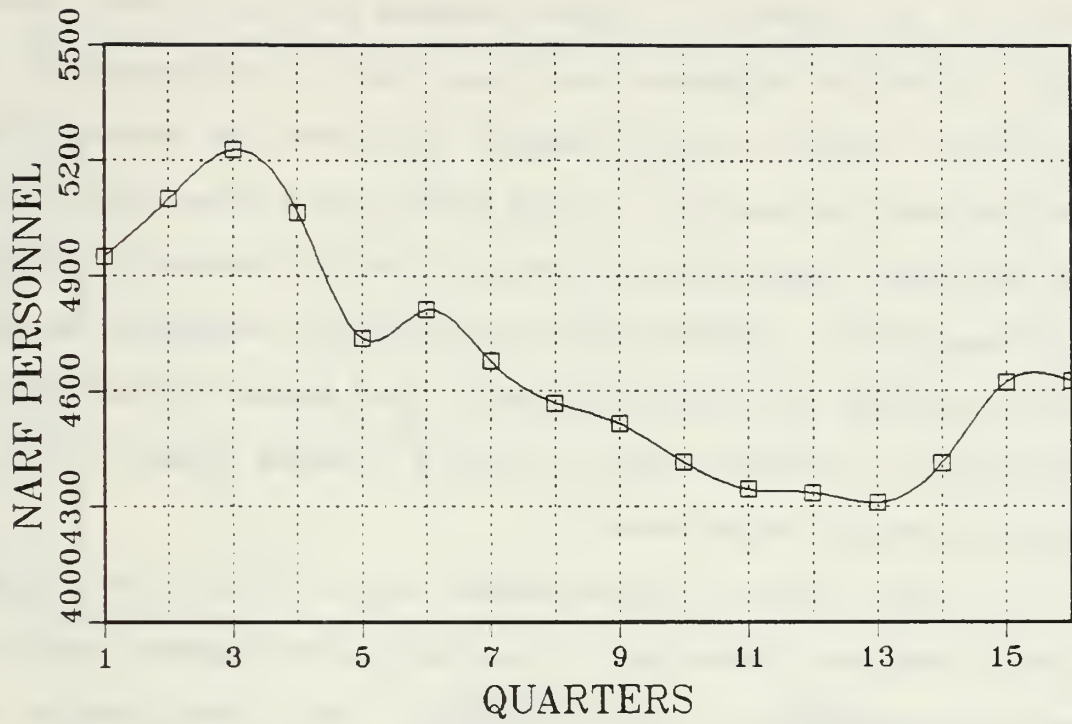
Figure 5.11 NARF and Airframes Division Personnel
Strengths for FY82-FY85

plots of the quarterly volume changes and the direct labor cost residuals[5] together for comparison. The residuals are plotted a second time to compare them with the volume changes of the previous quarter. From these plots some patterns can be observed, especially in the A-6 and A-3 segments (Figures 5.12 and 5.15). Indications are that the residuals move in the direction of volume changes. This means increases or decreases in volume result in costs tending toward above or below average respectively.

The rate of volume change and duration also appear to affect residual behavior. The sharper the volume change, the more instantaneous is cost response. With more gradual but continually increasing or decreasing volume changes, costs tend to lag volume changes by one or two quarters and are more resistant to reversals.

By all means this is not conclusive evidence, for the P-3 and S-3 segments show the opposite in a couple of instances. However, this certainly indicates the possibility of predictable cost responses to the workload fluctuations inherent in the NARF aircraft program. This kind of knowledge would obviously be valuable and is certainly worth further research. For example, with a sharp increase in volume this quarter, being able to predict with some

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[5]Only direct labor was used because it is the most reliable variable relationship regressed and identifiable to each segment.
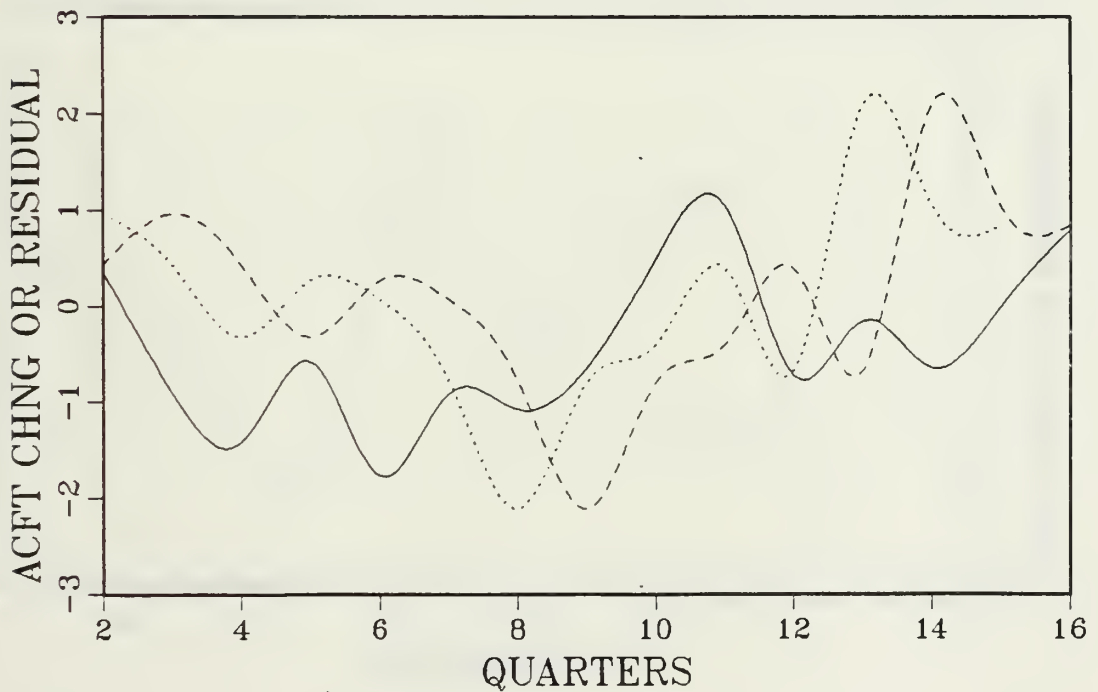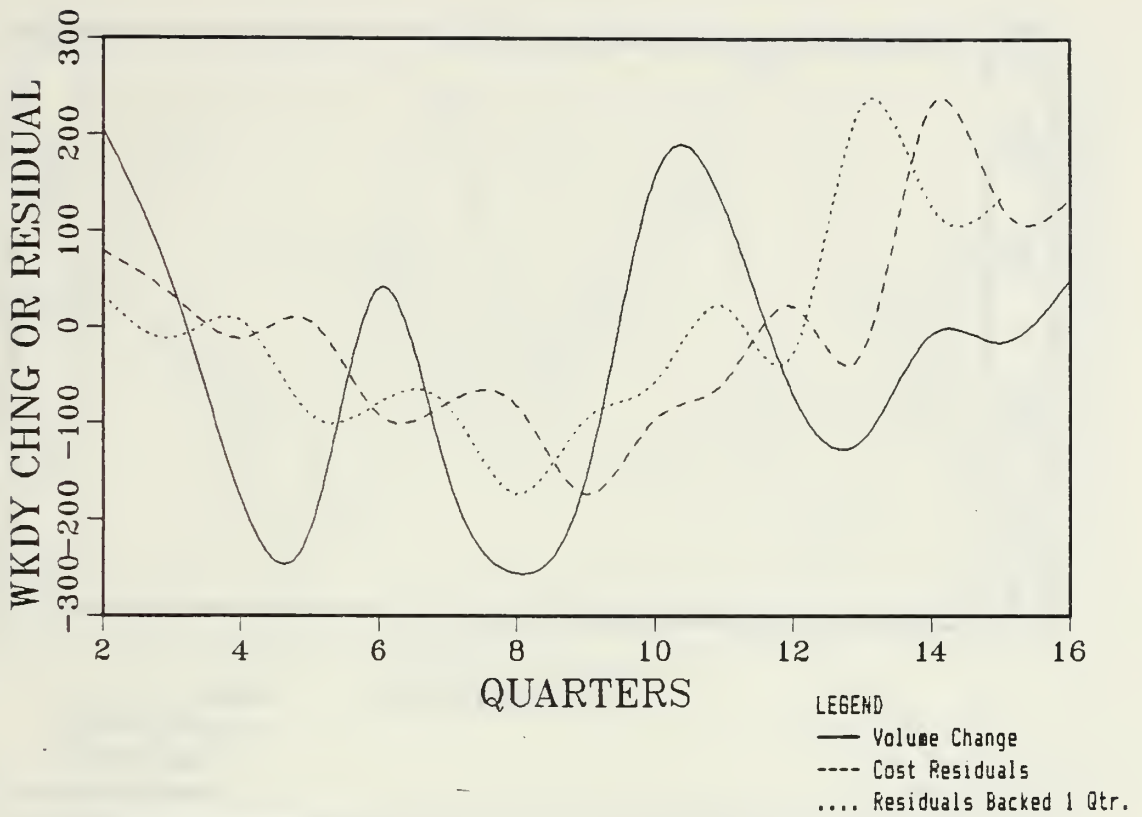
Figure 5.12   Comparison of A-6 Segment Volume Changes
              with Direct Labor Cost Residuals

