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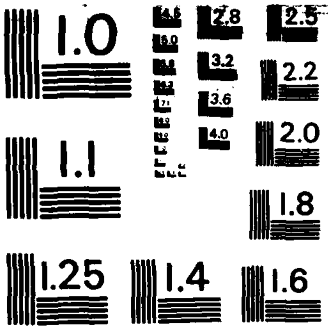

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STUDY REPORT
CAA-SR-84-2
AD

TRANSPORTATION WORKLOAD FORECASTING (TWF) STUDY

JANUARY 1984

PREPARED BY
STRATEGY, CONCEPTS AND PLANS DIRECTORATE

US ARMY CONCEPTS ANALYSIS AGENCY
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The study examined the Army process of forecasting its overocean surface cargo transportation requirements, identifies the nature and extent of forecasting errors and examines methods of improving the forecasts. Specific analysis is made of systemic and methodological aspects of the Army forecasting process and external system factors contributing to forecasting error. The study examines several system solutions and develops models to be used within the system. Box-Jenkins and Winters Models for each of several commodities are developed and presented as accurate forecasting tools when used with program information.

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DEPARTMENT OF THE ARMY
US ARMY CONCEPTS ANALYSIS AGENCY
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REPLY TO
ATTENTION OF

CSCA-SPP

15 March 1984

SUBJECT: *Transportation Workload Forecasting (TWF) Study*

Deputy Chief of Staff
  for Logistics
Department of the Army
ATTN: DALO-TSP
Washington, DC 20310

1. Reference letter, DALO-TSP-C11, 11 May 1983, SAB.

2. The Deputy Chief of Staff for Logistics requested that the US Army Concepts Analysis Agency study US Army transportation workload forecasting and develop procedures to improve the system.

3. This report describes the study approach, the current forecasting system, and several alternative systems and methods that should result in improved forecasts of over-ocean cargo transportation requirements.

David C. Hardison
DAVID C. HARDISON
Director

CONCEPTS ANALYSIS AGENCY
CAA
UNITED STATES ARMY

TRANSPORTATION WORKLOAD FORECASTING (TWF) STUDY

ONE SHEET
STUDY GIST
CAA-SR-84-2

THE PRINCIPAL FINDINGS of the work reported herein are as follows:

(1) The transportation workload forecasting system has produced inaccurate forecasts resulting in inefficient Military Sealift Command (MSC) industrial fund operations.

(2) Accurate forecasting of cargo transportation requirements can be accomplished by forecasting at a single activity.

(3) Either HQ Military Traffic Management Command (MTMC) or HQ, US Army Materiel Development and Readiness Command (DARCOM) is a suitable location for a single point forecasting activity.

(4) The Box-Jenkins and Winters Forecasting Models can provide accurate forecasts when used in conjunction with program information.

(5) Changes to the allocation of transportation account codes and requirements for forecasting shipping mode are also required to improve forecasting accuracy.

THE MAIN ASSUMPTION on which the work reported herein rests is that transportation workload forecasting requirements, contained in JCS Publication 15, would not be changed.

THE PRINCIPAL LIMITATIONS of this work which may affect the findings are as follows:

(1) Only the forecasting of peacetime over-ocean surface cargo transportation requirements was evaluated.

(2) Historical lift data was extracted exclusively from MSC records and could not be validated from Army sources.

THE SCOPE OF THE STUDY was taken to include an analysis of the Army's long-range cargo transportation requirements forecasting process and its impact on budgets and transportation costs.

THE STUDY OBJECTIVE was to develop cost effective systems and methods for improving the forecasting of Army over-ocean surface cargo transportation requirements.

THE BASIC APPROACH followed in this study can be defined as: research was conducted into the nature and extent of the forecasting problem, to identify its impact, and its systemic and methodological causes. Several alternative systems were evaluated based on their relative costs and efficiency. Then a series of mathematical techniques was evaluated for suitability as forecasting tools. Two of the techniques, the Box-Jenkins and Winters models, were used to forecast the 1982 cargo transportation requirements based on 1977 to 1981 MSC cargo lift data.

REASONS FOR PERFORMING THE STUDY are mainly as follows: recent forecasts of Army over-ocean surface cargo transportation requirements have been inaccurate. As a consequence MSC industrial funds have incurred significant losses and the MSC controlled fleet was not efficiently utilized for cargo transport. This study was directed to develop methods to improve the forecasts.

THE STUDY SPONSOR was the Deputy Chief of Staff for Logistics, who also established the objectives and monitored the study activities.

THE STUDY EFFORT was directed by LTC James N. Keenan, Strategy, Concepts and Plans Directorate.

COMMENTS AND QUESTIONS may be directed to CAA, ATTN: Assistant Director for Strategy, Concepts and Plans.

(Tear-out copies of this synopsis are at back-cover.)

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CHAPTER 1

INTRODUCTION

1-1. INTRODUCTION. The Department of Defense transports approximately 7.5 million tons of cargo annualy via the Defense Transportation System (DTS). In excess of 50 percent of this cargo is generated by the Army. Planning for and use of military and commercial shipping is dependent on the accurate forecasting of the services' requirement for movement of cargo. The current Army transportation workload system does not produce accurate forecasts of Army cargo movement requirements. As a consequence, the Deputy Chief of Staff for Logistics (DCSLOG), Headquarters, Department of the Army (HQDA), tasked the US Army Concepts Analysis Agency (CAA) to study the transportation workload forcasting issue and to report the study findings in January 1984. This report discusses the study approach, the forecasting system, other studies of the issue, other service solutions to the problem, and approaches to the Army's forecasting problem.

1-2. BACKGROUND. The Army is required to submit periodic forecasts of its over-ocean transportation to Military Sealift Command (MSC). Recent Army forecasts have shown considerable variance from actual cargo lift. This discrepancy between forecasted and actual lift requirements impacts adversely on the operation of the MSC and Military Traffic Management Command (MTMC) industrial funds, on the MSC controlled fleet sizing process, and on Army transportation budget preparation and execution.

1-3. PURPOSE AND SCOPE. The purpose of this study was to develop procedures to improve the US Army transportation workload forecasting system. The study focus was primarily on the long-range, over-ocean surface transportation requirement forecasting process.

1-4. OBJECTIVES. Objectives of the study were to determine the nature and extent of the transportation workload forecasting problem and to explore and evaluate alternative solutions.

1-5. LIMITATION. Historical lift data, used in model development. was extracted exclusively from Military Sealift Command records and could not be validated from Army sources.

1-6. ELEMENTS OF ANALYSIS. The elements of analysis of the study were designed to explore those facets of the transportation workload forecasting environment which would help identify the extent of the problem, contributing factors, and potential solutions. These elements were as follows:

a. What are the recorded variances between long-range transportation workload forecasts and actual utilization of cargo shipping?

b. Do systemic conditions exist which contribute to unrealistic forecasting? If so, what are they?

c. What is the economic and operational impact of long-range forecasts which are at variance with actual utilization?

d. Do short-range forecasts impact on long-range forecasting? If so, how?

e. What is the impact of the current separation of responsibility for long- and short-range forecasting?

f. What methodologies exist in the other services which could be applied to the resolution of the Army problem?

g. What DARCOM activities affect major items of equipment planned for overseas distribution?

h. What is the impact of the Total Army Distribution Program (TAEDP) on forecasting of requirements?

i. What is the commodity impact of Army and Air Force Exchange Service (AAFES) forecasting procedures?

j. What are the feasible and cost effective methods for improving forecasting accuracy?

k. What, if any, unique commodities are marked as general or special cargo?

1-7. STUDY TASKS. To fulfill the study objectives and to answer the elements of analysis, five principal tasks were identified and were the basis of the study methodology. These tasks were:

a. Identification of the nature and extent of the variances between forecasts and actual lift.

b. Determination of the impact of erroneous forecasts.

c. Development and examination of forecasting systems and methods.

d. Evaluation of alternative locations for forecasting responsibility.

e. Documenting recommended methodology.

1-8. STUDY METHODOLOGY. The methodology used in the study is depicted in Figure 1-1.

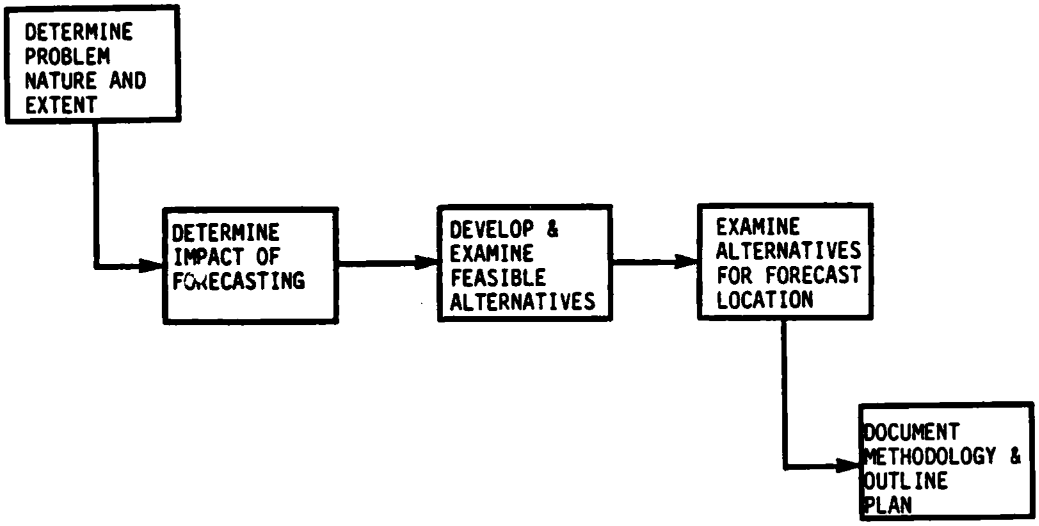


Figure 1-1. Study Methodology

a. Activities in the determination of the nature and extent of the problem consisted of:

(1) Research into completed and ongoing studies of the transportation workload forecasting problem.

(2) Research into Joint Chiefs of Staff (JCS) publications, MSC, Military Airlift Command (MAC), and MTMC directives, and Army, Navy, and Air Force regulations which were related to transportation workload forecasting and operations.

(3) Analysis and evaluation of the procedures used by Army transportation workload forecasting and budgeting agencies.

(4) Analysis of MSC, MTMC, and MAC operations and the relationship between these commands and the Army transportation forecasting system.

(5) Collection and analysis of 4 years of forecasts and 6 years of cargo lift data.

b. Activities in the determination of the impact of long-range transportation workload forecasts on the Army budgets and on the industrial funds of MSC and MTMC included:

(1) Examination of the interfaces between the forecasting system and budgetary process and quantification of the effects of incorrect forecasts.

(2) Review of HQDA budget documents and interviews with personnel involved in the budget process.

(3) Examination of the development and operation of MSC industrial funds.

(4) Investigation of the MSC controlled fleet sizing process.

c. Actions in the development and examination of alternative methods for increasing forecasting accuracy consisted of:

(1) Analysis and evaluation of previously collected performance data, focusing on systemic contributions to erroneous forecasts.

(2) Identification of the forecasting systems data requirements and the most accurate data sources.

(3) Formulation of alternative forecasting systems and evaluation of costs in terms of personnel and facilities.

(4) Investigation of Navy and Air Force forecasting systems.

(5) Evaluation of mathematical forecasting techniques to determine their suitability as tools in transportation workload forecasting.

(6) Application of several mathematical techniques to historical cargo lift data to determine the most appropriate technique and to identify the parameters of the forecasting model.

d. Examination and evaluation of alternative locations for forecasting responsibility consisted of the following actions:

(1) Evaluation of the availability and accuracy of the information required to manage the transportation workload forecasting system.

(2) Identification and evaluation of the availability of data processing support which is required by proposed systems.

e. Documenting the recommended methodology consisted of documentation of the Box-Jenkins and Winters models and the actions required to improve the systemic and external aspects of the forecasting system.

CHAPTER 2

THE CURRENT ARMY TRANSPORTATION WORKLOAD SYSTEM

2-1. GENERAL. The Army's transportation workload forecasting system is governed by Joint Chiefs of Staff (JCS) Publication 15, AR 55-23, AR 55-30, and several MSC, MAC, and MTMC directives. This chapter defines the regulatory basis for the system, observations on how the actual system works, the performance of the system in terms of forecasting accuracy, the effects of inaccurate forecasts, and some external factors which may contribute to the inaccuracies.

2-2. THE REGULATORY FORECASTING SYSTEM

a. JCS Pub 15, Mobility Systems Policies, Procedures and Considerations, 2 June 1974, contains approved joint transportation procedures applicable to the submission of common user movement requirements. Specifically Chapter 4 (Transportation Requirements, Allocations, and Priorities) addresses, inter alia, shipper service forecasted cargo movement requirements. It requires that each military service and the Defense Logistics Agency (DLA) submit four specific forecasts of sealift requirements.

(1) On 1 May a preliminary annual forecast (MSC-9) is submitted which states the worldwide MSC surface movement requirements for the fiscal year which begins 17 months later (e.g., 1 May 84 for fiscal year 1986).

(2) An annual forecast (MSC-10) is submitted on 1 March for the subsequent fiscal year (e.g., 1 Mar 85 for FY 86). This forecast refines the preliminary forecasts.

(3) A sealift cargo requirement (short range) is submitted by the fifteenth day of each month for the succeeding 3 months. Each of the reports states the monthly sealift cargo requirements in measurement tons for each traffic route, program, commodity, and type of shipment or mode.

(4) Change reports are required when significant changes to the above forecasts are anticipated.

b. Each military service is also responsible for the collection and submission of movement requirements of government agencies outside DOD for which the service has sponsorship responsibility and whose requirements have been approved by competent authority as eligible to be handled within the DOD transportation system.

c. AR 55-23, Military Sealift, implements JCS Pub 15 within the Army. It identifies 57 numbered traffic areas and their associated geographic areas. These areas are the terminals of the traffic channels for which forecasts are submitted. Additionally, AR 55-23 identifies sponsor codes, budget programs, cargo classes/commodities, types of shipment, and formats for reports submitted to the Military Sealift Command. These are discussed below.

(1) Budget programs to be used in the forecasts are Troop Support, Military Construction, Military Aid, and Civilian Aid.

(2) Cargo classes/commodities to be forecasted in the reports are:

Reefer-chill (CHL)
Reefer-freeze (FRZ)
Coal and Coke (COK)
Bulk-Other (BLK)
Privately Owned Vehicles (POV)
Household Goods (HHG)
Ammunition and Explosives (AMO)
General Cargo (GEN)
Special Cargo (SPC)
Assembled Aircraft (AAC)
Empty Conex (CNX)
Cargo Carrying Trailers (CCT)

(3) Type shipments or modes to be forecasted in the reports are breakbulk, container, and MILVAN.

d. AR 55-30, Space Requirements and Performance Reports for Transportation Movements, prescribes procedures for the preparation and submission of cargo requirements and performance reports and defines responsibilities for report submission.

(1) Responsibilities defined in AR 55-30 are as follows:

(a) The Deputy Chief of Staff for Logistics, HQDA, is responsible for developing longe-range cargo movement requirements (preliminary and annual forecast reports) and for programing and budgeting for transportation services.

(b) DARCOM Logistics Control Activity (LCA) has DA responsibility for developing and programing short-range movement requirements.

(c) The following commanders and agency heads are responsible for the provision of inputs to both long-range and short-range forecasts:

Military Postal Service Agency
Army and Air Force Exchange Service
Armed Forces Courier Service
US Army Intelligence and Security Command
Chief of Engineers
National Security Agency
Ballistic Missile Defense Systems Command
US Army Communications Command

US Army, DARCOM, Logistics Control Activity
US Army, Europe
US Army, Japan
Eighth US Army
Western Command
US Army Forces Command
193d Inf Bde (Panama)
172d Inf Bde (Alaska)
Deputy Chief of Staff Logistics, HQDA

(2) The commands and agencies listed in paragraph 2-2d(1)(c) above, are required to submit their long-range reports to US Army Management Systems Support Agency (USAMSSA). USAMSSA provides a consolidated report to the Director for Transportation, Energy and Troop Support, ODCSCLOG, who analyzes and adjusts the stated requirements. The adjusted data is then provided to USAMSSA for preparation and submission to MSC and MTMC. As an exception, the US Army Installation Support Activity, Europe, Energy Center, Rheinau is required to submit long-range solid fuel (coal and coke) requirements semiannually to HQDA ODCSLOG.

(3) Short-range requirements for surface cargo movement are to be submitted monthly to DARCOM LCA. LCA is required to consolidate the reports and forward the Army's statement of requirements to MSC and MTMC.

(4) Change reports are to be submitted when there is a 600-measurement-ton-change over a traffic area (e.g., Gulf Coast to Europe).

e. Military Sealift Command uses the long-range forecasts to plan the use of its nucleus fleet and, when required, plans for augmentation by commercial or National Defense Reserve Fleet resources. (The total of these assets is the MSC controlled fleet.) The long-range forecasts are also used by MSC to formulate the shipping rates to be charged to the services for cargo shipped and by the services for budget preparation. The stated use of short-range forecasts by MSC and MTMC is the scheduling of ship and port workloads.

f. JCS Pub 15 directs that monthly utilization reports be provided to the Army comparing final forecasted requirements with actual cargo for a particular month.

g. The Army's forecasting system is portrayed at Figure 2-1, and the report submission sequence is shown at Figure 2-2.