101
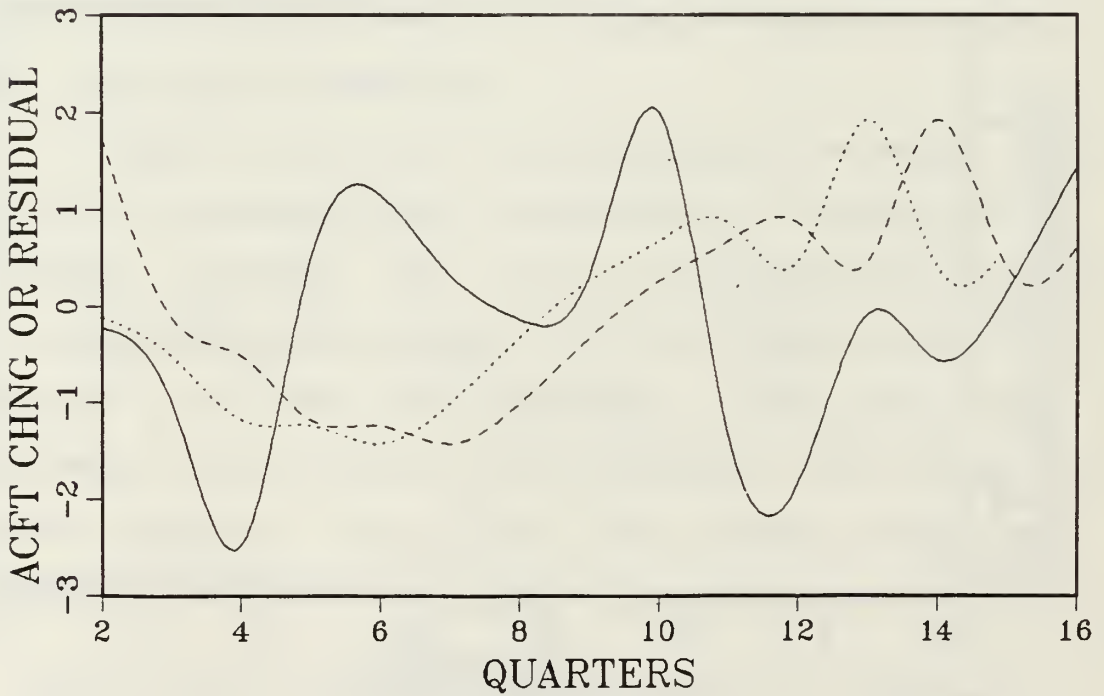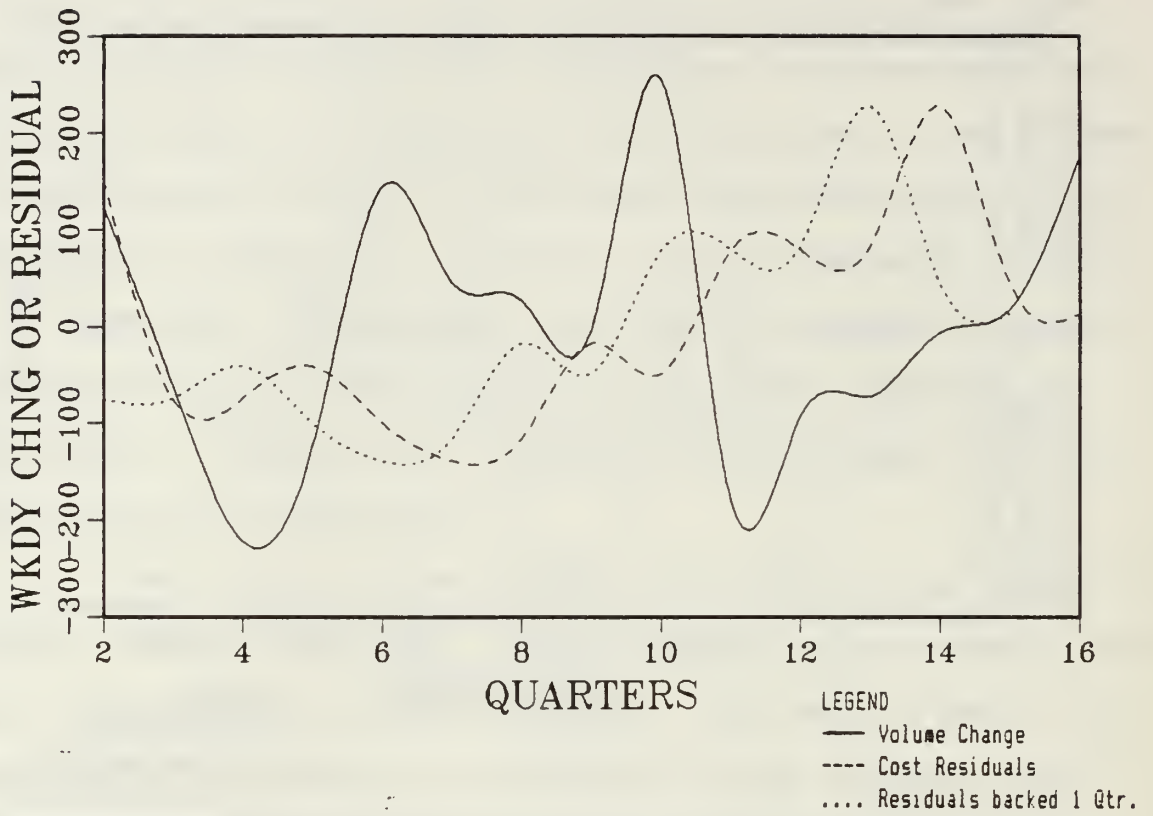
Figure 5.13   Comparison of P-3 Segment Volume Changes
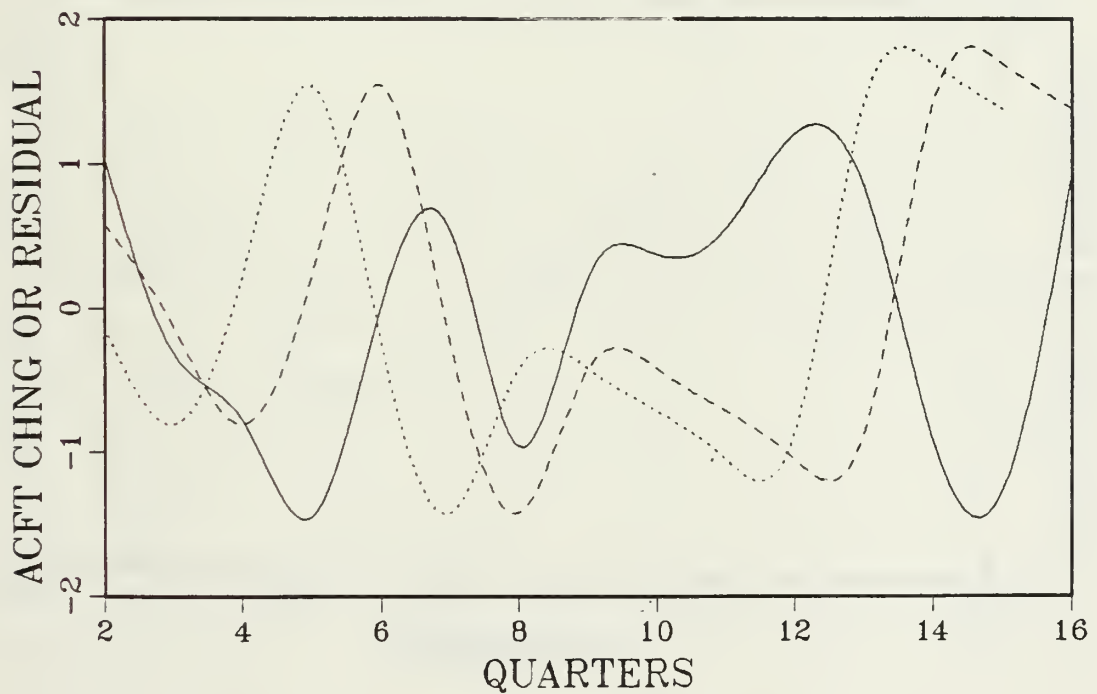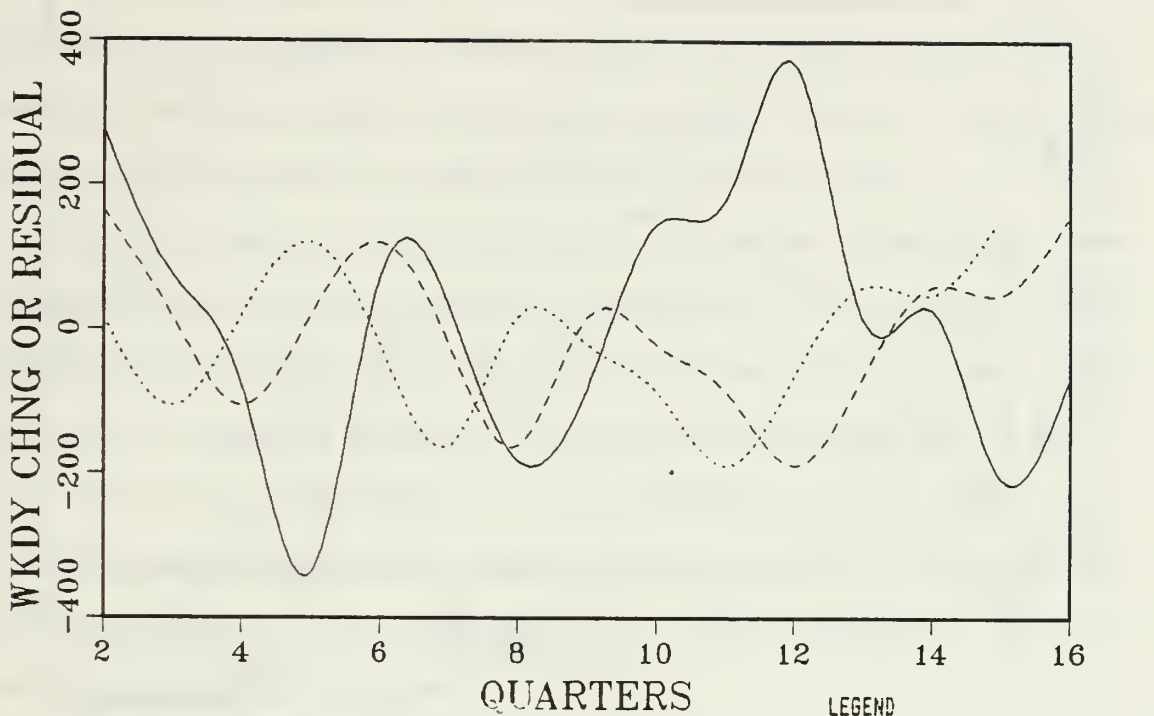with Direct Labor Cost Residuals

Figure 5.14   Comparison of S-3 Segment Volume Changes
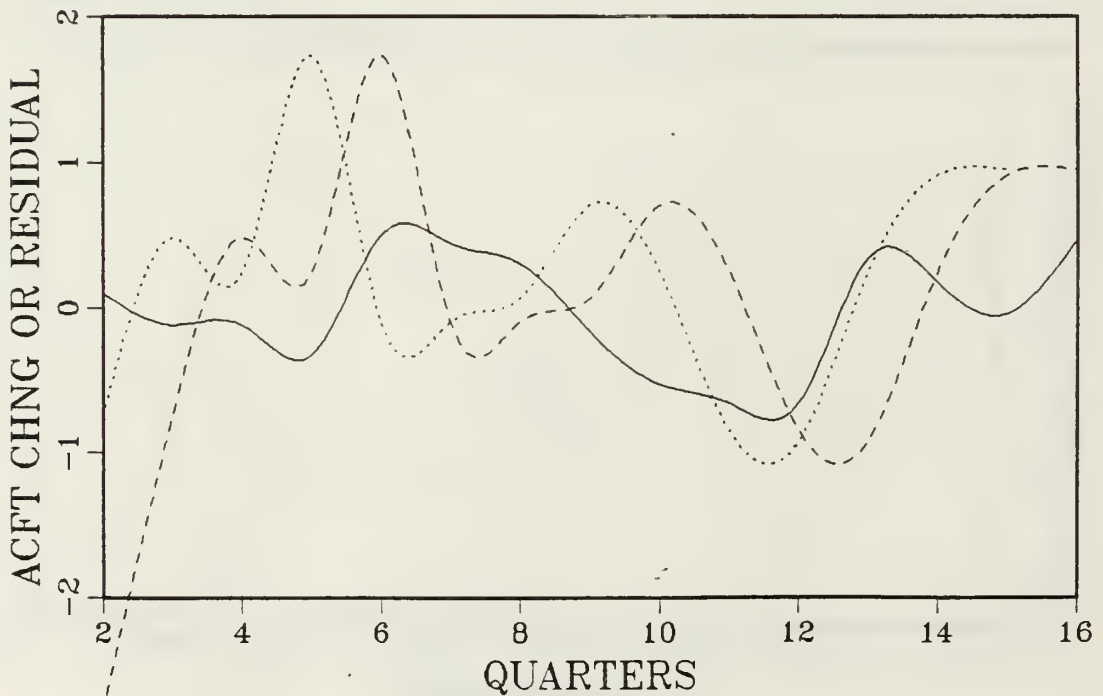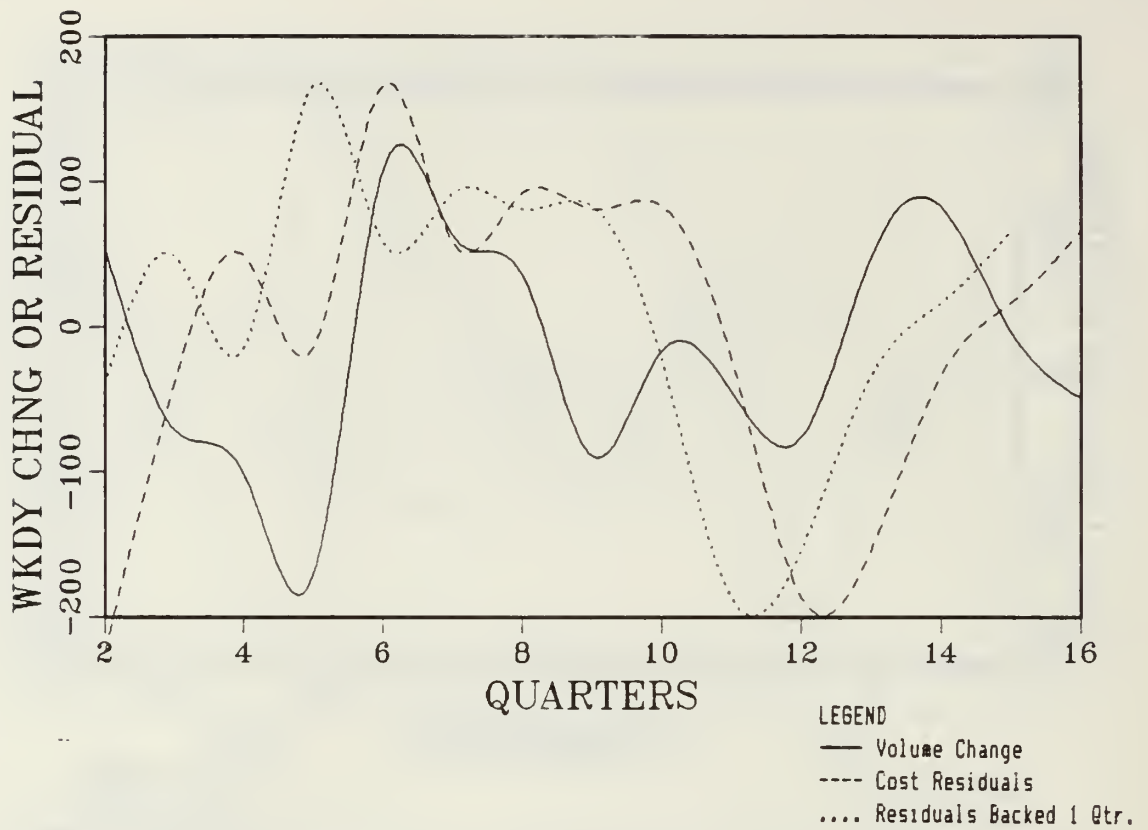with Direct Labor Cost Residuals

103

Figure 5.15 Comparison of A-3 Segment Volume Changes
with Direct Labor Cost Residuals

probability a segment's costs should be significantly above average next quarter, even though slightly below average now, would greatly assist negotiating aircraft prices.