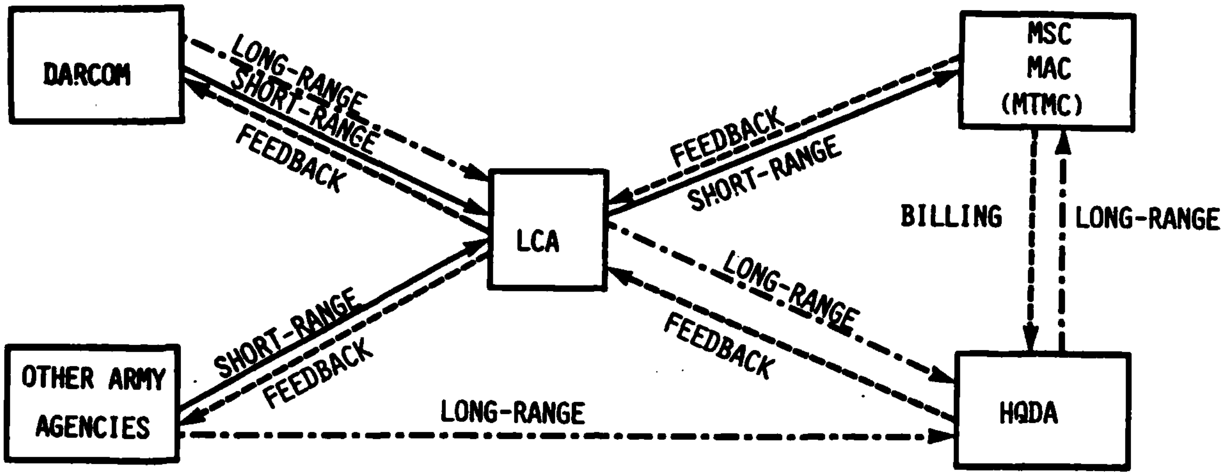
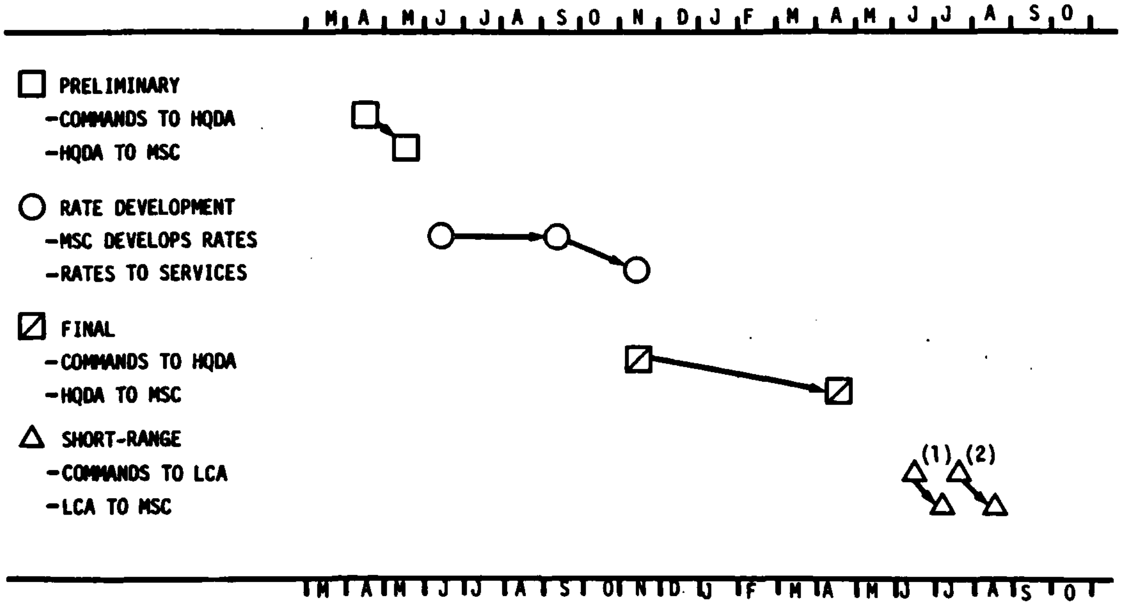


Figure 2-1. The Army Forecasting System



NOTES: (1) FOR AUGUST-SEPTEMBER-OCTOBER
(2) FOR SEPTEMBER-OCTOBER-NOVEMBER

Figure 2-2. Report Submission Sequence

2-2. OBSERVATIONS OF THE ARMY FORECASTING SYSTEM

a. Long-range Forecasts. The long-range forecasts, as required, are submitted by the forecasting agencies identified in AR 55-30. However, methods and procedures for preparation of these reports are inconsistent and vary extensively in their accuracy. A synopsis of forecasting procedures by the various commands follows.

(1) DARCOM forecasts for major items and ammunition are prepared at the DARCOM major subordinate command inventory control points (ICP). The reports are, in theory, based on The Army Equipment Distribution Plan (TAEDP), Materiel Movement Reports (MMR), Logistics Intelligence File (LIF), and forecaster judgment. Due in part to forecaster mistrust of the TAEDP accuracy, inability to accurately correlate LIF data with actual movement, and the absence of accurate timely feedback, significant subjective forecasting is made. Additionally, indications are that there is inadequate information exchange between the item managers and the personnel making the forecasts. Consequently the program information available to the transportation workload forecaster may not be the most current.

(2) DARCOM forecasts for secondary items are prepared by the Logistic Control Activity using the previous year's actual lift data extracted from MSC billing records.

(3) Army/Air Force Exchange System forecasts are prepared using the arithmetic mean of three previous years of lift history. This is adjusted by anticipated sales growth; inflation factors, changes in troop strengths; opening, closing, or consolidation of facilities; and changes in mode of transportation.

(4) The Military Postal Service Agency (MPSA) uses historical data on the volume of consolidated Army and Air Force mail moved over an MSC channel. Adjustments are made based on knowledge of strength increases, new missions, and changes to traffic routes. History is developed from MSC billing tapes which are provided directly by MSC to the MPSA. An automated management information system, the Military Automated Mail Accounting System (MAMAS), is used by MPSA in their forecast formulation.

(5) The Chief of Engineers forecasts are submitted only by the US Army Engineer District, New York, and apply only to cargo originating at Bayonne, NJ and destined for Thule, Bremerhafen, Rotterdam and the Azores. The forecasts are based on previous forecasts and have not changed for several years. Forecasts are not made by, or for, other engineer commands or agencies.

(6) The Ballistic Missile Defense Systems Command forecasts are prepared by the Logistics Support Contractor (LSC) at Kwajalein Missile Range from inputs submitted by six range contractors who perform range services. Forecasts are based on 3 years of historical data as determined by the contractor records of items shipped. The quantities obtained from the contractors' historical data have not agreed with the cargo movement feedback reports provided by LCA.

(7) The US Army Communications Command reports that their forecasts are "strictly guesswork."

(8) US Army Europe has not submitted the required surface cargo movement forecasts for at least 2 years.

(9) Eighth US Army forecasts are derived from data provided by nine subordinate elements based on forecast history.

(10) US Army Japan (USARJ) forecasts are based on history and projected requirements. USARJ does receive monthly feedback reports from LCA.

(11) Western Command forecasts are straight line projections from historical data adjusted by experience.

(12) 193d Infantry Brigade (Alaska) uses monthly tonnage reports compiled locally as the historic basis for their forecasts.

(13) 172d Infantry Brigade (Panama) forecasts are based on historical cargo lift data provided by the local MTMC facility.

(14) ODCSLOG, HQDA consolidates and adjusts the aggregated inputs of the Army forecasting commands and agencies. It also prepares the long-range CONUS outbound household goods and POV cargo space requirements forecasts. The household goods and POV forecasts are based on the most recent year of complete cargo movement data available.

b. Short-range Forecasts. Short-range forecasts are prepared by all activities which submit long-range forecasts and by Headquarters, Forces Command.

(1) Many of the short-range forecasts are a straight line monthly average of the annual forecast and do not account for monthly or seasonal variations. Others, particularly DARCOM, use program and historical data.

(2) Forces Command does not prepare a long-range forecast. It does prepare and submit a short-range forecast for all CONUS outbound household goods and privately owned vehicles, although it does not have knowledge of all movements. In FY 81 and FY 82, household goods were approximately 20 percent and 11 percent, respectively, overforecast in the long-range

forecasts and approximately 80 percent and 38 percent, respectively, overforecast in the short-range forecasts.

(3) LCA consolidates the short-range forecasts provided by the forecasting agencies and forwards the report to MSC and MTMC. Additionally, LCA prepares the short-range forecast of DARCOM secondary items using a modified Kalman filter algorithm and data from the LIF. A recent DARCOM Inventory Research Office study concluded that the current smoothing algorithm was not optimal and recommended a replacement.

c. Performance Reports

(1) Chapter 3, AR 55-30, requires DARCOM LCA to produce monthly feedback reports for each reporting command or agency which reflect the forecasted and actual lift of surface cargo tonnage. The data provided are to be used as guidance in the preparation of the long-range and short-range forecasts. Most Army forecasters cite there is a lack of information on shipments and identify this as a barrier to improved forecasts.

(2) Feedback reports produced by LCA are extracted from the MSC billing tapes and the forecasts provided by the forecasting agencies or commands. LCA attempts to identify the cargo shipper either through a comparison of the shipping information to the LIF or through the Transportation Account Code (TAC). The LIF to shipping information comparison cannot identify a large number of transactions due primarily to the absence of the information within the LIF. Identification of the shipper through TACs, under which all shipments are reported, is not currently achievable. This is primarily a result of the current TAC structure which allocates a single TAC to all cargo shipped by DARCOM and several other commands and agencies.

d. Cargo Transportation Budgeting. The MECHTRAM (Mechanization of Selected Transportation Movement Reports) system produces long-range cargo forecast reports and provides them to DCSLOG and DCSPER to be used in budget preparation. Review of the budget formulation process indicates that the MECHTRAM reports are not used and that other tools have been developed. MILPERCEN personnel reports, MSC/MTMC provided shipping rates and historical factors are the basis of the transportation costs within Military Personnel Army (MPA) budget, while history and program knowledge are the basis of the second destination transportation costs in Military Assistance Program (MAP), and Operations and Maintenance (OMA) budgets. None of the forecasting commands or agencies have any responsibility for budget formulation and execution. Payment of shipping charges is made by US Army Finance and Accounting Center based on MSC and MTMC billings.

2-3. FORECASTING SYSTEM PERFORMANCE

a. Forecasts submitted by the Army in recent years have generally overstated requirements. While the total forecast compared to actual shipment has shown significant improvement, forecasts by commodity and type of shipment have continued to exhibit significant variances. Table 2-1 shows in thousands of measurement tons (MTON) the aggregated long-range forecast and the actual lift and error, by commodity and type shipment for FY 1981. Table 2-2 portrays the same data for FY 1982. It should be noted that overforecasts for some commodities in some modes are offset by underforecasts in the same commodities in other modes. For example, breakbulk general cargo was overforecast by 115,000 tons and seavan general cargo was underforecast by 191,000 tons.

b. Forecasting errors by the Army in FY 81 were much greater than those of other services. In FY 82, the differences were less pronounced as Army forecasts were more accurate. As the Army's cargo accounts for approximately 60 percent of all cargo carried by MSC, the effects of percentage errors are much more severe than errors by the other services. Tables 2-3 and 2-4 show comparisons of the aggregate 1981 and FY 82 breakbulk forecasts and shipments by the shipper services.

Table 2-1. FY 81 Forecast Performance (000 MTON)

	Breakbulk			Seavan			MILVAN		
Commodities	Forecast	Lift	Error	Forecast	Lift	Error	Forecast	Lift	Error
General	465	170	-286	1,736	1,610	-126	11	21	-10
Household	45	42	-3	65	36	-29	--	13	+13
Special	671	579	-92	19	20	+1	--	--	--
POVs	350	286	-64	136	198	+62	1	--	-1
Reefer	0	1	+1	36	41	+5	--	--	--
Ammunition	165	120	-45	--	3	+3	28	20	-8
CCT	54	76	+22	--	--	--	--	--	--
CNX	5	2	-3	--	--	--	--	--	--
Coal/bulk	462	377	-85	--	2	+2	--	--	--

Table 2-2. FY 82 Forecast Performance (000 MTON)

Commodities	Breakbulk			Seavan			MILVAN		
	Forecast	Lift	Error	Forecast	Lift	Error	Forecast	Lift	Error
General	297	182	-115	1,639	1,830	+191	18	14	-4
Household	61	32	-29	39	52	-20	--	5	+5
Special	519	321	-198	27	9	-18	--	--	--
POVs	344	278	-66	138	240	+102	--	1	+1
Reefer	--	1	+1	31	50	+19	--	--	--
Ammunition	135	132	-3	0	3	+3	36	43	9
Aircraft	--	2	+2	--	--	--	--	--	--
CCT	64	75	+11	--	--	--	--	--	--
CNX	4	1	-3	0	2	+2	--	--	--
Coal/bulk	436	-53	--	--	--	--	--	--	--

Table 2-3. FY 81 Comparison of Service Forecasts

Component	FY 1981 breakbulk cargo (000 MTON)				FY 1981 seavan cargo (000 MTON)			
	Forecast	Actual	Error	Percent	Forecast	Actual	Error	Percent
Army	2,208	1,676	532	24 over	1,992	1,910	82	4 over
Navy	456	377	79	17 over	939	897	42	4.7 over
Air Force	486	487	1	.2 over	562	531	31	5.5 over

Table 2-4. FY 82 Comparison of Service Forecasts

Component	FY 1982 breakbulk cargo (000 MTON)				FY 1982 seavan cargo (000 MTON)			
	Forecast	Actual	Error	Percent	Forecast	Actual	Error	Percent
Army	1,860	1,407	453	24 over	1,874	2,186	312	17 under
Navy	375	393	18	18 over	918	934	16	2 under
Air Force	523	463	16	11 over	557	684	127	23 over

2-4. EFFECTS OF FORECASTING

a. General. Erroneous forecasting has several negative effects. It results in inefficient MSC shipping and MTMC port operations, as measured by losses in MSC and MTMC industrial funds, in ship utilization, in unreliable service budgets, and in inaccurate MSC-controlled fleet sizing.

b. Industrial Fund Impact. The MSC industrial fund losses for FY 82 attributable to erroneous Army forecasts are shown in Table 2-5. Losses to the industrial fund are initially absorbed by the MSC but are recouped in the following year through increases in the rates charged to the shipper services. This would appear to be an accounting problem. However, the industrial fund losses do reflect inefficient use of cargo carrying resources and expenditures in the subsequent year which would not occur if the forecasts were accurate.

Table 2-5. Losses in MSC Industrial Fund

	Tons (000)	Miles (000.00)	Income ($ 000)
FY 1982 rates (developed on preliminary requirements)	2,076	8,378	$257,132
Actual FY 1982 Army lift	1,470	5,240	157,293
Difference	(606)	(3,138)	$(99,839)

c. <u>Budget Impact</u>. Budget preparation for second destination (over ocean) costs of shipping cargo is impeded by the lack of accurate forecasts of the cargo movement requirements. As stated earlier, budget preparers have developed their own tools to produce the budget. OMA (p 7) is the predominant source of funds for over-ocean cargo movement. Table 2-6 shows the FY 82 performance of this budget element.

Table 2-6. Army Budget Performance

FY 82 budget OMA (p 7)	$ 601.3 million
Anticipated disbursements	$ 576.6 million
Deobligated	$ 24.7 million

d. <u>MSC Controlled Fleet Impact</u>

(1) The MSC-controlled fleet consists of a nucleus fleet of Navy-owned cargo ships and time chartered commercial vessels. These are used primarily to carry breakbulk cargo. The size of this fleet is calculated from the cargo movement requirements forecasted by the shipper services. MSC uses the percentage of cargo that historically was shipped on the various types of lift within the controlled fleet and then allocates

that percentage of the forecasted cargo to each type lift. From this, contracts are entered into between MSC and the commercial carriers for provision of required vessels. If the forecasted cargo is not generated, more shipping is available than required. Since ships are contracted for a minimum of 1 year, they are not returned until the end of the contracted period but are placed in reduced operating status. During FY 1982 the MSC controlled fleet average utilization rate was 40 percent. Army breakbulk forecast for FY 1981 was 555,000 measurement tons and in FY 1982 was 453,000 measurement tons in excess of actual shipments. This equates to a peacetime requirement excess of a minimum of four breakbulk cargo vessels within the MSC controlled fleet.

(2) MSC controlled fleet vessels are also considered by MSC when calculating its contingency shipping requirements. Therefore, it may be expected that the MSC fleet would not be reduced by a number equal to the savings generated by accurate forecasts and that the cost of operating contingency vessels would be absorbed by a source other than the shipper services. An excellent study on MSC controlled fleet sizing is contained in the OSD Logistics Systems Analysis Office Dry Cargo Sealift Forecast Study, December 1982.[1]

2-5. OTHER OBSERVATIONS. During the study of the Army's forecasting system, several factors were observed which have major impacts on the preparation and the use of the forecasts which were not all under the control of the Army. These include mode determination, household goods shipment mode, the use of short-range forecasts, commodity classification, and the MSC billing process.

a. Mode Determination

(1) JCS Pub 15 and AR 55-30 require that forecasts state the mode or type shipment as breakbulk, container, or MILVAN. However, the decision as to whether cargo is transported by breakbulk or container vessel generally does not rest with the Army forecaster or shipper, but with MTMC. As most breakbulk cargo is carried on MSC controlled fleet vessels and most container cargo on commercial shipping, this decision has a significant impact on forecast accuracy. As stated, MSC uses this data for MSC controlled fleet sizing and in the development of commercial cargo rates. Examination of FY 82 forecasted and lift data shows that breakbulk cargo was overforecast by 453,000 MTON or 24 percent and that container cargo was underforecast by 312,000 MTON or 17 percent. Table 2-7 shows those commodities in which offsetting forecasted versus shipped cargo variances occurred in FY 82.

Table 2-7. Selected FY 82 Breakbulk vs Container Forecast Performance (000 MTON)

Commodity	Forecast	Actual	Error
		Breakbulk	
General	297	182	115 over
Household	61	32	29 over
POVs	344	319	66 over
		Container	
General	1,639	1,830	91 under
Household	39	72	13 under
POVs	138	240	102 under

(2) From this analysis of the FY 82 forecast performance, it appears that a significant portion of the forecasting error is attributable to the breakbulk versus container shipping decision. Continuation of the requirement for the shipper to forecast the type or mode of shipment will most likely result in continued forecasting problems and consequently in MSC controlled fleet sizing errors. Routing of annual forecasts through MTMC to MSC would allow MTMC and MSC to determine the allocation of cargo between the various modes.

b. Household Goods Shipments. International household goods shipments are classified into six categories, one of which (door-to-door container, surface code 5) is processed by MSC. Door-to-door container, code 4, is processed totally by commercial carrier and does not appear in MSC billing information. Currently, code 5 shipments are less than 3 percent of those shipped under code 4. Minor shifts of cargo from code 4 to code 5 have a major impact on the accuracy of the forecast of household goods to be processed by MSC. As the forecasting agencies do not make the modal decision for household goods shipments, the accuracy of their forecasts is not under their control.

c. Use of Short-range Forecasts

(1) JCS Pub 15 and AR 55-30 direct submission by the shipper services of sealift cargo requirements (short range) each month for the succeeding 3 months. Discussions with MTMC personnel indicate that ships are not booked until MTMC has been notified by the shipper that a shipment is available and that short-range forecasts are not used in the process. Given the nature of shipping schedules, it is highly unlikely that schedules can be firmly arranged if only the month and area of shipment are known and not the date and port.

(2) Evaluation of short-range forecasts indicate that, in general, they are as inaccurate as the long-range forecasts and for some commodities and modes they are much less reliable. This may, in part, explain their nonuse. Table 2-8 shows the performance of short-range forecasts for FY 81 and FY 82. Long-range error is shown in parentheses.

(3) Observations of most commodity shipping history reveals monthly and seasonal trends that should be predictable with reasonable accuracy as components of the long-range forecast when progrm information is included in the assessment. Discussion with MSC personnel indicate that an accurate long-range forecast and periodic change reports would be adequate for their use.

d. Commodity Classification

(1) The special cargo commodity contains all military wheel and track vehicles (including sedans) and all items measuring 30 feet in any dimension. Most special cargo is carried by the MSC controlled fleet. Privately owned vehicles are a separate commodity and are transported by breakbulk and sea-van carrying vessels. As there is no physical difference between POVs and military sedans and other small military vehicles, the transportation requirements should be the same. Therefore military sedans and other small vehicles should be in the same commodity group.

(2) The general cargo category contains a significant number of end items, particularly communications-electronics equipment. Current Army transportation account code (TAC) structure does not facilitate the identification of these items. As a result, general cargo requirements contain elements which are affected by program decisions and for which impact on forecasts cannot be readily assessed.

(3) The empty CONEX and assembled aircraft commodities constitute a small segment of the total cargo and do not vary significantly. The previous year's lift, extracted from the billing information, should be adequate forecasts for these commodities unless program information indicated otherwise.

e. MSC Billing Process. Analysis of several years of MSC billing information, discussion with personnel involved in the budget process and forecasting personnel, review of data developed by US Navy Support Command, and information received at Air Force Logistics Center indicate that the monthly billings received from MSC usually do not contain all bills for the reported month and usually contain erroneous entries. Improvements to the MSC billing process are needed if the services are to accurately capture monthly and seasonal cargo shipping behavior to improve their forecast.

Table 2-8. Short-range Forecasting Error (000 MTON)

Commodity	FY 81			FY 82		
	Breakbulk	Container	MILVAN	Breakbulk	Container	MILVAN
General	+42(-286)	+110(-126)	-38(+10)	+39(-115)	+248(+191)	--(-4)
Household	-3(-3)	-89(-29)	+13(+13)	-71(-29)	-20(+13)	+5(+5)
Special	-4(-92)	+15(+1)	-- --	-15(-198)	+7(-18)	-- --
POV	-26(-54)	-12(+62)	-- --	-41(-66)	+17(+102)	+1(+1)
Reefer	+1(+1)	+1(+5)	-- --	+1(+1)	+9(+9)	-- --
Ammo	+19(-45)	+3(+3)	-14(-8)	-23(-3)	+3(+3)	-- --
Cargo trailer	+36(+22)	-31(0)	-- --	+50(-11)	-10(-)	-- --
CONEX	+2(-3)	-- --	-- --	--(-3)	+2(+2)	-- --
Coal/bulk	-334(-85)	+2(+2)	-- --	-108(-53)	-- --	-- --

( ) Long-range forecast error.

2-6. SUMMARY OF OBSERVATIONS

a. General. Observations in the study of transporation workload forecast system were categorized into three principal areas: systemic--those aspects involving the structure and interactions within it; methodological--those aspects relating to the methodologies used by various forecasters; and external environmental--those aspects within the JCS directed forecasting system which the Army does not control.

b. Systemic Observations

- The Army's transportation workload forecasting is not a closed loop system and can be classified as many forecasters performing duplicative functions at widely separated locations.
- The long-range and short-range forecasting systems are not independent but flow on separate reporting and aggregation channels.
- The budget and cargo forecast systems are not supportive of each other.
- Review and adjustment of forecaster input at HQDA and LCA is restricted by aggregation of inputs and lack of performance data.

- Army historical lift and forecast files are limited to 1 year of lift data.
- Present allocation of TAC does not facilitate forecast performance evaluation or identification of shippers' programs, or specific sources of errors.
- Some agencies are required to submit cargo movement requirements for commodities and programs about which they have limited information.
- The link between the various programs and statements of their transportation requirements is not well defined.
- The present operation processes of the MECHTRAM system are not adequate for accurate forecast or budget formulation.

c. Methodological

- There are no standard forecasting methodologies or tools in use within the system.
- Extensive subjective forecasting is used throughout the system.
- An adequate data base does not exist within the Army on which to base forecasts.
- MSC billing information is the most complete source of shipping data but does not currently identify shipper and program in sufficient detail to develop accurate forecasts for all commodities.
- Current methodologies generally do not produce accurate forecasts.
- Those agencies using several years of historical data and program knowledge as the basis for their forecasts have traditionally been most accurate.

d. External Environment

- JCS Pub 15 requires the Army to forecast the shipping mode (container vs breakbulk), but the decision on mode is generally made by MTMC.
- Household goods shipments through MSC constitute a small percentage of total household goods shipments. The accuracy of shipper forecasts can be significantly affected by shifts between modes. This decision is not made by the shipper service.

- Indications are that short-range forecasts are not used for port and ship scheduling and are otherwise of questionable value.
- The MSC billing system, which is the primary data source, is slow and may contain significant inaccuracies.
- The TAEDP is not currently an accurate source of information for forecasting of equipment distribution.

CHAPTER 3

RECENT STUDIES OF THE TRANSPORTATION WORKLOAD FORECASTING PROCESS

3-1. GENERAL. During the study of transportation workload forecasting, several related studies and reports, which were conducted during the previous 10 years, were reviewed to minimize duplication of effort and to benefit from data already available. Most recent of these were the Dry Cargo Sealift Movement Forecasting and Sizing of the MSC Fleet Study, conducted by the OSD Logistics Systems Analysis Office (LSAO) in December 1982 for the Deputy Assistant Secretary of Defense (L&MM); the Over-ocean Cargo Forecasting Procedures Study, conducted by the DARCOM Inventory Research Office (IRO) in September 1983; and an MTMC Forecasting Methodology (draft) 1983.

3-2. OSD LSAO STUDY. The OSD LSAO Study focused on breakbulk cargo forecasting only and its impact on the MSC-controlled fleet sizing process. The study was critical of the Army forecasting process and highly recommended both the current Air Force and developmental MTMC methodologies. They concluded that a wide range of forecasting methods with varying degrees of accuracy were now in use, and that the most accurate methods (USAF) use minimum judgment, are mathematically simple, use program data, have a single computation point, and have accurate feedback systems. Their recommendations include a proposal that the DASD (L&MM) direct the services to develop forecasting methodologies containing the characteristics as outlined above and contained in the USAF system. As stated, the LSAO Study only addressed breakbulk and not container cargo. This omitted consideration of the relationship between the cargo shipping modes. Further, it did not address (as previously discussed) the function of MTMC in determining the type of shipment or mode. The study focused on FY 81 data only.

3-3. THE DARCOM STUDY. The DARCOM IRO has recently completed a study of the procedures now in use within DARCOM. Their observations paralleled many of those contained in this study and were developed in coordination with the study team. They recommended a new mathematical forecasting model (Winters), an expansion of the number of TACs to identify program items, that more effort be given to producing an accurate long-range forecast, and that the use of the TAEDP be evaluated.

3-4. MTMC DEVELOPMENTAL FORECASTING METHODOLOGY. HQ MTMC is developing a methodology which would allow MTMC to prepare improved transporation workload forecasts. Initial efforts were to create and evaluate a 4-year average. This was later revised to include a smoothing technique. The OSD Dry Cargo Sealift Movement Forecasting Study recommends that the MTMC model be used to evaluate the service forecasts.

CHAPTER 4

OTHER SERVICE FORECASTING SYSTEMS

4-1. GENERAL. USAF and USN transportation workload forecasting systems were investigated to determine the methodologies used and their efficacy, and to identify elements which had potential application to the solution of the Army forecasting problem.

4-2. USAF FORECASTING SYSTEM

a. USAF forecasts of transportation requirement procedures are contained in AFR 75-15, dated 6 June 1979 (currently being revised). Headquarters, USAF Logistics Command (AFLC) has responsibility for forecasting and budgeting for Air Force cargo requirements. AFLC automated data processing procedures are contain in AFLC Regulation AFL171-125 dated 15 November 1979. This regulation provides a detailed operational description of the system and its associated environment.

b. The Air Force long-range forecast is developed from a bivariate regression analysis of projected flying hours with an 8-year data base of actual lift history which has been developed from MSC billing information. Additionally, designated commands are required to report nonrecurring or unusual requirements which are added to the forecast. In those cases where a commodity constitutes a small percentage of the total forecast, the previous year's actual shipment is used for the forecast. Mode of shipment is based on the percentage of the total shipment sent by the particular modes during the previous year.

c. Short-range forecasts are prepared by a triple exponential smoothing of the 8-year data base.

d. USAF TACs are structured to identify both the program and the shipping customer.

e. The USAF system includes effective procedures to validate MSC billing information.

4-3. US NAVY FORECASTING SYSTEM

a. Forecasting of US Navy sealift requirements is governed by NAVSUPINST 4620.7D. Navy Material Transport Office (NAVMTO), Norfork, Virginia, collects and submits both long-range and short-range forecasts for the Naval Support System Command, which is responsible for the forecasting system.

b. Navy cargo transportation requirements forecasting is currently a manual process which uses historical data, major program requirements, and forecaster judgment. Sealift requirements, excluding personal property, Coast Guard items, construction material, and aircraft, are reported only as an exception to the previous year's lift.

c. Navy over-ocean cargo movement requirements are approximately one-third of those required by the Army and, as a consequence, their errors have less impact. Their greatest diffculties are determining the shipping mode and the route to be used. Additionally, the delay in receiving complete actual lift and billing data from MSC complicates both forecasting and budget execution.

d. The Navy has approved a program to automate their forecasting system. The objectives of the automated system are to maintain historic lift and forecast files, and generate all required forecasts. It is expected that the system will incorporate the essential features currently used in the USAF system.

4-4. APPLICATION TO ARMY FORECASTING. The USAF system, with the exception of the forecasting routines, is an appropriate paradigm on which to base a revised Army forecasting system. The USAF system contains all the components required for forecasting, cost and performance reporting, Transportation Operating Agency (TOA) bill processing, and data base maintenance.

CHAPTER 5

ALTERNATIVE METHODOLOGIES CONSIDERED TO IMPROVE THE FORECASTING SYSTEM

5-1. GENERAL. The requirements of the forecasting system, the sources of information, and the systemic, external environment, and methodological aspects of the forecasting system were considered in the development of proposals for changes to the current projects. Systemic and external environment factors are discussed in this chapter. Forecasting methodologies are discussed in Chapter 6.

a. System Requirements. To satisfy the essential requirement of JCS Pub 15, AR 55-23, AR 55-30, and an accurate cargo forecasting process, the systems should provide the following capabilities:

(1) Forecasts of cargo movement requirements by commodity, route, mode, and program.

(2) Forecasts of budget requirements.

(3) System performance data by commodity, route, mode, and program.

(4) A historical data base of cargo movement requirements.

b. Information Sources. Cargo which generates peacetime over-ocean movement requirements is generally in support of personnel and equipment deployed overseas or in support of specific programs such as force modernization. As peacetime overseas deployed personnel and equipment densities do not vary significantly, historical cargo movement requirements and current program information contain most of the data required for forecast development. The MSC cargo billing is the most comprehensive and could be the most accurate source of historical lift data. Sources of program data are (1) personnel related programs--MILPERCEN and ODCSPER, (2) materiel related programs--DARCOM and DCSRDA, (3) fuels (coal and coke)--ODCSLOG, and (4) AAFES and MPSA for their specific programs.

5-2. ALTERNATIVE SYSTEM STRUCTURES

a. General. Several system structures were examined considering the requirements of the system, the sources of the information, and the costs in personnel and facilities. In each case it was assumed that (1) improved forecasting models or procedures were available, (2) TACs were restructured to ensure identification of force modernization items and the specific generators of general and special cargo, and (3) that the present forecasting requirements will continue. There are many possible system structures which can satisfy the forecasting requirements to some degree. Of these, four predominate: (1) the current system with improved methodology, (2) the current system with the long-range and short-range systems combined, (3) forecasting by a single Army agency using historical program data from DARCOM, DCSLOG/DLA and MILPERCEN, (4) forecasting by MTMC and other TOA with program input from the Army. The first two represent decentralized options while the latter two are centralized options.

b. Current Forecasting System Retained. This alternative, which is portrayed in Figure 5-1, envisions the retention of the present forecasting agencies and channels, correction of current forecasting anomalies, and improved forecast and budget coordination. It assumes that, given an improved methodology and restructured TACs, improvements in forecast accuracy could be achieved within the framework of the present system. This option requires that each forecasting agency/command be provided (or develop) an accurate mathematical forecasting model capability an accurate data base, and that the forecasters have access to program data. The TAC structure is such that it allows each forecasting agency to identify the amount of each commodity that it has shipped and the program responsible for the shipment. The time sequencing and frequency of reports remain as required by the current procedures. Reports stating forecasted tonnage by route, commodity, and program are prepared using a directed forecasting methodology for all commodities except for nonrecurring or program specific items. Program data is derived from the most appropriate sources. These sources include TAEDP, Materiel Management Reports (MMR), the Committee on Ammunition Logistics Support Report, and the Annual Solid Fuels Requirement Report. The final annual forecast and each short-range forecast are updated versions of the previously submitted forecast including the effects of program changes. Also, in this option, the LCA system and MECHTRAM are modified to identify forecasts which are significantly different from expected values and periodically compare performance reports with individual command/agency forecasts. Significant variances are resolved between the forecasting agency and HQDA for long-range forecasts and with LCA for the short-range forecasts. The monthly performance reports are segregated at LCA and forwarded to the forecasting/shipper agencies for comparative analysis and retention for data base purposes.

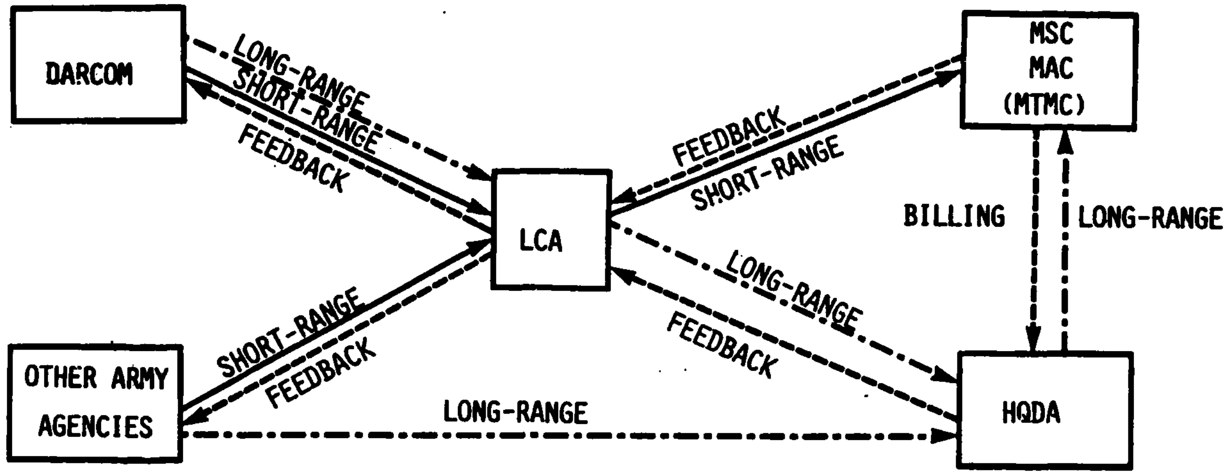


Figure 5-1. Current Forecasting System

c. <u>Current System Modified with Long-range and Short-range Forecast Systems Combined</u>. This alternative, Figure 5-2, requires that the same agencies as in the previous alternative prepare and submit forecasts, except that both the long-range and short-range forecasts are submitted to one agency versus two for consolidation and adjustment. This agency could be either HQDA, HQ DARCOM, LCA, or any other designated agency. All other processes are as in the previous alternative. Consolidation of the two procedures provides a more positive linkage between the long-range and short-range forecasts.

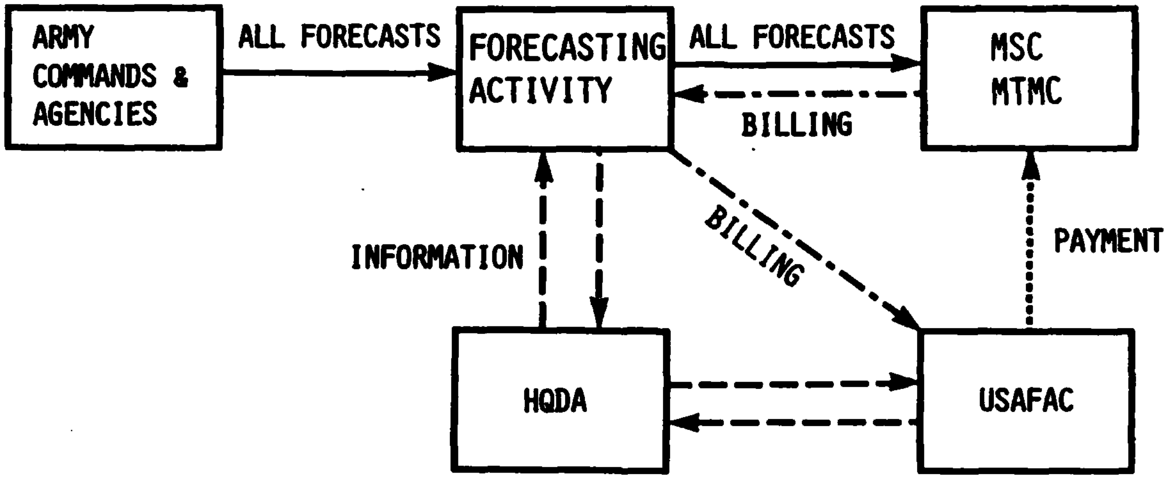


Figure 5-2. Current Forecasting System Modified

d. Single Agency Forecasting with Program Input. The alternative, Figure 5-3, envisions a single agency preparing the forecasts for all commodities, routes, and programs based on forecasting model outputs. These are modified by current information on specifically identified programs such as coal and coke, ammunition, and force modernization items. Program data is submitted by AAFES, MPSA, DARCOM, and DCSLOG annually, stating projected monthly shipping requirements by item, origin, and destination. All other commands report projected or nonrecurring requirements. Negative reports are required. Projected annual personnel movements are provided from MILPERCEN/DCSPER to the forecasting agency. Where the personnel movement forecast is significantly different from the previous year's, the model generated forecasts for POV and household goods (if forecast) shipments are modified to reflect the expected movements. Agencies submitting annual program information also forward quarterly reports indicating changes to the previously submitted annual reports. Other change reports would be submitted when shipments on a given route are expected to differ from the forecast by 600 MTON. Monthly performance reports are analyzed by the forecasting agency to evaluate the accuracy of the forecasts. The reports are used to identify and resolve discrepancies between forecasts and actual lift, and to modify forecasting models. The forecasting activity in this option requires an automated data processing system which provides for those capabilities currently in the MECHTRAM system. It provides a route and system performance monitoring process such as that employed by USAF and incorporates mathematical forecasting capabilities developed in this study. MSC bills received by the forecasting agency are validated. They are then used as source data for forecast performace evaluation and for the data base to be used in future forecast formulation. Activities of the agency would consolidate all actions now performed in the MECHTRAM system at HQDA and the ADP support to forecasting at LCA. Personnel in the forecasting all should be of military rank O4/O3, MOS 49, or their civilian equivalent who possess a knowledge of the Defense Transportation System and computer operations.