Further study may indicate different cost responses exist for each of the aircraft segments. It's possible that production methods, such as the P-3's moving line, or other efficiency factors peculiar to an aircraft type may also influence cost response to volume changes. With more reliable data and a more sophisticated analysis, specific probabilities of cost response to volume changes or other factors could be learned.

VI. BREAK-EVEN ANALYSIS

Up to this point the focus has been solely on the costs
associated with the aircraft program and its segments.   In
order to make meaningful use of this cost behavior knowledge,
it must be compared to the revenues of the program to assess
its net income status.   As was discussed in part C. of
Chapter III, break-even analysis compares the cost-volume
relations with the revenue-volume relations and provides the
means to estimate how current or projected workloads will
affect an operation's net income.

A.   REVENUE DETERMINATION

1.   Matching Costs and Revenues

Revenue for the NARF Alameda aircraft program comes
from the individual SDLM rework jobs accomplished on fleet,
reserve and RDT&E aircraft.   The amount NARF is compensated
for each aircraft is based on the fixed price established for
each aircraft TMS for the quarter in which inducted.

In order to properly compare costs to revenue in a
break-even analysis, it is imperative that costs and revenues
be matched as closely as possible.   Since a single aircraft
is rarely inducted and completed all in a single quarter,
quarterly revenue is difficult to match with quarterly

expenses. Assuming all costs incurred during a fiscal quarter are recorded by the job order system, and their behaviors are reflected in the cost-volume relationships derived in Chapter V, then what is needed to match these costs are equivalent average quarterly revenue-volume relationships over this period for the aircraft program and each of its segments.

Percent completion is an accepted manner with which to recognize revenue for periods much less than the length of a project. Normally this involves determining the percent of total budgeted or estimated costs incurred during a period and applying it to the total expected revenue. Thus, x% of project costs for the period are matched with x% of the revenue.

2. Calculating Revenue

The only per quarter measure of job completion readily available on a historical basis is workdays per quarter. This measure is derived from the physical induction and completion dates. Considering that on the average within the aircraft program and its segments costs are distributed evenly over each workday an aircraft is in-house, the revenue received for that aircraft can be likewise distributed. This means the percent completion per quarter can be calculated using the workdays during the quarter and the total estimated workdays to complete the job. Since historical data are being used in this case, the percent completion is based on the actual total workdays required.

Applying the percent completion factors to each aircraft's fixed price distributes the aircraft's revenue over the quarters it is in-house. Summing all aircraft revenue per quarter gives the total aircraft program or segment revenue per quarter and is displayed in Table 6.1. From quarterly workday and aircraft per quarter totals, average quarterly revenue per workday and average revenue per aircraft are calculated.

TABLE 6.1

AIRCRAFT PROGRAM REVENUE

(thousands)

QTR	A-6 Segment	P-3 Segment	S-3 Segment	A-3 Segment	ACFT Program
821	$4327	$3710	$1721	$1576	$12105
822	4574	3622	1994	1761	12529
823	4440	3339	1916	1717	12100
824	4021	2427	1671	1653	10298
831	3931	2527	1365	1462	9287
832	3326	2875	1492	1899	9594
833	3054	3382	1603	2237	10278
834	2520	3518	1356	2349	9744
841	2470	3731	1493	2308	10004
842	3147	4596	1701	2127	11571
843	3880	3964	1922	1694	11461
844	3658	3154	2254	1229	10295
851	4126	3753	2793	1691	12364
852	4748	4278	3286	2047	14360
853	5565	4757	3485	2215	16023
854	6129	5742	3991	2598	18462

3. Evaluating the Results

There are two possible revenue rates that can be calculated from the data, one including FY85 revenues and one without (see Table 6.2 below). As can be seen by reviewing the quarterly revenues, FY85 values are significantly higher than those in FY82-84. During FY85 aircraft prices were heavily subsidized for recoupement of losses incurred in FY84. These FY85 data distort the overall 16 quarter revenue-volume trend. Using "no constant" regression analysis (where the regression line passes through the

TABLE 6.2

AIRCRAFT PROGRAM REVENUE RATES

(thousands)

Per Workday

ACFT Segment	FY82-84	FY85	FY82-85	Variable Cost Rate
A-6	$3.26	$7.20	$4.39	$2.42/wkdy
P-3	5.20	7.99	5.97	2.89
S-3	1.94	2.99	2.27	1.52
A-3	3.62	5.20	4.22	2.59
AC PROG	3.36	5.95	3.97	2.24

Per Aircraft

A-6	$398	$862	$537	$280/acft
P-3	416	666	478	228
S-3	298	535	361	235
A-3	675	1037	773	284
AC PROG	414	715	497	251

origin) the FY82-84 data produced high confidence results
(r² of 70% or more).   However, it can also be considered that
since the FY85 recoupement made up for past losses, then this
higher rate matches more closely with costs on the average
over the 16 quarter period.

B.   BREAK-EVEN CHARTS
    Figures 6.1 through 6.5 graph the fixed and variable
costs and the two revenue rates (FY82-84 and FY82-85) as
break-even charts for the aircraft program and its segments.
Further example revenue rates are plotted on the charts to
demonstrate the range of revenue rates that are applicable
within the relevant ranges (ranges of volumes occurring over
the 16 quarter period) to meet the costs described by the
average 16 quarter cost-volume curve.
    1.   Break-Even Volume
        The level of activity where revenues are equal to
total costs is called the break-even point or break-even
volume.   The break-even volume is dependent on both the fixed
and variable components of the costs associated with an
aircraft segment.   Lowering either will cause a reduction in
the break-even volume.   For instance, in the case of aircraft
program, dropping the fixed costs $100,000 will decrease the
break-even volume by 50 workdays per quarter (about 1%).   To
reduce the break-even volume the same amount with variable
costs would require a decrease of about $32,000 per workday.
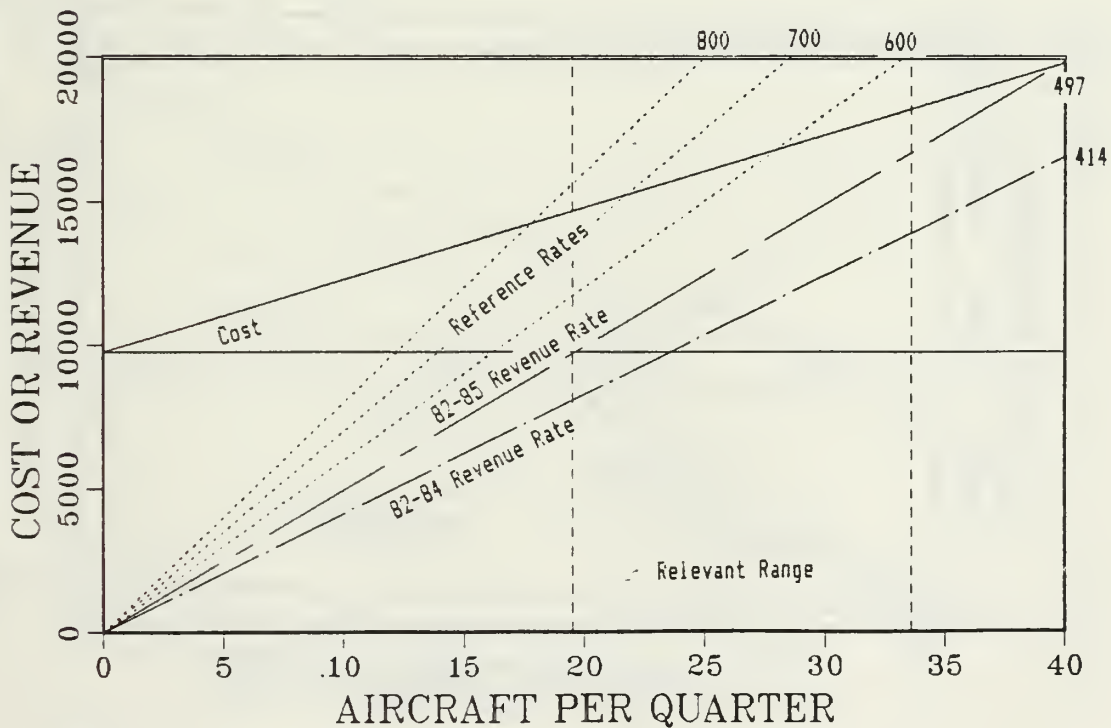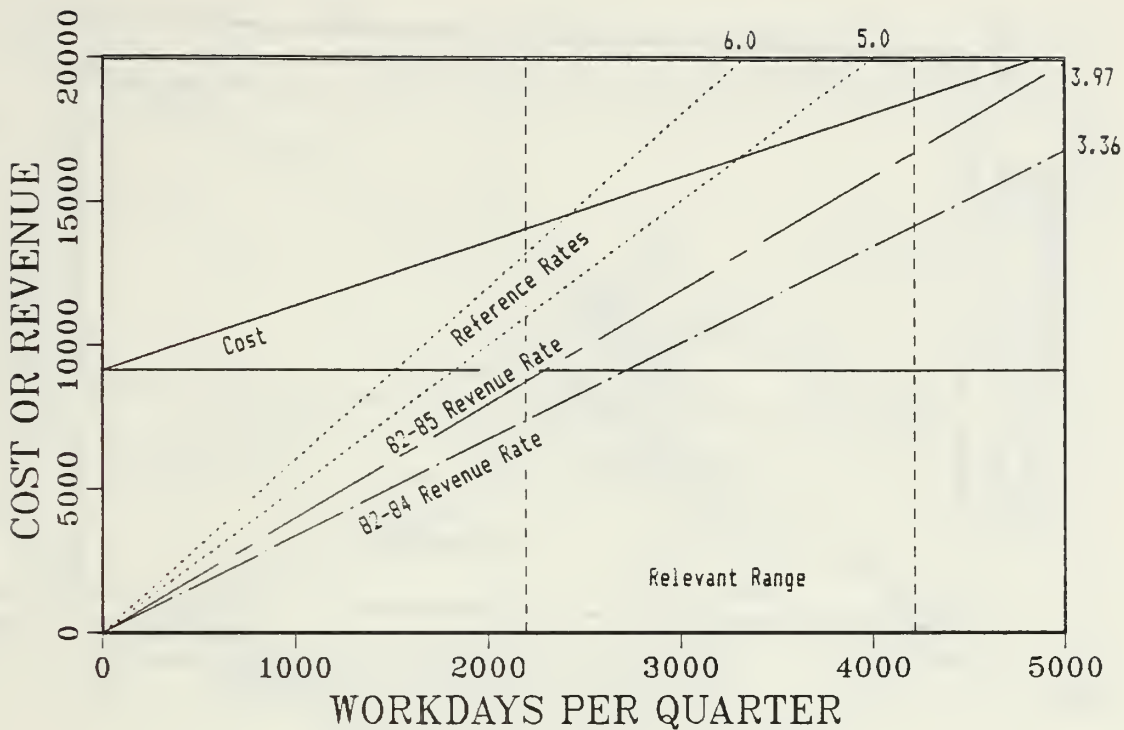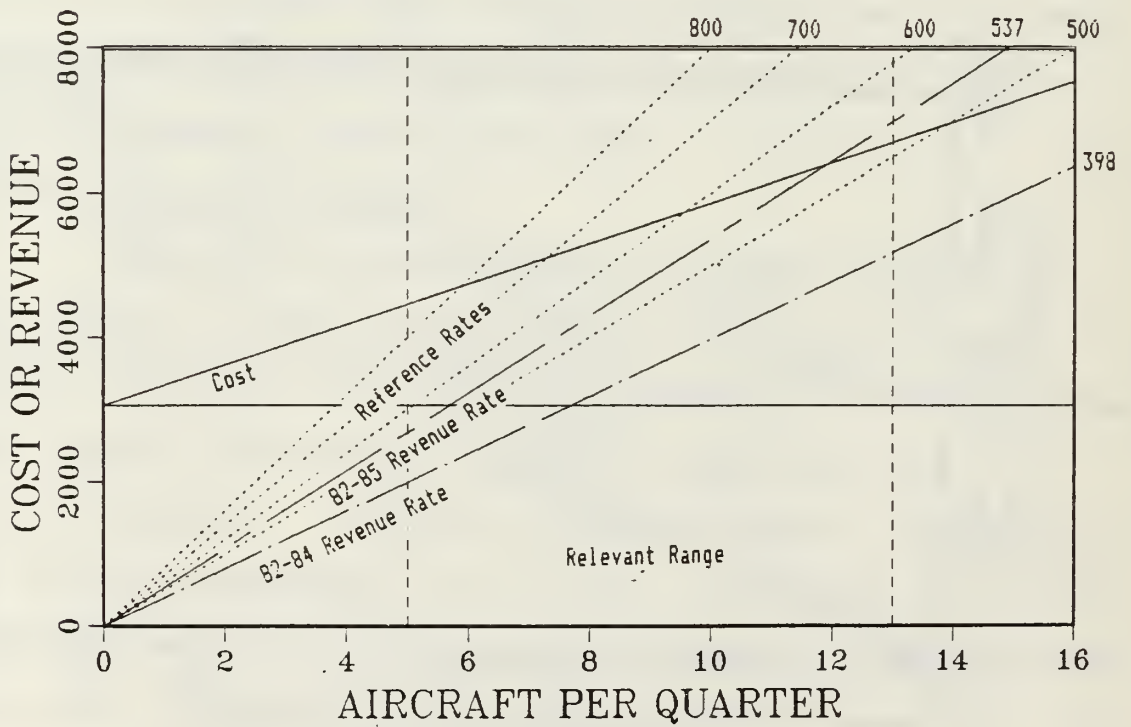
Figure 6.1   Aircraft Program Break-even Charts
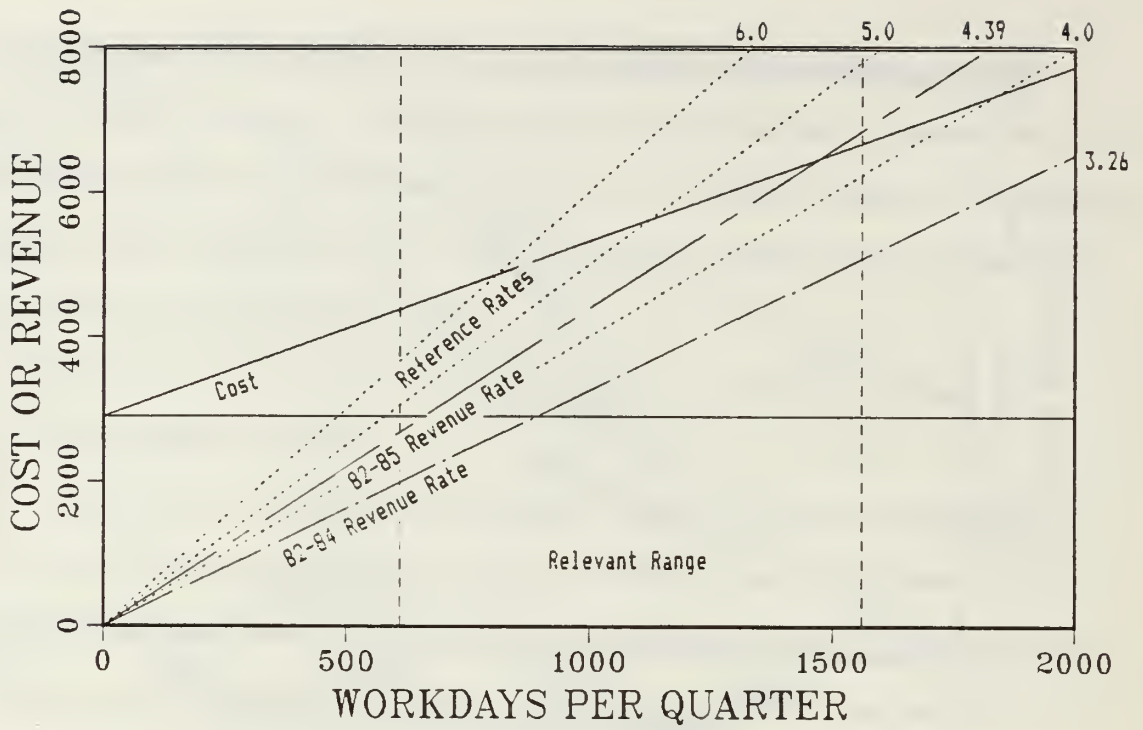
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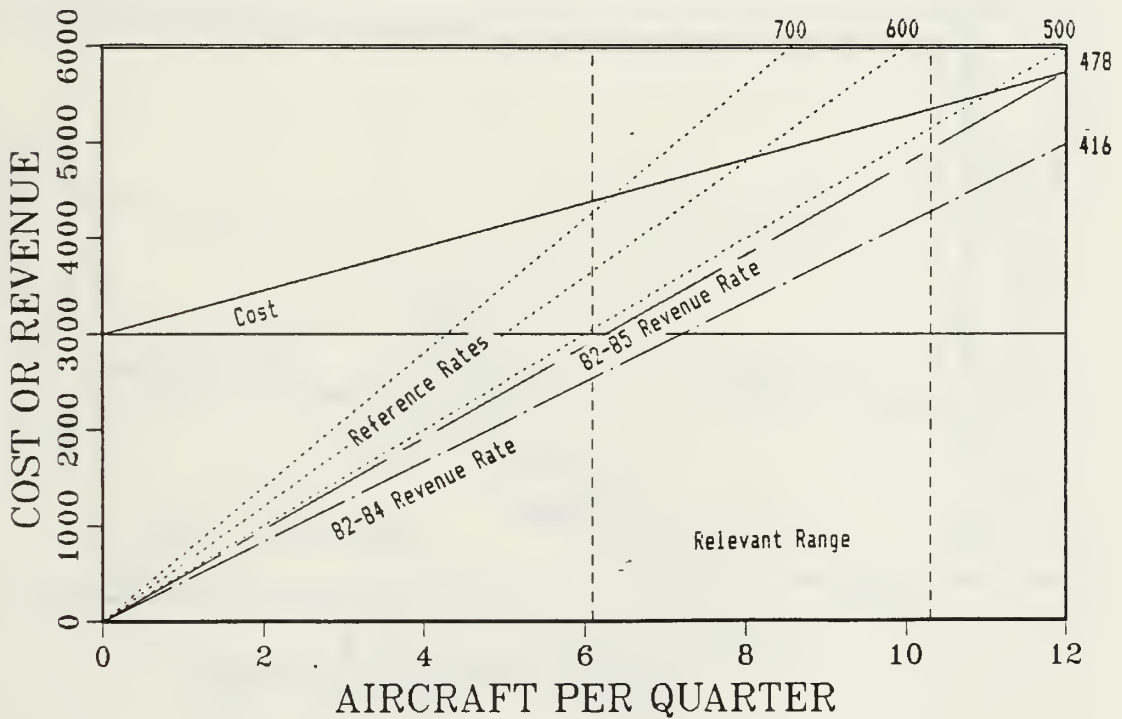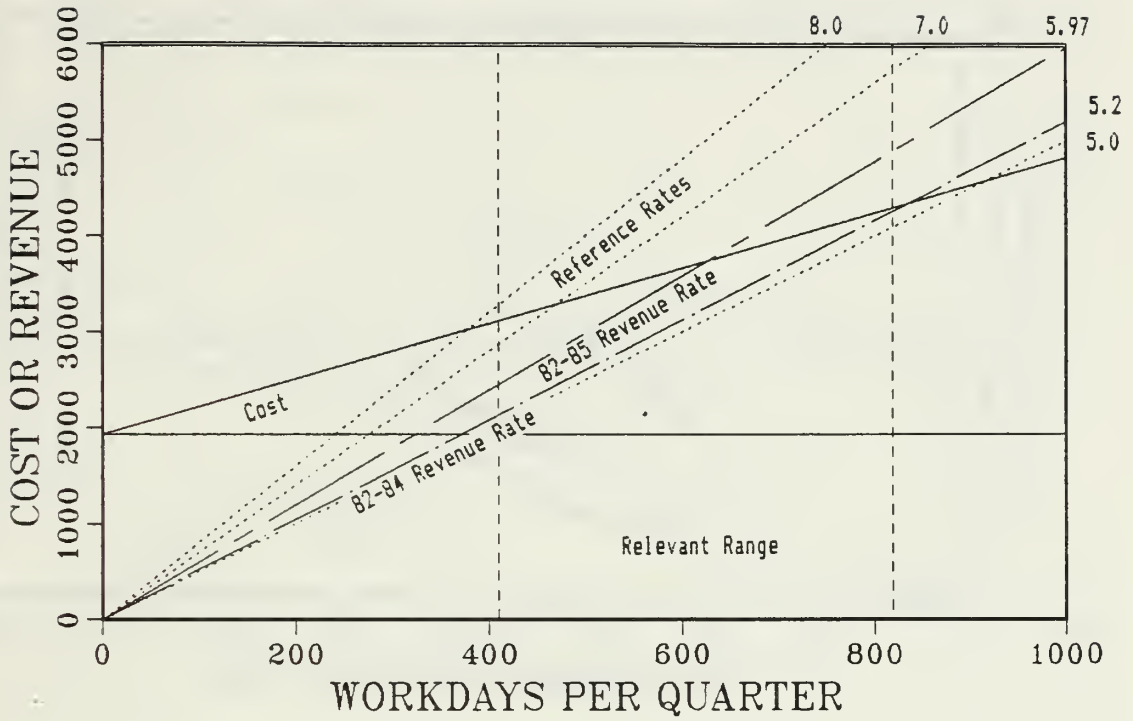Figure 6.2   A-6 Segment Break-even Charts
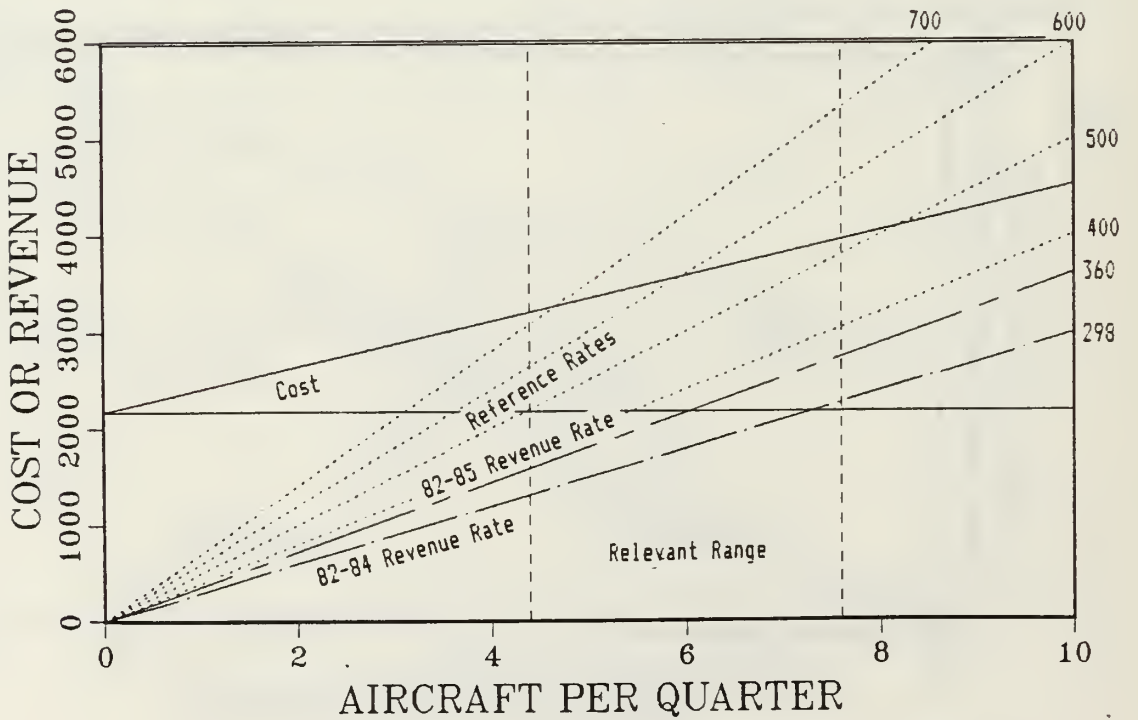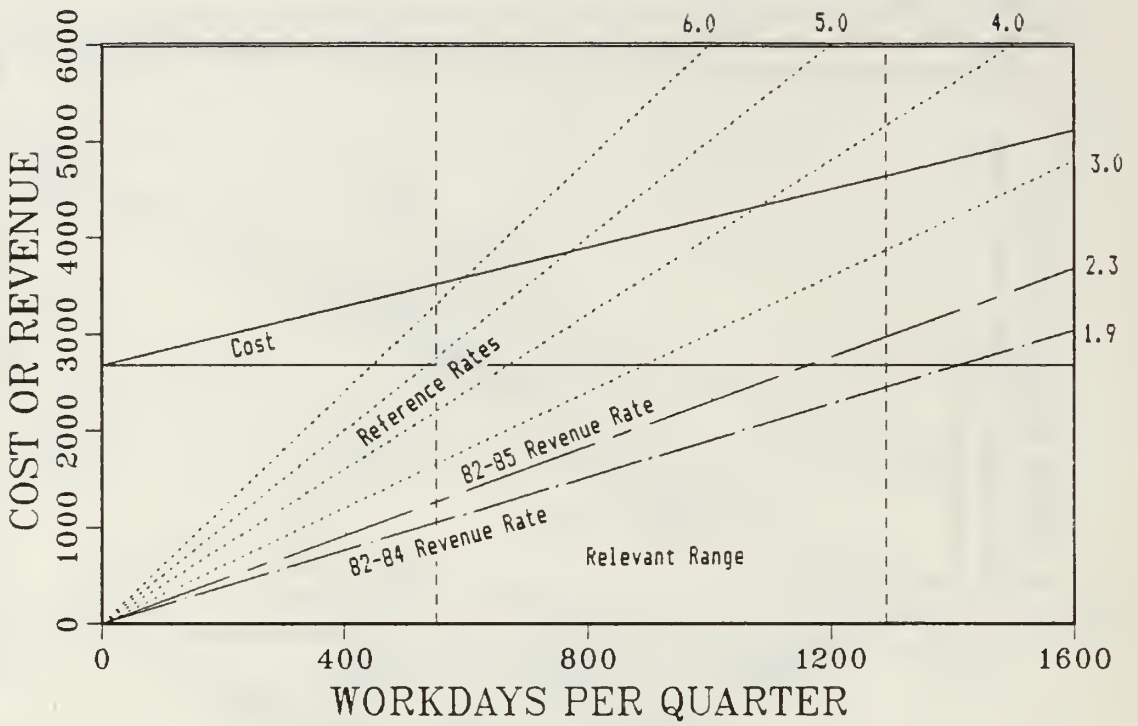
Figure 6.3 P-3 Segment Break-even Charts