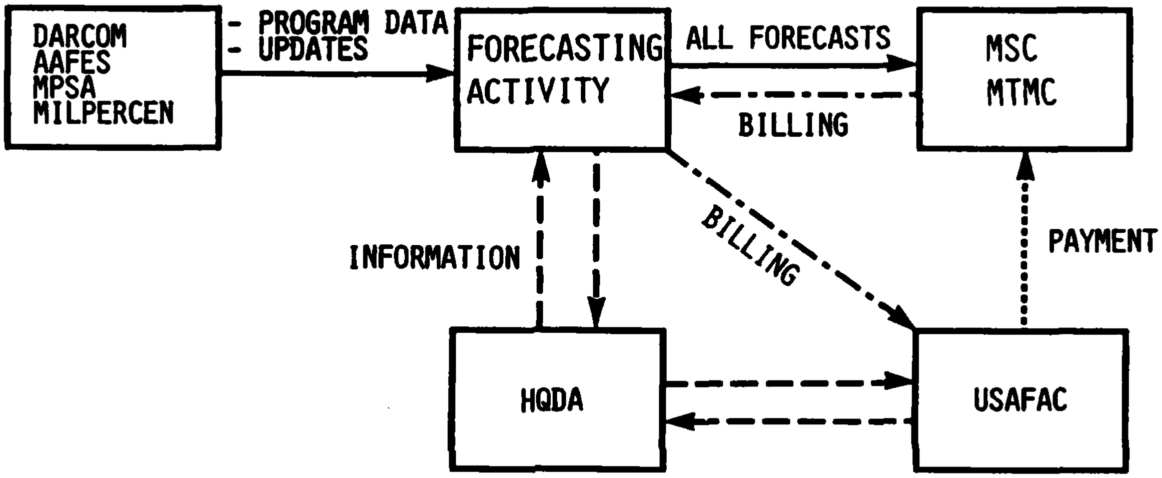


Figure 5-3. Single Agency Forecasting

e. Forecasting by the TOA (Objective System). In this alternative, Figure 5-4, MTMC prepares the annual forecasts based on cargo movement history and program information provided by the shipper services. HQDA consolidates program information provided by DARCOM, MILPERCEN, and the Army Staff and forwards it to the MTMC. MTMC computes cargo requirements based on forecasting model output and program information, provides the forecast to MSC, and from this, transportation costs are estimated. The TOA provide HQDA with forecasted tonnages and costs for service budget preparation purposes. Transportation costs are paid as under the present system. Budget performance reporting and validation of billing information functions are performed by the MECHTRAM or similiar system. MECHTRAM also produces monthly, and as required, cost and performance reports for the various HQDA staff elements (DCSLOG, DCSPER). As the historical shipping data used in forecasting is originated from TOA billing and the TOAs are supported by extensive computing facilities, it is feasible and desirable for the TOAs to develop the forecasts. In particular, HQ MTMC is capable of producing forecasts of over-ocean cargo movement requirements for both MTMC and MSC as a result of its own forecasting model development which has occurred concurrent with this study. Model parameters developed by this study, and discussed in the next section, can be provided to MTMC to assist in forecast development.

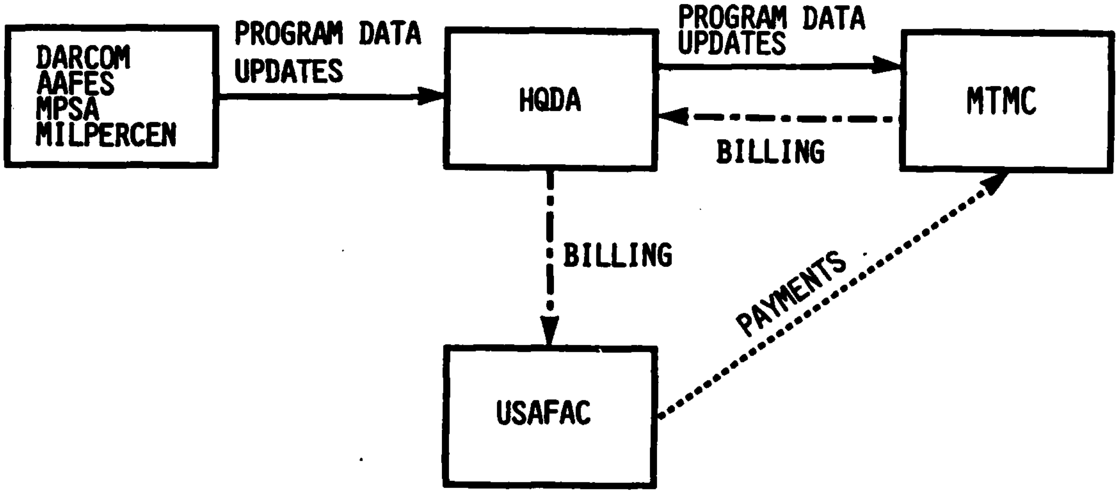


Figure 5-4. Forecasting by TOA

5-4. EVALUATION OF ALTERNATIVE SYSTEMS. Table 5-1 portrays the identifiable direct cost associated with the four alternatives previously described. This section discusses the four alternatives in terms of personnel and operational costs.

Table 5-1. Alternative System Costs

	(1) Current system	(2) Current system modified	(3) Single Army forcasting activity	(4) Forecast by TOA (objective system)
Man-years	14	13	6	5
Models	17	16	1	1
Data bases	17	16	1	1

a. Alternative 1, the present system, requires at least 23 personnel. Of these, 9 are full-time forecasters. The efforts of the other 14 range from 10-50 percent of their time. This effort equates to approximately 14 man-years annually. By eliminating the dual reporting system as in Alternative 2, an estimated one space would be saved as the result of combining the HQDA-LCA effort. Largest savings of personnel occur in Alternatives 3 and 4. Alternative 3 envisions a three-person forecasting cell, a HQDA program officer, a DARCOM program coordinator, and part-time effort by one person at AAFES and MPSA. Alternative 4 would reduce the size and effort of the Army forecasting cell and, if adapted by all shipper services, would result in similar personnel savings by each shipper service.

b. In addition to the direct costs in personnel, already discussed, there are significant indirect costs associated with the forecasting activitives. These include management, clerical, and communications support. Currently, 17 separate commands or agencies and HQDA prepare forecasts. Additionally, several of these agencies consolidate forecasts prepared by subordinate commands, e.g., LCA, a forecasting agency, also consolidates forecasts prepared by five DARCOM commands. This would be reduced significantly in Alternatives 3 and 4. Reduction of the number of agencies, as in Alternatives 3 and 4, also reduces lead time required for forecasts, thus allowing more recent data to be considered when they are developed.

c. Accurate forecasting and use of a predictive model requires each forecasting agency/command to maintain an accurate historical record of cargo forecasted and cargo shipped. Most forecasting models require a minimum of 50 data points. This results in a data base at least 50 months of shipping data. Current estimates of MSC records of Army shipments are 30,000 records, each containing 140 characters per year. Alternative 1 has a complete data base at MSC/MTMC, HQDA, and LCA. Each forecasting agency in turn maintains the data relevant to its operations. Alternative 2 would eliminate either the HQDA or LCA data base. Alternative 3 requires only one Army data base and Alternative 4 requires only the retention of the MSC/MTMC data base, which is the source of data for all other data bases in the other alternatives.

d. Accurate forecasting requires the use of some form of predictive model. Alternatives 1 and 2 require the development and maintenance of a large number of models, as it is unlikely that a general model would be applicable to each commodity and each shipper. This, combined with the maintenance of the data bases, requires a significantly greater effort than Alternatives 3 and 4. (Specific forecasting models are discussed in Chapter 6.)

e. Forecasting systems require accurate and timely information on their programs. All agencies which currently forecast, with the exception of HQ FORSCOM and District Engineer, New York, have access to the program information which is required to formulate the cargo movement requirement for which they are responsible. However, aggregated program information is available at HQDA/HQ DARCOM to determine most materiel associated cargo movement requirements and at HQDA/MILPERCEN to determine personnel associated cargo movement requirements. As AAFES and MPSA have other service responsibilites, these agencies alone have cognizance of the programs which will affect their requirements for cargo movement. Historic cargo lift data is available from the MSC and MTMC billing tapes at HQDA, LCA, and to a limited extent at some of the forecasting agencies. Options 1 and 2 require the processing of program information and, as discussed earlier, the MSC billing information by all forecasting commands/agencies. Options 3 and 4 use consolidated program information and TOA bills. They convert program and historic information into forecasts at a single location. The quality of the program information available to forecasters in any of the options should be comparable. However, the translation of the data into cargo movement requirements would appear to be more efficient if performed at a single location as in Options 3 and 4.

5-4. COLLOCATION OF CARGO MOVEMENT REQUIREMENTS AND BUDGET FORECASTING ACTIVITIES

a. Discussions during the early stages of the study surfaced a concern that an underlying cause of current forecasting inaccuracies is the separation of budget and cargo movement requirements forecasting. Investigation of the forecasting system did not confirm this as a condition or source of error. From a management perspective, if the budgets are the estimated costs of shipping the cargo, then the budgets should be developed from the forecast of the cargo movement requirements and the projected cost schedule. This does not imply that the cargo movement and budget forecasts should be performed by the same office but does imply that a procedure exists which ensures coordination and interdependence of the two processes. The documentation of the MECHTRAM process describes this function as occurring at HQDA; however, as discussed earlier, the current budget development process does not use the MECHTRAM reports.

b. USAF and USN budget systems were examined to determine what effects, if any, could be attributed to the separation or collocation of cargo forecasting and budget preparation processes. USAF budget development and execution and cargo movement requirements forecasting are all performed by a single office at USAF Logistics Command. USN has separated the functions. Budget processes are performed by Naval Supply Systems Command, Arlington, Virginia, while cargo movements forecasting is performed by the Navy Material Transport Office (NAVMTO), Norfolk, Virginia. The systems are equally accurate. No other systems were identified wherein the separation of operations forecasting and fiscal forecasting made a difference to the accuracy of the operations forecasting, and no alternatives were developed which varied budgeting responsibility.

CHAPTER 6

METHODOLOGY DEVELOPMENT

6-1. GENERAL. The purpose of this section is to describe the development of the forecasting methodologies used to model the transportation workload forecasting (TWF) data. Paragraph 6-2 describes the data gathering and data manipulation processes. Paragraph 6-3 discusses time series analysis and the reasons for using this type of data analysis. Paragraph 6-4 provides a general description of the Box-Jenkins modeling approach for time series data. (A detailed description of this approach is discussed in Appendix E.) Paragraph 6-5 discusses the Winters approach to modeling time series data. (A detailed description of the Winters method is discussed in Appendix G.) Paragraphs 6-6 thru 6-14 discuss the individual commodities that were forecasted, the processes involved in developing the mathematical models, and the forecasting results. Figures 6-2 through 6-10, presented later, compare the commodity forecasts of the Box-Jenkins and Winters models with the actual lift data for FY 82. Appendix F details specific analytic steps of Box-Jenkins model building for each commodity. Appendix H contains similar information for Winters models. Paragraph 6-15 summarizes the results of the forecasting models.

6-2. DATA DESCRIPTION. This paragraph details the steps taken to develop the TWF data base: (1) data acquisition, (2) computer system conversion, (3) data format and condition, and (4) data reduction.

a. Data Acquisition. Six years of lift information (tonnage) on Army cargo shipments was acquired from MSC. The data provided by MSC contained lift information by route, commodity, and mode of shipment.

b. Computer System Conversion. The following specifications were followed during tape creation:

Tracks	9
Code	ASCII
File(s)	Sequential, unformatted
Density	1,600 BPI
Logical record length	80
Block size	3,200
Label	None

c. Data Format and Condition. Each record contained 35 columns of data, formatted shown in Table 6-1.

Table 6-1. Data Format

Columns	Data entry
1-2	Fiscal year
3-4	Sail year
5-6	Sail month
7	Container type
8-10	Port of embarkation (POE)
11-12	POE traffic area
13-15	Port of debarkation (POD)
16-17	POD traffic area
18-21	TAC
22-23	Commodity
24-35	Measurement tons

Initial attempts to read the data with a univariate statistics program failed, due to the existence of nonnumeric entries in data fields. Records containing aberrative subfields were corrected or deleted, as appropriate. Records indicating zero shipment of measurement tons were removed. This process reduced the original data base of 184,645 records to a final count of 150,387 records covering the timeframe October 1977 through June 1983.

d. Data Reduction. Several special purpose FORTRAN programs were developed in order to transform the revised data base into forms suitable for analysis.

(1) In preparation for preliminary time series analysis, the data base was broken out into 12 general commodity files, each of which contained records of shipment tonnage versus time.

(2) The 12 (raw) commodity files were segregated into various route subfiles and 7,202 "credits" discovered in the original data base were removed. The credits had been entered into the original data base in order to offset certain debits.

(3) Time series data were developed for 424 unique routes, and the routes were rank-ordered according to decreasing levels of shipment activity.

(4) Finally, tonnage was segregated on a monthly basis and according to chronological shipment date. One program was designed to process routes individually. The other was designed to form composites of all routes for each commodity.

e. Time Series. Aggregated time series data for each commodity are contained in Figures G-1 through G-12, Appendix G. Of the 81 months of data, 60 were deemed necessary for model construction and adequacy verification. It is generally recommended that at least 50 observations be used, if possible, when developing Box-Jenkins time series. Specifically, data from October 1977 through September 1981 were used to build both the Box-Jenkins and Winters models.

f. Forecast Interval. The 12 observations from the sixth year of data (FY 82) were used as the basis for testing the forecasting accuracy of each model. Two measures of forecasting accuracy were selected from among several potentially acceptable alternatives:

(1) Annual Percentage Error. The annual percentage error between forecasted and actual cargo shipments was used as a simple aggregate measure of relative accuracy from a practical point of view.

(2) Mean Square Error (MSE). The mean squared error of the 12 monthly observations was used to capture the absolute accuracy from a statistical standpoint.

6-3. TIME SERIES ANALYSIS

a. Background. Time series analysis is the application of analytical techniques to model historical data. It differs from most types of historical data analysis in that no attempt is made to determine the factors affecting the behavior of the historical trend. Another difference is that time series analysis is concerned with historical data that are serially correlated and not independent. Time series analysis attempts to model behavioral trends and relationships between consecutive observations.

b. Analysis Considerations. Time series analysis techniques were considered the most apropriate analytic tools to forecast the US Army transportation workload requirements after considering three important factors: (1) data pattern, (2) time and efficiency, and (3) accuracy of forecasts.

(1) Time series analysis is usually the analysis of a single variable over time, i.e., univariate. In many cases, the univariate series exhibits a behavioral pattern over time. The pattern may be seasonal or a persistent trend may exist in the data. This behavior is usually made up of dependent observations and unlike most analytic techniques, time series analysis does not rest on the assumption of independent observations. Instead, time series analysis capitalizes on the dependency of the observations, determines the patterns in the data and then models the patterns. The data contained in the TWF study was highly dependent, therefore time series analysis was selected as the most appropriate statistical modeling tool.

(2) Due to the complexity of events that produced the transportation lift history, it was virtually impossible to determine all the factors that affected the historical process. In many cases the factors affecting the

process could not be defined quantitatively or a causal relationship between the factors and the process could not be determined. Sufficient proxies, such as troop density, could have been developed to resolve these issues, however, the time and energy required to obtain statistically relevant factors would have been immense. Time series analysis enables quick development of forecasting models since factors affecting the process are for the most part ignored. Several studies which compared simple time series models to complex econometric models indicated that time series models can provide comparable forecasting results and, in some cases, better forecasting results than the complex models.

(3) Finally, as indicated earlier, time series models are primarily concerned with identifying systematic behavioral patterns in the data. Once the systematic pattern is identified, the data can be separated into two components: (1) the data pattern and (2) the random error of the data pattern. This statement is expressed as:

DATA = PATTERN + RANDOMNESS

If the future observations of a time series can be predicted, without any error, then a deterministic model is sufficient because the randomness of the data is negligible.[4] If the data exhibit random behavior over time, the predictions of future observations are mainly concerned with the identification, modeling, and prediction of the error term. Time series analysis is the best forecasting methodology to employ when the accurate modeling of the error term is critical. TWFS data exhibited a random behavior over time; thus, stochastic time series analysis was determined to be the most appropriate modeling approach.

6-4. BOX-JENKINS MODELING APPROACH

a. Background. Box-Jenkins models are a unique set of linear time series models used to model stochastic time series data. Box-Jenkins models fall into three classes: autoregressive (AR), moving average (MA), and mixed (ARMA). Box-Jenkins models find their origin in the AR models that were first introduced by Yule (1926) and later generalized by Walker (1931). MA models were first developed by Slutzky (1937), and ARMA models were initially theorized by the work of Wold (1938). George Box and Gwelym Jenkins are responsible for collating these previous works and establishing an approach to apply these models.[2] The Box-Jenkins approach consist of three steps (see Figure 6-1):

(1) Identification - the first step in applying the Box-Jenkins methodology was to identify the degree of homogeneity in the data, i.e., how many times the series must be differenced to achieve stationarity. Once the degree of homogeneity was established, the data pattern was identified as AR, MA, or ARMA.

(2) Estimation - After the data pattern was correctly identified, parameter estimates for AR, MA, or ARMA models were generated to obtain a model that best fit the data.

(3) Verification - Finally, a test run using the estimated model parameters was conducted. The results and diagnostic checks were performed on the model parameter estimates and residual estimates to ensure goodness of fit and adequacy of the model. The predictive value of the model was evaluated and analyzed using historical data that was not used to develop the original model. If the model was not adequately verified, then steps 1-3 were repeated until an appropriate model was identified.

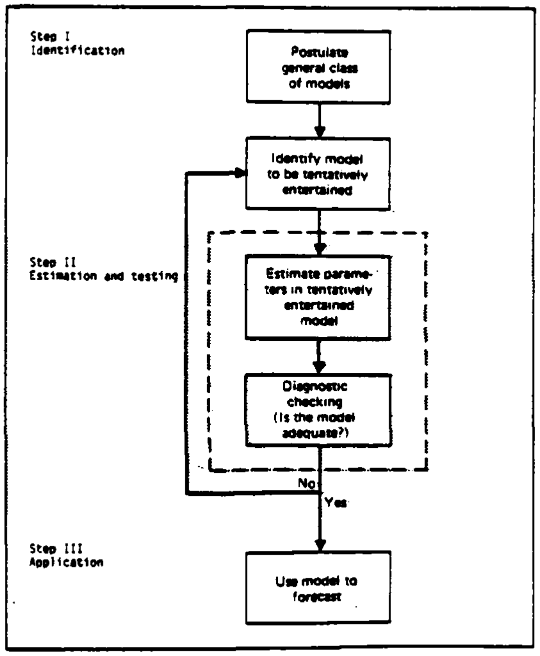


Figure 6-1. Box-Jenkins Modeling Approach

b. <u>Stationarity</u>. The most crucial element in applying Box-Jenkins models is the principle of stationarity. Stationary data are defined as data that are invariant with respect to time. A stationarity data series is characterized by a constant mean, variance and covariance throughout the series, i.e., no change over time.

c. <u>Data Transformations</u>. It is uncommon for a data series existing in its natural form to be stationary. Thus, the data must be transformed to achieve stationarity. Three major transformations were applied to the data to achieve stationarity: (1) differencing the series, (2) applying natural log transformations to the series, and (3) applying a square power transformation to the series. If these techniques did not produce stationary data, then differencing of the logged series (#2) or differencing of the squared series (#3) was attempted. Model applications to differenced series are referred to as integrated and noted by the letter "I."

d. Box-Jenkins Models. Once stationarity was achieved, the data were modeled using the three general classes of Box-Jenkins models: AR, MA, or ARMA.

(1) Autoregressive (AR) Models. AR models follow the general form

$$x_t = \delta + \phi_1 x_{t-1} + \phi_2 x_{t-2} + \dots + \phi_n x_{t-n} + \epsilon_t$$

where δ is drift, x_t are the dependent observations of the series, ϕ_n are the regression estimates of the model, and ϵ_t is the error term. The most common models are the AR(1) model

$$x_t = \delta + \phi_1 x_{t-1} + \epsilon_t$$

and the AR(2) model

$$x_t = \delta + \phi_1 x_{t-1} + \phi_2 x_{t-2} + \epsilon_t$$

Autoregressive models differ from the general regression equations in that there are no independent variables to regress upon. The regression is performed on past values of the dependent variable, thus the term autoregressive.[6]

(2) Moving Average (MA) Models. MA models follow the general form

$$x_t = \mu + \epsilon_t - \theta_1 \epsilon_{t-1} - \theta_2 \epsilon_{t-2} - \dots - \theta_n \epsilon_{t-n}$$

where μ is the mean of the series, ϵ_t are the past error terms and θ_n are the parametric estimates of the model. The most common form of MA models are the MA(1) model

$$x_t = \mu + \epsilon_t - \theta_1 \epsilon_{t-1}$$

and the MA(2) model

$$x_t = \mu + \epsilon_t - \theta_1 \epsilon_{t-1} - \theta_2 \epsilon_{t-2}$$

Unlike the AR models which are a linear function of past observations, MA models are a linear combination of past errors. Also, unlike the general moving average models where the sum of parameters equals 1 ($\theta_1 + \theta_2 + \dots \theta_n = 1$), Box-Jenkins MA model parameters do not necessarily add up to 1. Finally, the error terms of the model are assumed to be distributed normally with a mean of zero (0) and a constant variance (σ^2).[6]

(3) Autoregressive - Moving Average (ARMA) Models. ARMA models are combination models which are derived from the following equality:

$$\phi(B)\ x_t = \theta(B)\ \epsilon_t$$

where ϕ and θ are the AR and MA parameters, x_t and ϵ_t are the past observations and error terms, and B is the backshift operator $Bx_t = x_{t-1}$. In essence, this equality states that a complex AR process can be expressed as a MA process of infinite order and vice versa. The resultant of this equality is the general equation for forecasting X_t:

$$X_t = \phi_1 x_{t-1} + \ldots + \phi_n x_{t-n} + \delta + \epsilon_t - \theta_1 \epsilon_{t-1} - \ldots - \theta_n \epsilon_{t-n}$$

The combination of AR and MA terms produces a model that is more accurate than the pure MA or AR models.[6] A more detailed discussion of the Box-Jenkins modeling approach is contained in Appendix E.

e. To standardize model identification, all models are specified as autoregressive integrated moving averages (ARIMA) of order p, d, q, where p refers to the order of autoregressive parameters, d refers to the number of differencing transformations, and q refers to the order of moving average parameters. Therefore, all models will be referred to as ARIMA (p,d,q) models.

f. Box-Jenkins models for the TWFS were developed using the BMDP Statistical Software package.[3] All figures depicted in Appendix F are copies of the computer printouts from BMDP program applications.

6-5. WINTERS MODEL

a. Background. Historically, the fitting of systematic functions to observations has typically relied on least-squares criteria in which all the observations are given equal weight. However, it is often the case, when data is being observed as a function of time, that more weight should be given to the recent past, and that observations taken a long time ago should be discounted in comparison. In 1957, C. C. Holt published a paper entitled "Forecasting Seasonals and Trends by Exponentially-weighted Moving Averages." The procedure proposed therein addressed development of a set of weights proportional to powers of a parameter β, where β was defined to be greater than zero but less than unity. Thus, the set of weights were 1, β, β^2, etc. Constraints were imposed whereby the sum of the weights must equal unity, and β must serve to minimize the mean square error. Holt ultimately considered two parameters, the import of the second being to account for a trend in the data. In 1960, P.R. Winters extended Holt's method to cover seasonal effects. Thus, the model for which he is responsible is a three-parameter model.

b. Applications. Winters model owes its development primarily to the fact that there are many time series that cannot be adequately modeled by a polynomial. Time series with cyclical or seasonal variations fall into this category. For example, at least a cubic equation (which has a single point of inflection between regions of upward and downward concavity) is required to capture the cyclical pattern of periodic data. Furthermore, from an applications viewpoint, many industrial time series exhibit seasonal behavior. Good examples include the seasonal movement of specific commodities such as POVs.

c. General Form. The general form of Winters model expresses an observation x_t at time t as

$$x_t = (a_1 + b_2 t)\, c_t + \epsilon_t.$$

The three parameters of the model are a_1, b_2, and c_t, while the term ϵ_t is taken to represent the usual random error component. The parameter a_1 is called the permanent component, and is analogous to a y-intercept. Similarly, the parameter b_2, or trend factor, corresponds to the slope of a simple linear equation. The third parameter, c_t, represents a set of seasonal factors for each cycle. The seasonal factors induce fluctuations above and below the line segments that are fitted to each cycle. The Winters model as described herein is a multiplicative seasonal model, so named because the seasonal parameter c_t is applied multiplicatively, not additively. Multiplicative seasonal models are most appropriate for time series in which the amplitude (or excursion) of the seasonal pattern is *proportional to the* average level of the series. This pattern was evident in the TWFS data.

d. Specific Form. The specific form of Winters prediction equation is

$$\hat{x}_{T+\tau}(T) = \left[\hat{a}_1(T) + \hat{b}_2(T)\tau\right]\hat{c}_{T+\tau}(T+\tau-L)$$

where, conventionally, carats are used to denote estimates. The equation gives the forecast at time T for an observation at time $T + \tau$. Quantities in parentheses indicate the times of computation of the estimates. Thus in order to forecast period $T + \tau$, the seasonal factor which was computed one season (L periods) ago in period $T + \tau - L$ must be used.

e. Parameters. As mentioned earlier, the three parameters of the Winters model are the permanent component, the trend component, and the seasonal factor. Estimates of these parameters for the period T are weighted and combined with estimates from previous periods. The manner in which the current estimate of a parameter is apportioned with respect to a previous value is such that the mean square error is minimized over the entire time series. Smoothing constants (or weights) are used to apportion present and past estimates. For example, if the smallest mean square error were produced by a weight of 0.80 for the current estimate of a parameter and 0.20 for the previous estimate of the parameter, then this would mean simply that the current estimate is four times as important in the parameter updating process as the previous estimate.

(1) Permanent Component. The estimate of the permanent component is updated by

$$\hat{a}_1(T) = \alpha \frac{x_T}{\hat{c}_T(T-L)} + (1-\alpha)\left[\hat{a}_1(T-1) + \hat{b}_2(T-1)\right]$$

where $0 \leq \alpha \leq 1$. Note that the value of x_T is divided by $\hat{c}_T$ (T - L), which is the estimate of the seasonal factor for period T computed one season (L periods) ago. This is done in order to eliminate seasonal fluctuations from x_T, i.e., to deseasonalize the current observation. The deseasonalized observation is then combined with the contribution of the permanent component and trend for the previous period T-1. This shifts the origin of time to the end of the current period. The adjustment for seasonality can best be understood by considering the case when $\hat{c}_T$ (T-L) is greater than 1. This occurs when the value in period T-L is greater than average in its seasonality. Dividing x_T by this number greater than 1 gives a value that is smaller than the original value by a percentage just equal to the amount that the seasonality of period T-L was higher than the average. Of course, the opposite adjustment occurs when the seasonality number is less than unity. It should be noted that the reason for using the seasonal factor from the previous season (L periods ago) is that the seasonal factor for the current season cannot be computed until the permanent component itself is calculated.

(2) Trend Component. The estimate of the trend component is updated by

$$\hat{b}_2(T) = \beta[\hat{a}_1(T) - \hat{a}_1(T-1)] + (1-\beta)\hat{b}_2(T-1)$$

where $0 \leq \beta \leq 1$. This equation is exactly as Holt's equation for smoothing the trend. The estimate of the trend component is simply the smoothed difference between two successive estimates of the permanent component. The procedure of determining the trend component is similar to evaluating the slope of a line segment, where the endpoints of the line segment correspond to the beginning and end of the period T.

(3) Seasonal Factor. The estimate of the seasonal factor is updated by

$$\hat{c}_T(T) = \gamma \frac{x_T}{\hat{a}_1(T)} + (1-\gamma)\hat{c}_T(T-L)$$

where $0 \leq \gamma \leq 1$. This equation specifies the seasonal index as the ratio of the current value of the series, x_T, to the current smoothed value for the series, $\hat{a}_1(T)$. If x_T is larger than $\hat{a}_1(T)$, the ratio will be greater than 1, while if it is smaller than $\hat{a}_1(T)$, the ratio will be less than 1. It is important to understand that $\hat{a}_1(T)$ is a smoothed average value of the series that does not include seasonality. The values of x_T, however, do contain seasonality (as well as randomness). Notice that equation smoothes (weights) the current observed seasonal variation ($x_T/a_1(T)$) with the estimate of the seasonal factor for period T computed L periods ago. That was the last opportunity to observe this portion of the seasonal pattern.

f. Smoothing Constants and Model Initialization. The method of initializing model parameters and of solving for the smoothing constants is not central to understanding the Winters method. A short explanation of these procedures has been included as Appendix G.

6-6. POV FORECASTING MODEL DEVELOPMENT

a. POV data is fairly constant on an annual basis; however, the monthly data is highly seasonal. Stationary data was achieved after differencing the series at a lag of 12 months.

b. The appropriate model for POV data was a nonseasonal ARIMA (2,0,0) model and seasonal ARIMA (0,1,1) model:

$$\underset{(.19)}{(1 - .0221B} - \underset{(3.05)}{.3554\,B^2)}\,(1 - B^{12})\,X_t = (1 - \underset{(16.77)}{.8581\,B^{12})}\,\epsilon_t$$

$$\chi^2\,(3,20) = 16.35$$

The results indicate that all of the estimated coefficients of the model, except ϕ_1 are significant at the 5 percent significance level. Verification of the model's adequacy using the Box-Pierce test indicates that the autocorrelations of the estimated model residuals are not significantly different from zero at the 30 percent significance level. (Details of the Box-Pierce test and model adequacy are contained in paragraph E-6, Appendix E). Using this model to forecast FY 82 POV shipments resulted in a forecast of 501.37 K/MTON versus an actual shipment of 510.25 K/MTON, which corresponds to an underforecast of 1.7 percent (see Figure 6-2). The MSE of the POV forecast for FY 82 was 8.54.

c. Variations of the aggregate POV data model were used to forecast POV mode requirements. The POV container shipments during FY 82 were underforecast by 20.1 percent. The POV breakbulk shipment forecast was overforecast by 8.8 percent. Specific details pertaining to Box-Jenkins modeling of POV data and all other commodities are contained in Appendix F.

d. When the Winters model was used to forecast POVs for 1982, an underforecast of 5.3 percent occurred. The aggregate forecast was 483.12 K/MTON, corresponding to an MSE of 12.92. Separation of this commodity by mode of shipment produced smaller errors of -3.3 percent (breakbulk) and 3.0 percent (containerized). However, based on increased mean square errors, the overall fits were not as good. The specific Winters parameters for each commodity and month have been included at Appendix H.

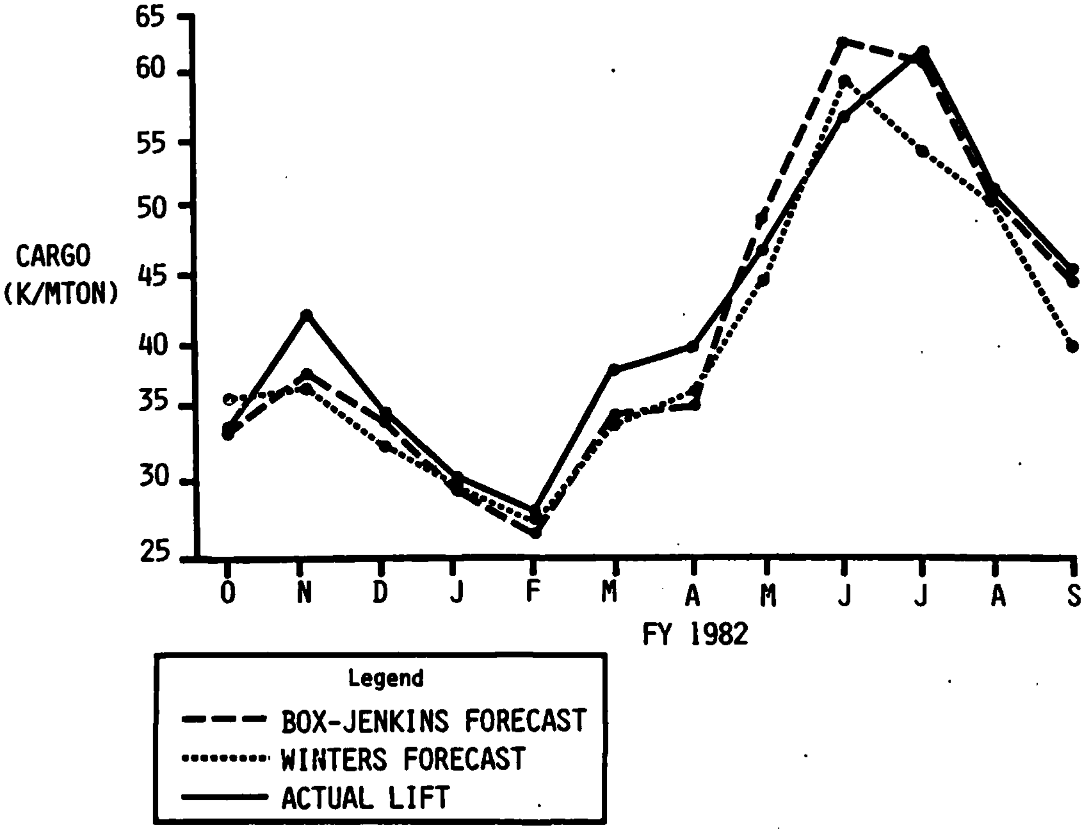


Figure 6-2. POV Cargo Forecast - FY 82

6-7. GENERAL CARGO FORECASTING MODEL DEVELOPMENT

a. General cargo accounts for the largest amount of cargo shipped under any single commodity code. General cargo accounts for approximately 50 percent of all cargo shipped by the US Army during any individual year. This commodity code not only includes operational and facility maintenance items, but also force modernization program data. The inclusion of this force modernization data within the time series data hinders the development of accurate forecast models for the general cargo commodity. If new TAC codes are used to isolate force modernization equipment, the accuracy of general cargo forecasts will improve. To demonstrate this point, the general cargo data series was separated into two components: (1) A205 TAC data--primarily DARCOM items and (2) non-A205 TAC data--other items shipped as general cargo. The results of this effort will be discussed later.

b. Annual general cargo data fluctuates within a narrow range of ±10 percent; however, the data is seasonal. Stationarity was achieved after two successive differencing operations. First the series was differenced at a lag of 12 months. This operation did not produce stationary data, thus the seasonally adjusted series was differenced at a lag of 1 month.

c. The appropriate model for general cargo data was a mixed ARIMA (1,1,1) nonseasonal model and a seasonal ARIMA (0,1,1) model:

$$(1 - \underset{(2.5)}{.3579\ B})\ (1 - B^{12})\ (1 - B)\ X_t = (1 - \underset{(8.31)}{.7962\ B})\ (1 - \underset{(13.43)}{.7753\ B^{12}})\ \epsilon_t$$

$$x^2\ (3,20) = 12.8$$

The results indicate that all of the estimated coefficients are signficant of the 5 percent significance level. The Q statistic for 20 degrees of freedom is 12.8. Thus, the null hypothesis, estimated model residuals are uncorrelated, should not be rejected at the 10 percent significance level. The general cargo seasonal model forecasted that 1856.61 K/MTON would be transported during FY 82 versus an actual shipment of 2021.55 K/MTON, equating to an underforecast of 4.6 percent error (see Figure 6-3). (Note: another model developed for general cargo underforecast the FY 82 lift by 4.2 percent. The goodness of fit of this model was not as good as the ARIMA (1,1,1) x (0,1,1) model, but the forecast accuracy of both models should be tracked in the future.) The MSE of the general cargo forecast for FY 82 was 318.54.

d. Box-Jenkins modeling of the general cargo mode shipments produced a 9.8 percent underforecast of container data and an 8.5 percent underforecast of breakbulk data. The non-A205 (non-DARCOM) forecast for general cargo was underforecast by 2.2 percent.

e. Application of the Winters model to general cargo resulted in a forecast of 1870.38 K/MTON. The prediction was about 7.5 percent below the actual shipment, while the MSE was 279.89.

f. Several excursions were conducted on general cargo in order to assess this important category accurately. The Winters model was accurate to within 1.4 percent for non-A205 (non-DARCOM) shipments (breakbulk and container combimed) and to within 1.6 percent for non-A205 (container only). Overall, the Winters model did not fit the breakbulk time series well (28.6 percent overforecast). The Winters general container forecast was within 4.9 percent of the actual data.