113
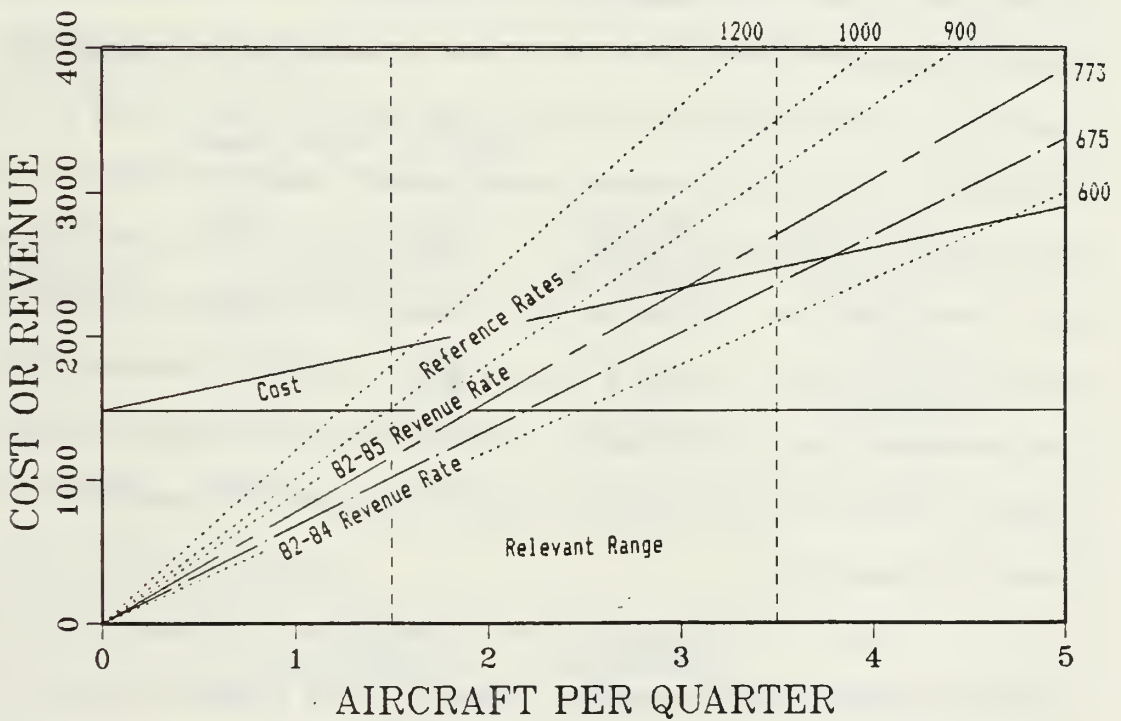
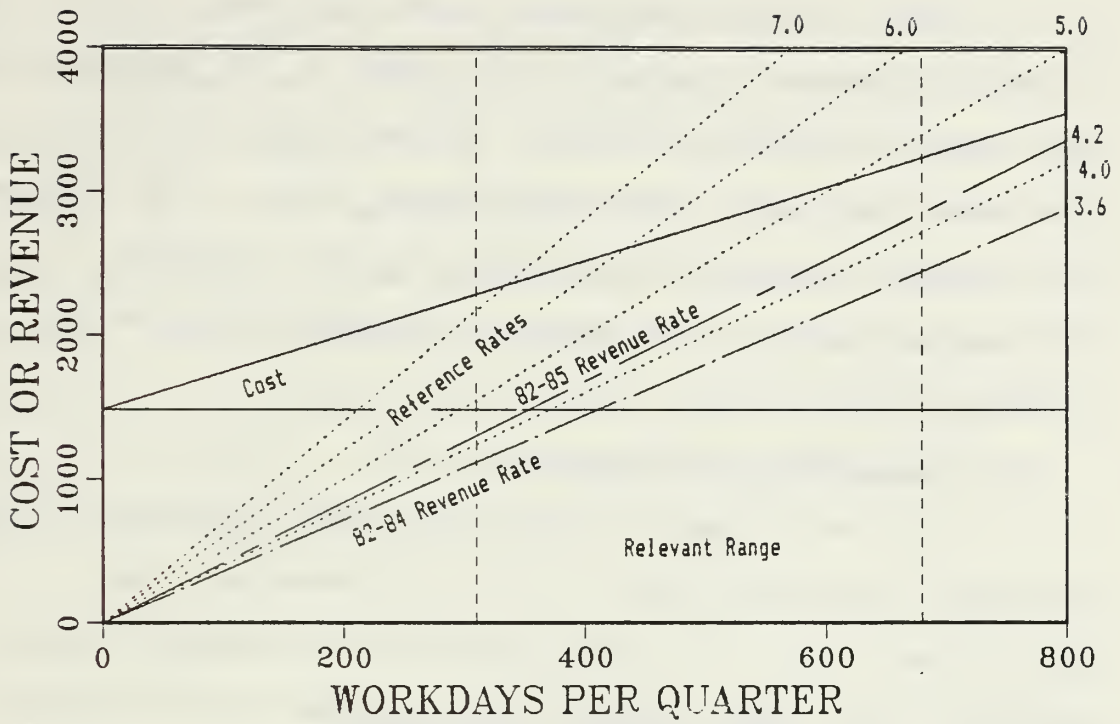Figure 6.4 S-3 Segment Break-even Charts