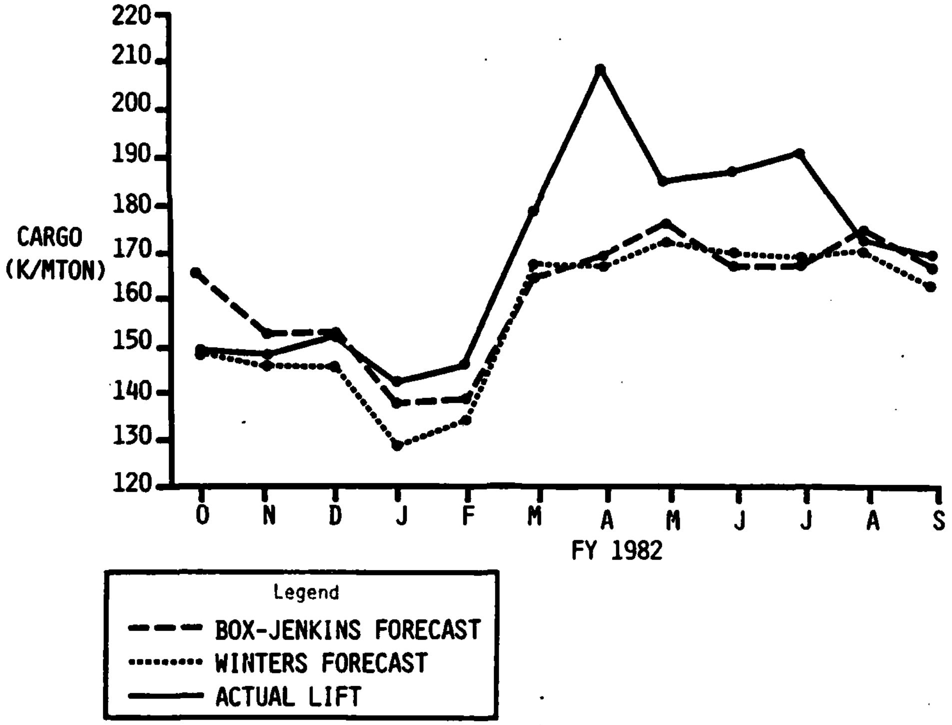


Figure 6-3. General Cargo Forecast - FY 82

6-8. HHG FORECASTING MODEL DEVELOPMENT

a. Transportation arrangements for DOD-sponsored household goods (HHG) are made by MTMC, using primarily two methods: freight forward (Code 4), and those that are MSC processed (Code 5). Freight forward shipments are shipments of HHG that are contracted with private carriers from door to door; shipments of HHG that are shipped using the assets of MSC are Code 5 shipments. Additionally, some HHG are returned to CONUS via MAC when cargo space is available.

b. Data used in the study only consisted of Code 5 shipments. According to other HHG shipment data that was gathered from MTMC, Code 5 shipments comprise less than 4 percent of the total HHG tonnaged shipped during a given fiscal year. However, any aberration in the commercial shipping process will cause HHG shipments by MSC to increase significantly. For example, assuming that Code 5 shipments comprise 4 percent of total HHG transported, a 1 percent change in Code 4 shipments due to a commercial shipping strike will increase Code 5 shipments by 25 percent. This fact complicates the development of accurate models to forecast the amount of HHG shipped by MSC. It also lends credence to the argument that MTMC should be involved in the HHG forecasting process. An accurate forecasting model for all HHG shipments cannot be developed until additional probability and economic analysis of commericial shipping is integrated into the forecast model.

c. Only data from October 1978 through September 1981 was used to develop the forecasting models due to the volatility of HHG during the period under study. As noted in Figure F-26, Appendix F, HHG shipments in FY 78 were approximately three times greater than any other year due to commercial shipping aberrations. Annual HHG data during FY 79 through FY 81 exhibited a slight trend downward, but the monthly data was seasonal. To achieve stationarity, the data were differenced at a lag of 12 months.

d. The appropriate model for HHG data was a nonseasonal ARIMA (0,0,1) model and a seasonal ARIMA (1,1,0) model with a series mean:

$$\underset{(-2.33)}{(1 + .3198B^{12})}\ (1-B^{12})\ X_t = \underset{(-3.67)}{1.163} + \underset{(1.88)}{(1-.3397B^4)}\ \epsilon_t$$

$$\chi^2\ (2,20) = 6.26$$

All of the estimated coefficients, except θ_4, are significant at the 5 percent significance level. θ_4 is significant at the 7 percent significance level. Verification of the model's adequacy using the Box-Pierce test with 20 degrees of freedom indicates that the null hypothesis (uncorrelated residuals) should not be rejected at the .5 percent significance level. This model forecasted FY 82 HHG shipments to be 80.19 K/MTON versus an actual lift of 87.68 K/MTON (see Figure 6-4). The MSE of the forecast was 5.24 and the annual forecast error was -8.5 percent. Mode forecast of HHG data resulted in a 23.4 percent overforecast of container data and a 16.9 percent underforecast of breakbulk data.

e. The Winters fit resulted in a forecast of 76.079 K/MTON, amounting to an overall underforecast of 13.2 percent. The MSE was 3.361. Separation of household goods into breakbulk and containerized shipments only served to worsen the forecast. The breakbulk fit produced an overforecast of 43 percent, while the containerized model resulted in a 36.5 percent underforecast.

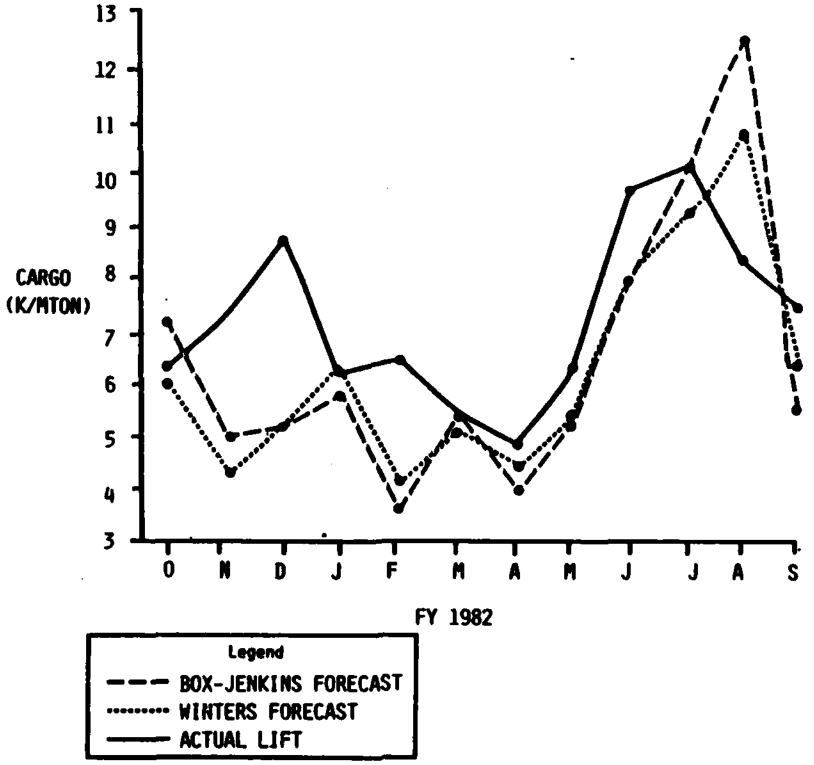


Figure 6-4. HHG Cargo Forecast Data - FY 82

6-9. COAL FORECASTING MODEL DEVELOPMENT

a. Coal shipments are concentrated on the shipping routes between East Coast/Gulf Coast to Europe. Less than .01 percent of all coal shipped is inbound for ports other than Europe. Coal forecasts are prepared by the Energy Center, Rheinau and forwarded to Defense Logistics Agency (DLA-DFSC). DLA is responsible for soliciting the contracts for the coal requirements and approving the negotiations. Once contracts are approved, the Energy Center at Rheinau and the MSC coordinate the shipment scheduling of coal.

b. During October 1977 to September 1981 (timeframe used to construct the statistical forecasting model), several factors affecting coal shipments occurred.

(1) In recent years, contract negotiations for coal procurements have been delayed due to several reasons, which in turn have delayed coal shipments during a given fiscal year. Thus, the data obscure the fact that some coal shipments which are ordered to be delivered in one fiscal year

are delayed and actually shipped in another fiscal year. Over time, this accordion effect will disappear. However, accurate forecasting for any given year is hindered because the current data are clouded by events external to the forecasting system.

(2) During the conservation efforts of the past few years, coal burners in Europe have transferred their source of fuel from anthracite to bituminous. Although the effort is made for cost and conservation purposes, the true impact of the change cannot be determined from the data. The total tonnage of coal shipped has not changed appreciably since any reduction of anthracite has been mostly offset by the increase in bituminous.

In sum, mathematical forecasting for coal shipments should be modified based upon knowledge of the energy program and external events that impact on the program.

c. Coal data during the period under study did not exhibit a recurring pattern or seasonal trend. However, it is evident that some adjustments to the raw data are necessary to improve the accuracy of the forecasts. Stationary data was achieved after differencing the raw series at a lag of 1 month.

d. The appropriate model for coal data was an ARIMA (1,1,1) model:

$$(1 - \underset{(9.46)}{.3461}B)\,(1 - B)\,X_t = (1 - \underset{(2.06)}{.859}B)\;\epsilon_t$$

$$x^2\ (2,20) = 10.87$$

The results indicate that all of the estimated coefficients are significant at the 5 percent significance level. The estimated ARIMA (1,1,1) model was verified using the Box-Pierce test and a visual examination of the estimated residuals of the model. The Q statistic test is 10.87, which indicates that the null hypothesis, uncorrelated residuals, should not be rejected at the 6 percent significance level. The ARIMA (1,1,1) model forecasted the FY 82 coal tonnage shipped to be 373.53 K/MTON as compared to the historical FY 82 lift of 375.94 K/MTON (-.6 percent) and the actual FY 82 DLA coal contract of 440.67 K/MTON (15.2 percent error). The forecast MSE was 192.60. Figure 6-5 illustrates the monthly forecast.

e. When the Winters model was used to predict the historical FY 82 lift, a forecast of 351.93 K/MTON resulted. Although the average forecast error was only 6.4 percent, the MSE was fairly high (210.18), indicating a relatively poor fit.

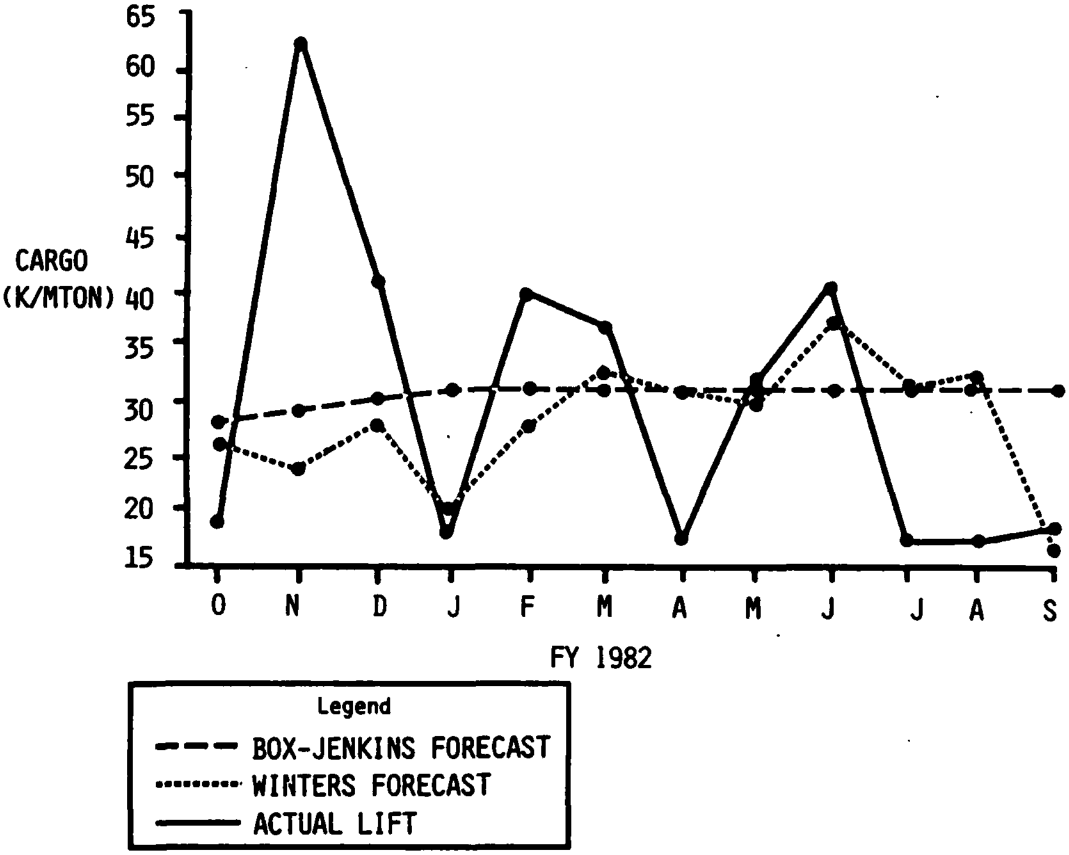


Figure 6-5. Coal Cargo Forecast - FY 82

6-10. AMMUNITION FORECASTING MODEL DEVELOPMENT

a. Ammunition requests fall into two general categories: (1) ammunition to increase war reserve stocks and (2) ammunition to be used for training purposes. The war reserve buildup program is an annually funded program that is reviewed every 6 months to address the manufacturing, transportation, handling, and stockpiling constraints of ammunition buildup. Ammunition dedicated for training purposes is strictly based upon demand and number of combat units in a particular theater. Additionally, safety testing of ammunition complicates the accurate forecasting of ammunition requirements. If manufactured ammunition fails safety tests, then ammunition shipment plans must be rearranged.

b. The ammunition movement planning process consists of two principal agencies: DCSLOG and Armament, Munitions and Chemical Command (AMCCOM). DCSLOG functions as a screening filter for the war reserve buildup program and training ammunition requests from theater commands. Requests are reviewed biannually at Committee on Ammunition Logistic Support (CALS) meetings, where ammunition allocations are determined for each command based upon priority and manufacturing constraints. The approved allocations are then used by AMCCOM to direct movement of ammunition to the selected commands. At the subsequent CALS meeting (every 6 months), the status of ammunition reserves and manufacturing capability is reviewed and adjustments are made to achieve the stated goals. As with coal, annual ammunition forecasts should be based upon mathematical models and inside information regarding the status of ammunition programs.

c. Ammunition data is relatively constant on an annual basis and the monthly data exhibits some seasonality. However, attempts to capture the seasonal aspects of the data were futile since stationarity could not be achieved. Like coal, the ammunition data should be monitored carefully and adjusted with caution. Stationary data was achieved after differencing the original series at a lag of 1 month.

d. The appropriate model for ammunition data was an ARIMA (2,1,4) model:

$$(1+\underset{(-7.33)}{.8418B} + \underset{(-4.59)}{.5399\,B^2})\,(1-B)\,X_t = (1+\underset{(-3.11)}{.3454B^4} - \underset{(3.86)}{.3689B^5} - \underset{(4.57)}{.3875B^6} - \underset{(2.43)}{.2561B^7})\,\epsilon_t$$

$$\chi^2\,(6,20) = 17.61$$

All of the estimated coefficients are significant at the 5 percent significance level. The Box-Pierce test for the model indicates that the null hypothesis, estimated residuals are uncorrelated, should not be rejected at the 40 percent significance level. The model forecasted that ammunition shipments during FY 82 would be 189.62 K/MTON versus an actual lift of 179.31 K/MTON of ammunition during FY 82 (see Figure 6-6). The MSE of the ammunition forecast was 119.91 and the annual error was 5.7 percent.

e. When the Winters model was used to forecast ammunition, a forecast of 158.080 K/MTON resulted, which corresponds to an error of -11.8 percent. The fit was quite good, except for the existence of a heavy ammunition shipment (outlier) during July of FY 82. MSE was 107.59.

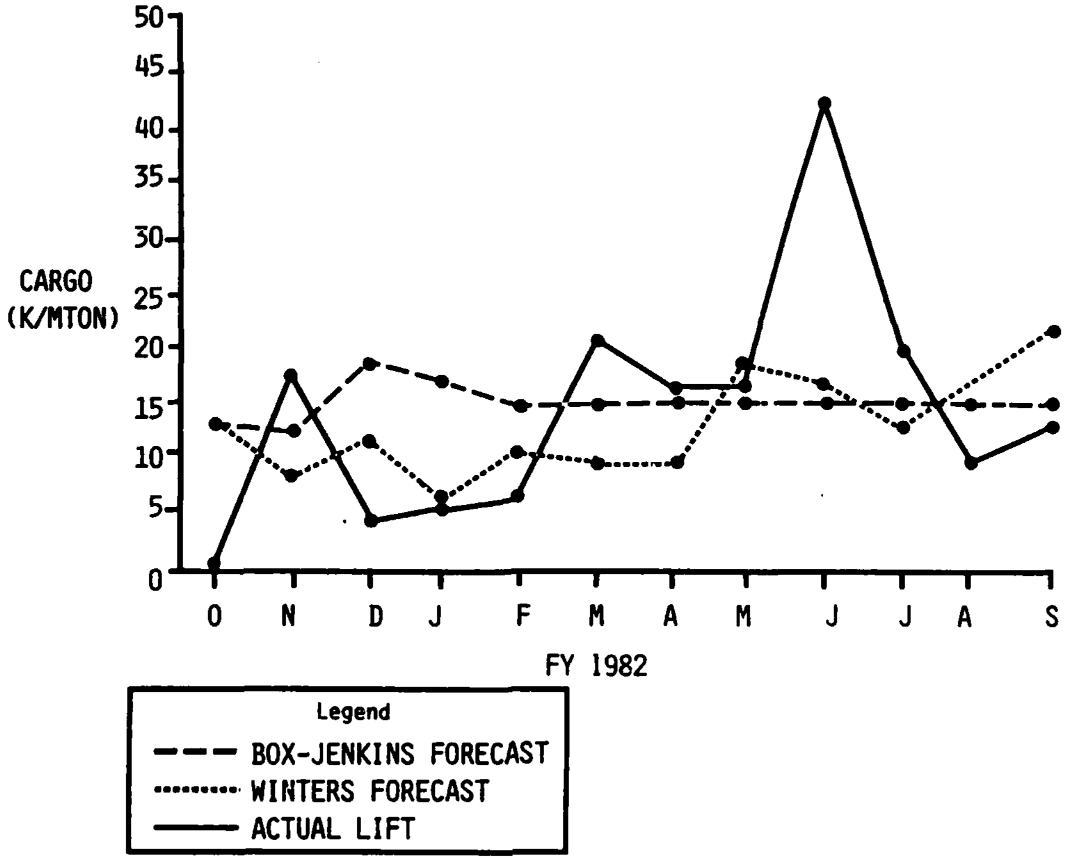


Figure 6-6. Ammunition Cargo Forecast - FY 82

6-11. SPECIAL FORECASTING MODEL DEVELOPMENT

a. The majority of items shipped under commodity code special comprise program items that relate to the Army Modernization Improvement Memorandum (AMIM). They include items such as M1 tanks, 5-ton trucks, and track vehicles. However, there are some program items which are small enough to be shipped in the general cargo category such as force modernization program equipment shipped by Communications and Electronics Command (CECOM). Radios and other electronic items that are shipped by CECOM that are small in size are shipped as general cargo. Items shipped under commodity code special are primarily AMIM program items; however, not all AMIM items are shipped as special cargo. For purposes of this study, AMIM items could not be isolated from the special cargo category due to the current TAC structure. However, with improved data base management and expanded TAC, more accurate forecasts of the special cargo commodity can be made.

b. Special cargo exhibited a trend that could possibly be interpreted as program funding of the defense budget and some aspects of seasonality. To achieve stationary data, the original series was differenced at a lag of 12 months.

c. The appropriate model for special cargo was an ARIMA (2,0,0) non-seasonal model and an ARIMA (0,1,1) model:

$$\underset{(1.21)}{(1 - .1496B} \underset{(3.16)}{- .3875B^2)} (1 - B^{12}) \ln X_t = (1 \underset{(10.61)}{- .801B^{12}} \underset{(1.65)}{- .1503^{14})} \epsilon_t$$

$$x^2 (4,20) = 13.15$$

All of the estimated coefficients except ϕ_1 and θ_{14} are significant at the 5 percent significance level. The model was verified using the Box-Pierce test and a visual check of the estimated residuals. The Q statistic for this model with 20 degrees of freedom is 13.15. This diagnostic indicates that the residuals are not significant and that the null hypothesis should not be rejected at the 16 percent significance level. This model forecasted that 559.42 K/MTON of special cargo would be shipped during FY 82 versus an actual amount of 189.83 K/MTON (see Figure 6-7). The annual forecast error was 14.2 percent and the forecast MSE was 159.23. It should be noted that the amount of special cargo tonnage shipped during FY 82 is much lower than any of the preceding years. In fact, the average tonnage of special cargo shipped over the past 5 years was 669.17 K/MTON. In all cases, forecasting methodologies are employed based upon the assumption that the behavior of future observations will not differ greatly from the behavior of past observations. When the future is radically different than the past, as in the case of special cargo tonnage for FY 82, forecasts cannot predict the future with any degree of accuracy.

d. Similarly, the radical change in special cargo shipments during FY 82 caused the Winters model to overestimate the actual lift by 28.1 percent. The forecast MSE was 404.018; the Winters model forecasted a lift of 627.52 K/MTON.

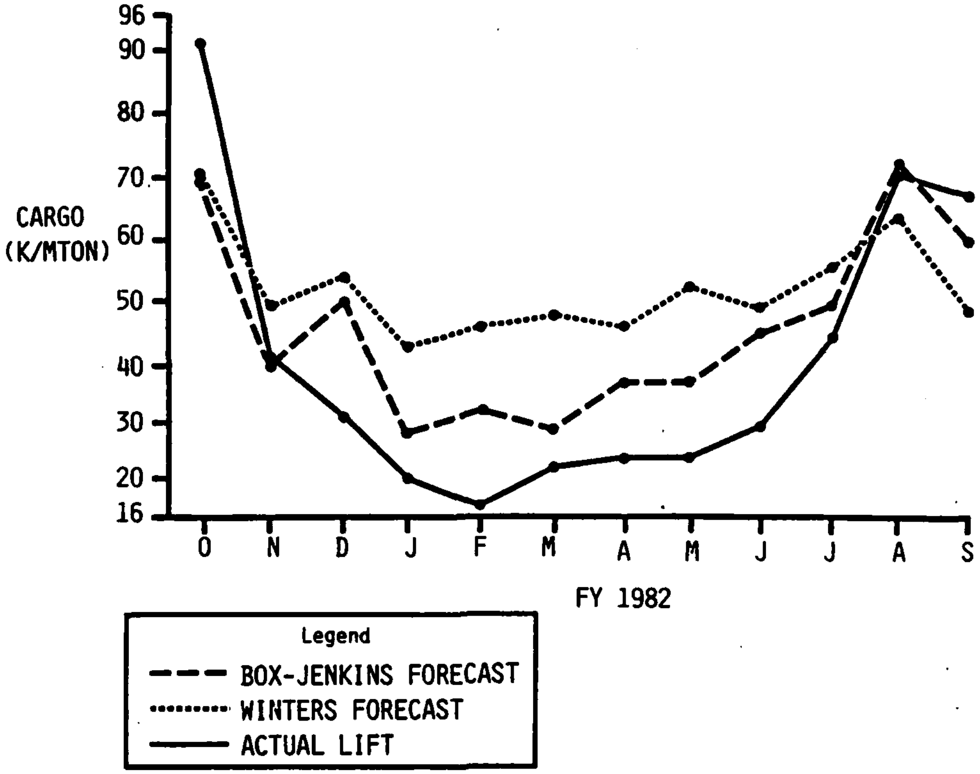


Figure 6-7. Special Cargo Forecast - FY 82

6-12. CARGO TRAILER/CONEX FORECASTING MODEL DEVELOPMENT

a. CONEX shipments, as annotated in the data (commodity 70), were in fact said to be roll on/roll off (RORO) trailer shipments. Empty CONEX data was negligible, therefore, it was combined with trailer data and the resulting series was modeled as cargo trailers. CONEX data demonstrated an upward annual linear trend and the monthly data exhibited seasonality. Stationarity was achieved after differencing the original series at a lag of 12 months.

b. The appropriate model for special cargo data was an ARIMA (0,0,1) nonseasonal model and an ARIMA (0,1,1) seasonal model with a series mean:

$$(1 - B^{12})\, X_t = \underset{(4.09)}{.4057} + (1 + \underset{(-2.32)}{.2912}B)\,(1 - \underset{(14.97)}{.8264}B^{12})\, \epsilon_t$$

$$\chi^2\ (2,20) = 12.74$$

The results indicate that all of the estimated coefficients are significant at the 5 percent significance level. The Q statistic for the estimated model residuals at 20 degrees of freedom is 12.74 which is significant at the 16 percent significance level. Therefore, the null hypothesis, uncorrelated residuals, should not be rejected at the 16 percent significance level. The model forecasted CONEX/cargo trailer shipments for FY 82 to be 76.43 K/MTON versus an actual lift for FY 82 of 74.47 K/MTON (see Figure 6-8). The MSE of the CONEX forecast was .81, and the annual forecast error was 2.6 percent.

c. When the Winters model was used to estimate CONEX/cargo trailer shipments, the forecast, 77.03 K/MTON, exceeded the actual lift by 2.56 K/MTON, or about 3.4 percent. The MSE was .78 K/MTON, and the fit was quite good.

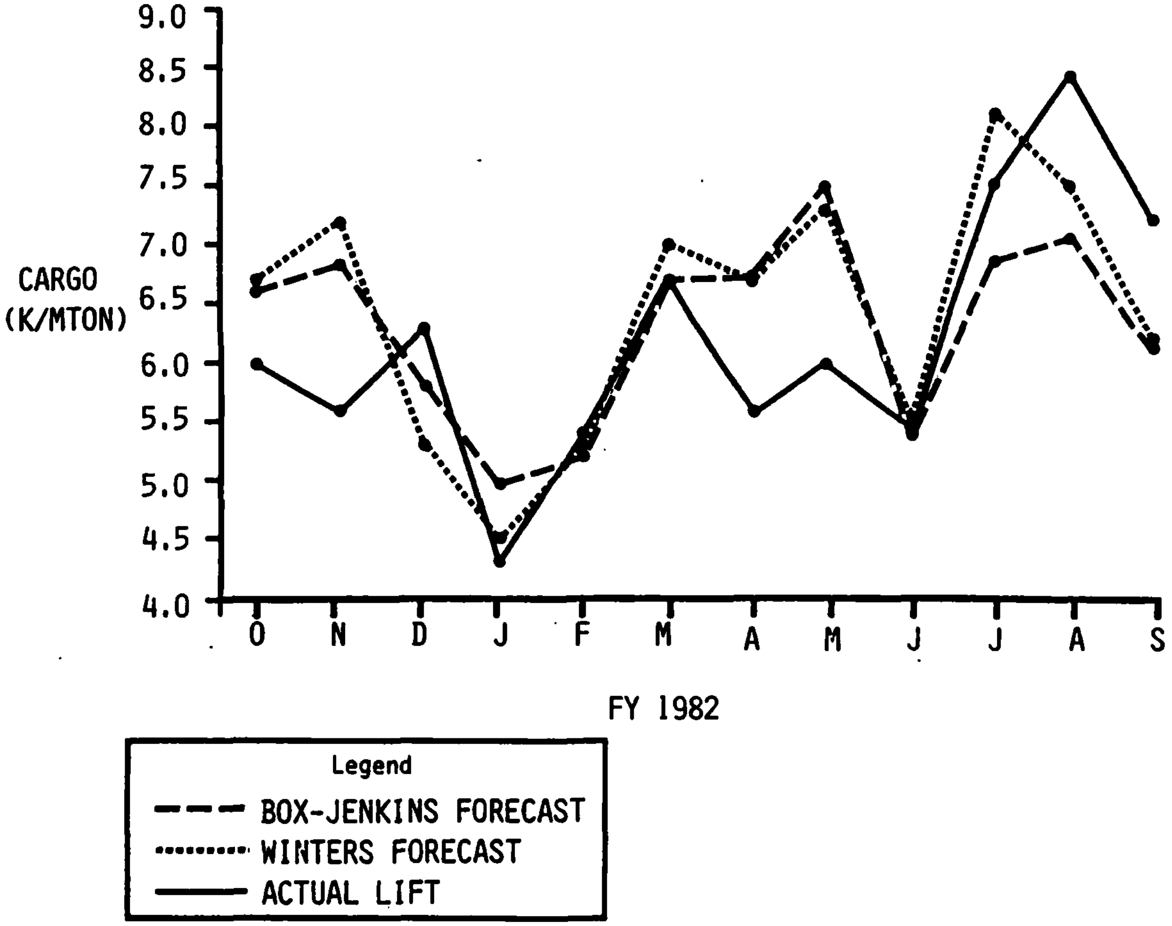


Figure 6-8. CONEX Cargo Forecast - FY 82

6-13. FREEZE FORECASTING MODEL DEVELOPMENT

a. AAFES shipments of freeze goods account for approximately 80 percent of freeze cargo shipped during a given year. Freeze shipments increased 24 percent during FY 82; however, AAFES freeze shipments increased 30 percent during the same period. Thus, like coal and ammunition, program information from AAFES must be integrated into the overall forecast of freeze data.

b. Freeze data depicts a trend and pattern very similar to CONEX data. The trend during the period under study was an upward linear function, and the monthly data exhibited seasonality. Stationarity was achieved after differencing the seasonally adjusted series at a lag of 1 month.

c. The appropriate model for freeze data was an ARIMA (2,1,2) non-seasonal model and a (0,1,1) seasonal model:

$$(1+\underset{(-6.76)}{.7740B} + \underset{(-5.96)}{.6789B^2})\ (1-B^{12})\ (1-B)\ X_t = (1-\underset{(4.32)}{.4729B} + \underset{(-5.76)}{.5038B^{11}})\ (1-\underset{(12.04)}{.7753B^{12}})\ \epsilon_t$$

$$\chi^2\ (5,20) = 14.66$$

The results indicate that all of the coefficients of the model are significant at the 5 percent significance level. The Q statistic for 20 degrees of freedom is 14.66. Therefore, the null hypothesis, residuals are uncorrelated, should not be rejected at the 20 percent significance level. The freeze seasonal model forecasted that 31.86 K/MTON would be transported during FY 82 versus an actual shipment of 36.42 K/MTON (see Figure 6-9). The MSE of the freeze forecast was .49, and the annual forecast error was -12.5 percent.

d. When the Winters model was used to forecast freeze shipments, a 12.8 percent underforecast resulted. The model forecasted a lift of 31.758 K/MTON, and the MSE of the forecast was 0.458, indicative of a relatively good fit.

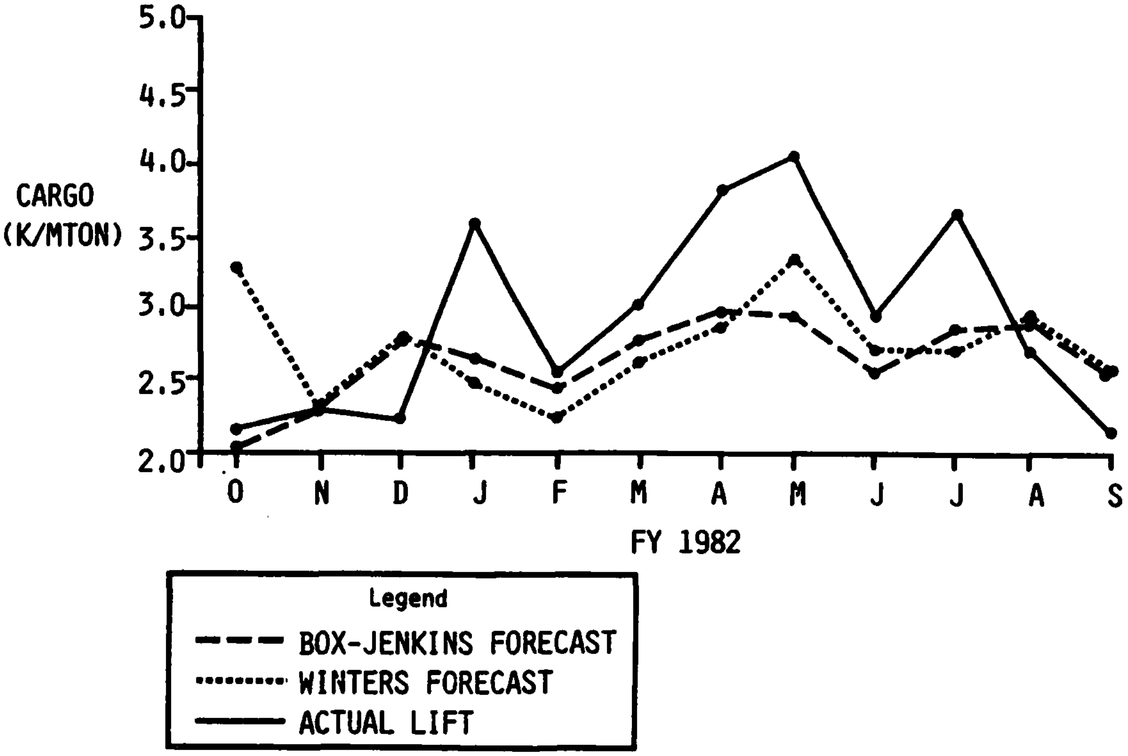


Figure 6-9. Freeze Cargo Forecast - FY 82

6-14. CHILL FORECASTING MODEL DEVELOPMENT

a. As stated previously, raw billing data from MSC were compiled into monthly time series data (cargo shipped monthly). The sorting process used to obtain the monthly time series data was done under the assumption that debits and credits contained in the raw data base would be eliminated by this process. Furthermore, it was assumed that this data manipulation would not produce any negative numbers (i.e., credit balance). This assumption follows from normal accounting practices when a credit is recorded to offset previous debit. However, due to problems with the raw data base, a negative number was generated from this process (November 1976--see Figure D-1, Appendix D). The cause of this negative number can only be resolved after a thorough review of the MSC and Army finance and accounting records which is beyond the scope of this study. Therefore, the first 2 months of the data series were eliminated. Time series data from December 1977 through September 1981 were used to develop forecasting models for the commodity chill.

b. Chill shipments were relatively constant on an annual basis, but monthly data did exhibit seasonality. Stationarity was achieved after transforming the original series using natural logarithms and then differencing the logarithmic series at a lag of 12 months.

c. The appropriate model for chill data was a nonseasonal ARIMA (0,0,2) model and a seasonal ARIMA (1,1,0) model:

$$\underset{(-5.61)}{(1 + .6371B^{12})}(1 - B^{12}) \ln X_t = (1 - \underset{(2.0)}{.3012B} + \underset{(-1.83)}{.2716B^2}) \epsilon_t$$

$$x^2\ (3,20) = 15.63$$

All of the estimated coefficients except θ_2 are significant at the 5 percent significance level. The Q statistic for 20 degrees of freedom is 15.63, which indicates that the residuals are not significant and that the null hypothesis should not be rejected at the 25 percent significance level. Also, all of the estimated residuals fall within the 95 percent confidence interval and appear to be distributed randomly. The FY 82 forecast for chill using this model was 15.32 K/MTON of cargo shipped versus an actual lift of 14.13 K/MTON (see Figure 6-10). The MSE of the chill forecast was .21, and the annual forecast error was 8.4 percent.

d. Application of Winters model to the chill time series resulted in a forecast of 13.03 K/MTON. This was an aggregate underforecast of 1.094 K/MTON, or -7.7 percent. The fit was good, and the MSE of the forecast was .13.