114

Figure 6.5   A-3 Segment Break-even Charts

As is well illustrated by the break-even charts, the relative differences between the slopes of the variable cost and revenue lines is critical. If the slopes are equal or divergent, obviously break-even cannot occur. The revenue rate must be sufficiently greater than the variable incremental cost rate to attain a desirable break-even volume.

2. Evaluation of Break-even

It must be kept in mind that these break-even charts are simply approximations of past performance. The cost-volume relations can be expected to represent future constant 1982 dollar costs 67% of the time within plus or minus one standard deviation. However, the revenue rates are totally discretionary and in these charts only represent the average conditions over the 16 quarter period. Overall, they illustrate what is already known about the profitability of the aircraft program; that it's been well below break-even over this period. This is why the higher FY85 revenue rates were authorized. Using these higher average revenue rates it can be seen that break-even comes closer to, and in many cases, within the relevant range and thus the average loss is greatly reduced.

Table 6.3 displays the break-even volumes using the FY82-84 and FY82-85 revenue rates. Also presented are the mean losses per quarter incurred by each segment. These mean loss per quarter figures are calculated using each segment's

116

mean volume per quarter and the higher FY82-85 revenue rates.
The S-3 segment has averaged the greatest losses over the
period at $1.5 million plus. The A-6 segment's average loss
of nearly $1 million per quarter is the most consistent when
comparing the two volume measurement outcomes. And in
contrast, the P-3 disparity between per workday and per
aircraft results appears once again, showing essentially
break-even under per workday calculations and over a $1
million loss using the per aircraft route.

TABLE 6.3

MEAN BREAK-EVEN VOLUMES

(dollars in thousands)

Workdays as Volume

| ACFT Segment | Break-even Volumes | | Mean Volume (wkdys/qtr) | Mean Loss $ Per Qtr |
| | FY82-84 Rate | FY82-85 Rate | | |
	(workdays)			
A-6	3445	1468	987	950,000
P-3	835	627	631	44,000
S-3	6440	3571	934	1,980,000
A-3	1480	910	469	717,000
AC PROG	6406	4491	3065	2,895,000

Aircraft as Volume

	(aircraft)		(acft/qtr)	
A-6	26.0	11.9	8.1	980,000
P-3	16.0	12.0	7.9	1,021,000
S-3	34.0	17.3	5.9	1,428,000
A-3	3.8	3.0	2.5	258,000
AC PROG	60.3	39.7	24.6	3,718,000

C. BREAK-EVEN APPLICATION

Knowledge of the relative profit or loss situation of the
past 16 quarters cannot predict future income prospects, but
unless action is taken to control the outcome, similar
results, whether desirable or not, are likely to repeat.
Using tools such as break-even analysis, "what if" accounting
can be played on a quarterly basis with various possible
induction schedules and aircraft mixes. In each situation
the revenue rate required to break-even can be determined.
Whether it's negotiating fixed prices or adjusting induction
schedules to meet the "needs of the fleet," break-even
analysis can assist in leading to the optimum decision.

VII.   CONCLUSIONS AND RECOMMENDATIONS

A.   CONCLUSIONS

1.   Regression Accuracy

Through regression analysis of 16 quarters of historical aircraft program cost data, the cost-volume relations can be considered only as accurate as the data used.   During the data collection process, the author observed several very large negative direct labor charges to the S-3 and A-3 segments and a few smaller ones to the P-3 program.   The author was unable to reconcile these obvious irregularities, which were removed from analysis.   How these irregularities should have been distributed over other quarters is not known.   It certainly raises doubts as to the reliability of the S-3 and A-3 segments and maybe the P-3 segments as well.

It was obvious during data collection that the A-6 segment data were more meticulously recorded and would produce more accurate and consistent results.   The regression analysis of direct labor reflected this, with the A-6 segment exhibiting considerably higher confidence results than the others.   This demonstrates that accurate recording procedures are possible and with them more meaningful and useful results are achieved.

2. Application of Results

NARF Alameda has suffered for many years with cost ouverruns, restricted personnel policies and widely fluctuating workload levels. Accurate and timely income status is essential to any operation regardless whether it's non-profit or not. The break-even chart, which is a comination of cost and revenue relations versus volume, can provide this, but is only as good as the user's ability to interpret the results obtained from using it.

This interpretation ability is probably more important than the actual cost-volume relationships themselves. Being able to take all influencial factors into account to estimate the probability of being on, above or below the average cost for any given volume is crucial. Although findings are far from conclusive, inferences concerning the effects of personnel staffing, productivity, and rate, duration and direction of volume changes can be drawn. What can be concluded is that these effects exist and with the proper study are predictable. Armed with this information, significant improvements to cost estimation and elimination of cost overruns can be made.

3. Overall Success

The original objective of this thesis project was to explore the effects of workload variations on the related costs of the aircraft program and its four segments. If a reasonable relationship could be derived between costs and

120

volume, a model would be constructed for each of the four segments as management decision support in negotiating aircraft fixed prices, workload and mix.

The objectives of this thesis project have been attained but with only limited success. Applying the theory of cost-volume analysis in the multi-product, multi-program, complex environment of a Naval Air Rework Facility was more difficult than originally imagined. Considering the fact that an insufficient number of data periods were available through historical records and several cost data descrepencies could not be reconciled, the results do furnish a reasonable description of aircraft program associated cost-volume relationships over the past four years.

If nothing else, this study has provided a significant beginning to understanding and predicting future aircraft program cost-volume behaviors. The accuracy or reliability of the specific cost-volume relationships are not as important as the potential information they represent. There is no doubt that these relationships can be improved upon. With a greater focus on recording data specifically for analysis of this type, reliability will soar. Also, with rigorously verified cost and volume data, matched consistantly over equal time periods, the subtle differences between aircraft segments will stand out more clearly. This thesis is the platform from which to seek better managerial control over cost-volume behavior.

B.   RECOMMENDATIONS

Since this thesis project was requested by the NARF
Alameda Deputy Comptroller, it is appropriate to make a few
recommendations with respect to the future use and
development of cost-volume relationships.   These
recommendations are meant not as criticism but as suggestions
intended to improve the prospects of cost-volume information
becoming a viable and effective decision support aid for NARF
management.   In these times of shrinking budgets and greater
emphasis on minimizing Naval Industrial Fund (NIF) losses,
pressures to optimize efficiency and reduce cost and
turnaround time overruns will undoubtedly increase.

1.   Data Management

A data management system should be designed and
implemented that is suitable for collecting, storing and
manipulating specific cost and production data.   Cost data
are currently recorded mainly for the purpose of periodic
reports only.   None is intentionally kept as a historical
data base for analytical purposes.   With the advent of
desktop computing and megabyte storage devices, no longer is
physical space a limitation to retaining historical data.
Through the use of a well designed data management system,
not only is it possible to collect pertinent cost data for
various cost analysis uses, but the methods of collection can
be refined and verification can be emphasized.

122

2. Data Aggregation

Aircraft program segment cost items should be broken down to the SDLM task level by direct labor and material. To seriously expect to observe subtle cost behavior changes due to volume or other factor variations, the aircraft program associated cost data must be recorded in the least aggregated segments as possible. Although recording data in this detail is more complex, the benefits may be worth the trouble. With the many different models/series in each aircraft segment, SDLM task cost-volume data could significantly improve cost estimation.

Serious attempts should be made to track indirect costs, specifically G&A and production expenses transferred to the airframes division, to individual segments of the aircraft program. The indirect job order system provides transferred costs by program only. There is no cost-volume knowledge to gain from allocated costs. Tracing at least some indirect costs to aircraft type would strongly enhance the validity and utility of cost-volume results.

3. Data Matching

Procedures should be implemented to ensure desired data are recorded accurately and consistently, and in the time period occurred. It can't be overemphasized how important it is to match costs and other data to the correct time period. When errors are discovered or unexpected transfers must occur, appropriate adjustments in the

historical data base must accompany, as far back as

necessary, or else cost behavior details and accuracy will be

irretrievably lost.

Cost planning and monitoring should be improved to

ensure budget cycle adjustments are not required. Large

fluctuations in various costs were frequently observed in the

last or first quarter of a fiscal year. There were no yearly

patterns, but certainly costs were being recorded in these

quarters that didn't match workload accomplishments.

A method of recording revenues should be devised that

will reasonably match quarterly revenues with costs incurred.

If accurate break-even analysis is desired, it's imperative

that costs are aligned perfectly. A percent completion

method based on estimated costs is one method to couple costs

and revenues. With accurate cost recording, precise

break-even status can be easily maintained.

    4. Collection Period

Volume, cost, revenue and other pertinent data should

be recorded and tracked on a monthly basis. In order to

improve the confidence level of regression or any other type

of cost analysis technique, not only must the data be

accurate, but it must be sufficient in numbers.

Statistically, a minimum of 30 data points is optimum. On a

quarterly basis this is 7 1/2 years. On a monthly basis only

2 1/2 years.

5. Further Study

A greater understanding of the effects of volume
changes on costs should continue to be sought. Certainly a
more accurate cost-volume model can be produced if other
volume factors, such as rate, direction and duration of
change, can be included. With two or three years of tight
monthly data, more significant findings may be attainable.
Although this project does not solve any specific problem or
provide any precise decision support aids, it does establish
the basis for better, more fruitful analysis of cost-volume
behavior. With whatever resources are available, internal or
external, further study should be sought so that eventually
significant knowledge can be realized that will benefit the
cost efficiency of Naval Air Rework Facilities.

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