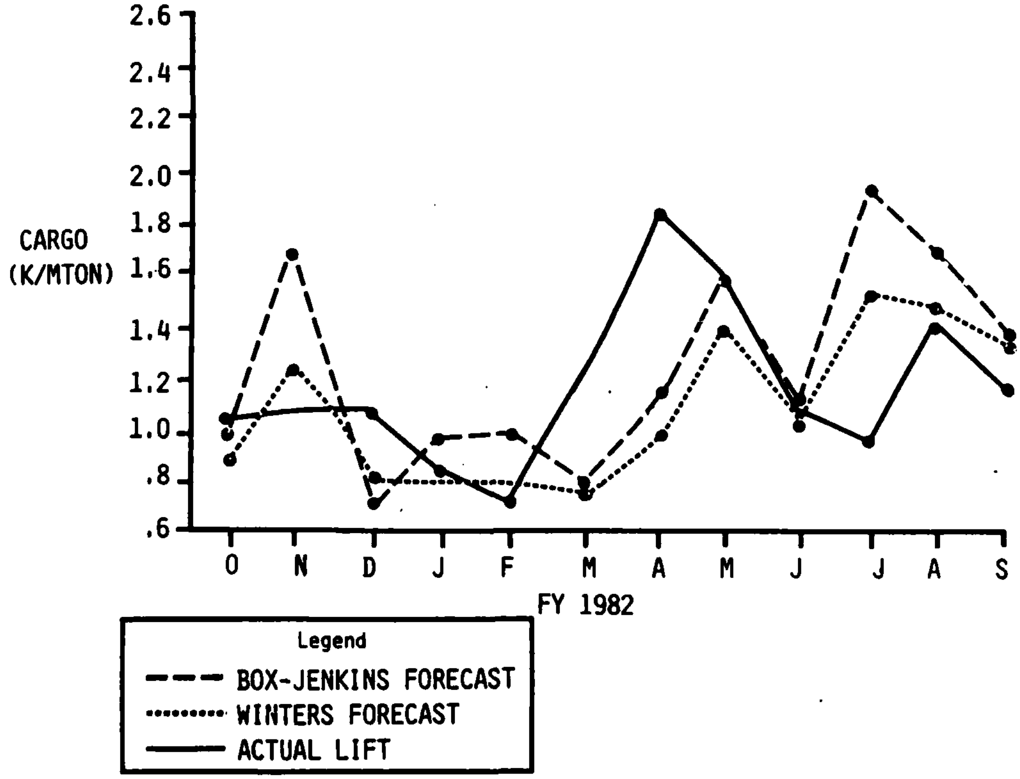


Figure 6-10. Chill Cargo Forecast - FY 82

6-15. SUMMARY OF FORECASTING RESULTS. Table 6-2 portrays the forecasting results of the Box-Jenkins and Winters models for each commodity for FY 82.

Table 6-2. FY 82 Forecasting Results

Commodity	Percent error			
	Present system		Box-Jenkins	Winters
	FY 81	FY 82	FY 82	FY 82
General	22.0	3.5	4.6	7.5
Breakbulk (4.7)	168.0	63.0	9.8	28.6
Container (44.5)	7.8	10.0	8.5	4.9
Nonprogram (33.5)	--	--	2.2	1.4
Special (16.6)	15.0	66.0	14.0	28.0
Coal (10.4)	22.0	13.8	.6	6.4
POV (13.5)	.4	7.3	1.7	5.3
Ammo (3.9)	36.0	3.9	.3	11.8
Household (2.5)	19.0	11.0	8.5	13.2
Cargo tlr (2.1)	30.0	14.6	1.6	2.9
Reefer (1.2)	14.0	39.2	7.0	10.0

( ) Percent of total lift.

CHAPTER 7

SATISFACTION OF ELEMENTS OF ANALYSIS

7-1. GENERAL. The course of the study was, to a significant extent, guided by all the sponsor's designated essential elements of analysis (EEA). However, identification of the variances between forecasts and lift, conditions which contributed to the variances, and effective methods for improving the forecast predominated the study efforts. All of the questions in the EEA were answered during the study, albeit some to a greater degree than others.

7-2. SYNOPSIS OF EEA. Discussion of the EEA is contained throughout the report. A capsule of the EEA and the answers to them follow:

a. **What are the recorded variances between long-range transportation workload forecasts and actual utilization of shipping cargo?** Tables 2-1 and 2-2, Chapter 2, contain the variances by commodity and shipping mode for FY 81 and FY 82.

b. **Do systemic conditions exist which contribute to unrealistic forecasting? If so, what are they?** Paragraph 2-2, Chapter 2, details the conditions observed in the current system. Most significant systemic contributions to the errors are the lack of an effective feedback system, some agency reports based on a limited knowledge of the forecasted commodity, inadequacies in the TAC structure, inadequate program input into the forecast, and separate long- and short-range forecasting systems.

c. **What is the economic and operational impact of long-range forecasts which are at variance with actual utilization?** Table 2-5, Chapter 2, shows the MSC industrial fund FY 82 losses which were directly attributable to errors in Army forecasts. Operationally, the forecasting variance resulted in underutilization of MSC cargo carrying capacity. The MSC-controlled fleet was approximately 40 percent utilized in FY 1982.

d. **Do short-range forecasts impact on long-range forecasting? If so how?** With the exception of CONUS outbound household goods and privately owned vehicles, long-range and short-range forecasts are prepared by the same personnel. In some cases, the long-range forecast impacts the short-range, as opposed to vice versa, as in those cases, the short-range forecasts are derived from the long-range.

e. **What is the impact of the current separation of responsibility for long-range and short-range forecasting?** Separation of the responsibility for long-range and short-range forecasting has created a dual system of reporting which does not contribute to the accuracy of the forecasts. It has produced long-range and short-range forecasts which are usually not in agreement. It requires the maintenance of similar records at LCA and HQDA, and diffuses responsibility for management of the forecasting system.

f. **What methodologies exist in other services which could be applied to the resolution of the Army's problem?** Discussion of USAF and USN forecasting procedures is contained in Chapter 3. The USAF forecasting procedures at AFLC could be used in conjunction with the procedures and models recommended in this report as the basis for an improved Army forecasting system. AFR 75-15, Forecast of Air Force Transportation Requirements, and AFLC Regulation 171-125, Surface Transportation Tonnage and Cost System (00278), contain a description of the USAF system.

g. **What DARCOM activities affect major end items of equipment planned for overseas distribution?** All program and project management decisions affecting the distribution of major end items to overseas locations impact the requirements for surface cargo space. In particular, changes to programs which occur subsequent to the formulation of the annual forecast of space requirements are critical in that the shipping vessel procurement and use is developed from this forecast. If the transportation forecasting activity is not cognizant of the changes to programs, then the match of shipping resources to available cargo is complicated. A major forecasting difficulty has been the information interface between the program decisions and the forecasting process. The analysis of the impact of DARCOM activities was limited by the masking of much of the DARCOM generated cargo within the general and special cargo commodities.

h. **What is the impact of the TAEDP on forecasting of requirements?** The TAEDP is provided to DARCOM Inventory Control Points (ICP) prior to the preparation of the preliminary annual forecast. It is used in conjunction with the Materiel Movement Report (MMR) and judgment to forecast major end-item movement requirements. There is limited confidence in the TAEDP at the ICPs; consequently, there is significant reliance on the MMR and forecaster judgment.

i. **What is the commodity impact of AAFES forecasting procedures?** The AAFES forecasting procedures, per se, do not impact the commodities. AAFES accounted for 30 percent of all cargo, 50 percent of general cargo, and 60 percent of reefer cargo shipped in FY 1982.

j. **What are the effective and cost effective methods for improving forecasting accuracy?** Chapters 5 and 6 identify procedures and methods that would improve the accuracy of the forecasting system.

k. **What, if any, unique commodities are masked as general or special cargo?**

(1) Much of the CECOM force modernization equipment is masked as general cargo and is not currently identifiable. This prevents accurate adjustment of general cargo forecasts to reflect force modernization programs.

(2) Military sedans and smaller military wheeled vehicles are classified as and are masked in special cargo. All special cargo is forecast as transported via MSC breakbulk ships. These vehicles can be transported via breakbulk roll on/roll off (RO/RO) or container vessels, and could be identified as a separate commodity or in a single commodity with POVs.

CHAPTER 8

CONCLUSIONS

8-1. GENERAL. The investigation of the current Army transportation workload forecasting system and the methodologies used within the process indicates that it can be improved. Significant improvements and efficiencies can be gained from refining the Army forecasting system, using accurate forecasting tools, and amending the reporting requirements of the transportation operating authorities. Annual cost avoidance potential should range betwen $30M and $100M.

8-2. FORECASTING SYSTEM

a. The Army transportation workload forecasting system can be improved by using improved forecasting methodologies and revising the forecasting process.

b. A sufficient data base has been created in this study which can be used as a basis with forecasting techniques for making accurate forecasts and for incorporation into a data base used by Army forecasters.

c. The Box-Jenkins and Winters models can provide accurate forecasts of the Army over-ocean surface cargo transportation requirements.

d. When used in conjunction with program information, the forecasts developed using the Box-Jenkins and Winters models should provide the transportation operating agencies (TOA) with accurate forecasts of Army over-ocean surface cargo transportation requirements.

e. The forecasting of Army transportation requirements by the TOA, using a forecasting model and program input from the Army, is considered to be the most efficient, accurate, and cost effective system.

f. Forecasting by a single Army agency would achieve similar accuracy as forecasting by the TOA and would also result in significant cost savings. If forecasting by the TOA is not achieveable in the near term, forecasting by a single Army agency is the most efficient alternative. If forecasting by the TOA is ultimately developed, then the transition from forecasting by a single Army activity to the TOA would require minimal effort.

g. If the present forecasting structure is to be retained, accuracy would be improved by combining long-range and short-range forecasting systems, using an accurate multiyear data base, applying uniform forecasting methods, structuring TACs to identify each shipper and program, upgrading MECHTRAM, and developing an effective feedback program to inform shippers on the cargo shipped.

h. HQ DARCOM is the most appropriate location for the forecasting activity if it is decided that a single activity within the Army will perform the forecasting function. Predominant reasons for this conclusion are:

(1) DARCOM is a major Army shipper.

(2) HQ DARCOM is cognizant of and has a command relationship with the program activities which have the most significant impact on irregular shipping requirements (e.g., force modernization or ammunition program decisions). Consequently, coordination problems would be minimized.

(3) Non-DARCOM shipments are accurately predictable and, for the most part, can be forecasted using a forecasting model.

(4) HQ DARCOM has the capability, with augmentation, to support the forecasting system.

i. HQDA and LCA also have the capability to support the system, and could, if augmented with the appropriate skills, perform the forecasting function.

j. TAC structure revision would allow identification of program specific cargo within the general and special commodity categories and facilitate forecasting of these commodities.

k. Interdependence of the transportation budgets and workload forecasts would be enhanced if they used the same data sources.

l. Accurate and timely program data for force modernization, ammunition, fuels, and personnel related programs would improve forecast accuracy.

m. The automated systems supporting the USAF surface tonnage and cost system, and the forecast of Air Force transportation requirements process is an appropriate paradigm for the Army's ADP system to support transportation workload forecasting when used with the forecasting models developed in this study. It is also an appropriate model for the cost and performance aspects of the system.

n. There are no indications that separation of budget and forecasting responsibilities contribute to forecasting error.

8-3. EXTERNAL FACTORS

a. The requirement to forecast the mode of shipment as breakbulk or container is a significant contributor to forecasting error. Resolution of this problem with MSC and MTMC, resulting in elimination of this forecasting requirement, would eliminate at least one-third of the forecasting error.

b. Short-range forecasts appear to be of minimal value to the TOAs and do not justify the amount of effort required for their preparation. Submission of annual reports and periodic change reports should suffice.

c. MSC billing system appears to contain significant inaccuracies and delays in its reports. Stringent audits of MSC bills, establishment of a history of accuracy and timeliness of the MSC billing system, and development of procedures with MSC to resolve system defects which are identified should result in more accurate costs and an accurate data base for forecast formulation.

d. The amount of household goods processed by MSC is a small proportion of the total household goods shipped. MTMC decides whether household goods will be shipped by a freight forwarder or through MSC. As a small shift from freight forward shipment to MSC would have a major impact on forecast accuracy, MTMC involvement in the forecast formulation should reduce the potential for error in the Army household goods forecast.

CHAPTER 9

ACTIONS TO IMPROVE THE TRANSPORTATION FORECASTING SYSTEM

9-1. GENERAL. This chapter outlines those actions identified in this study that, if taken, should improve the Army's transportation workload forecasting process. Regardless of the system chosen, the actions concerning TAC revision, resolution of mode, household goods and short-range forecasting requirements, refinement of forecasting procedures, and budget and forecast interdependence, if executed, would improve forecast accuracy. It is assumed during the implementation of suggested actions: (1) that the current forecasting system will be maintained until the selected system is totally in place, and (2) that a timetable and responsibilities for the completion of necessary actions will be established.

9-2. SELECT FORECASTING SYSTEM STRUCTURE. Selection, from the proposed forecasting system structures, of that system or combination of systems which most satisfactorily meets the requirements of an improved forecasting system is a necessary prerequisite to the implementation of other changes. Forecasting at a single location, using historic and program information, is considered the most efficient and effective.

9-3. RESOLVE TAC STRUCTURE. Restructuring of the TAC to include TAC identification of the major program under which the commodity is shipped (i.e., Force Modernization) is required to isolate force modernization. If either decentralized forecasting system option is selected, then including identification of the program and the shipping command/agency in the TAC structure is suggested.

9-4. RESOLVE MODE FORECASTING REQUIREMENT. Resolution with the surface transport TOA to eliminate the requirement to forecast whether cargo is to be shipped breakbulk or container and that the forecast state only the commodity and route is necessary to eliminate a significant source of forecasting error.

9-5. RESOLVE SHORT-RANGE FORECASTING REQUIREMENT. Resolving with MSC and MTMC to eliminate the monthly short-range requirements forecast and replacing it with periodic reports of changes to the annual forecast is suggested.

9-6. RESOLVE HOUSEHOLD GOODS FORECASTING PROCEDURE. Establishment of a process whereby MTMC will participate in the development of the household goods forecast to determine what proportion of household goods will be shipped as Code 4 and Code 5 should reduce the potential for forecast error.

9-7. ESTABLISH REPORTING REQUIREMENTS. Establishing reporting requirements, based on the system selected and the resolution of forecasting requirements with the TOA, will ensure understanding of revised reporting responsibilities. The type, content, and frequency of reports should be established in coordination with the forecasting agencies/commands, budget agencies, and the TOA.

9-8. DEFINE LINKAGE BETWEEN FORECAST AND BUDGET. Establishing mechanisms to ensure that the forecasting of transportation requirements and budget processes are coordinated and have access to the same source data will assist both forecast and budget preparation.

9-9. DEVELOP ADP SYSTEM REQUIREMENTS. This action is also a function of the forecasting system selected. If the present system or variations thereof are selected, then modification of the MECHTRAM system to provide a more extensive data base, evaluate the forecasts made by the commands/agencies, produce information of greater utility to the budget process, and provide timely cost and performance data will improve the forecasting process. If a single Army agency is to perform the forecasting, then replacing or overhauling the MECHTRAM system is suggested. In either of these cases, including in the system those capabilities now embodied in the AFLC system and the forecasting models developed in this study will facilitate system improvement. If the forecasts are to be prepared by the TOA, the modification of the MECHTRAM system to accept program input and produce consolidated program reports, accurately process MSC bills, and provide comprehensive cost and performance reports on the surface cargo transportation process will provide necessary forecast and budget information.

9-10. UPDATE FORECASTING MODELS. Depending on the time between completion of the models by the study agency and their use by the forecasters, it may be necessary to refine the forecasting models. The models should be checked by comparing the most recent lift data available to forecasts developed by the model for the time periods in question.

9-11. REVISE REGULATIONS. Changes to AR 55-23 and AR 55-30, reflecting changes to the system, will be necessary to ensure understanding of the revised process. Additionally, change recommendations to JCS Pub 15 should reflect the changes to forecasting procedures which may be developed with the TOA.

APPENDIX A

STUDY CONTRIBUTORS

1. STUDY TEAM

a. Study Director

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LTC G. Tilden, Strategy, Concepts and Plans Directorate

APPENDIX B

STUDY DIRECTIVE

DEPARTMENT OF THE ARMY
OFFICE OF THE DEPUTY CHIEF OF STAFF FOR LOGISTICS
WASHINGTON, D.C. 20310

REPLY TO ATTENTION OF
DALO-TSP-C11 8350494

11 May 1983

SUBJECT: Transportation Workload Forecasting (TWF) Study

Director
U. S. Army Concepts Analysis Agency
8120 Woodmont Avenue
Bethesda, Maryland 20814

1. Purpose of Study Directive. This directive tasks the Concepts Analysis Agency to conduct the subject study.

2. Study Title. Transportation Workload Forecasting (TWF) Study.

3. Background. Current forecasting procedures of Army cargo and mail workload requirements directed by AR 55-30 prescribe input from seventeen major commands/agencies/activities, world-wide. These consolidated requirements are submitted by HQDA to the Military Sealift Command (MSC) and the Military Airlift Command (MAC) in accordance with Joint Chiefs of Staff Publication 15. The MSC provides the Military Traffic Management Command (MTMC) a copy. MTMC, MSC and MAC utilize this data to generate their industrial fund budgets. History reveals significant variances in forecasted requirements versus actual lift, which result in distorted budgets by both the shipper service and MSC/MAC/MTMC. Transportation funds to pay these overseas movements are centrally budgeted at HQDA, with the U. S. Army Finance and Accounting Center (USAFAC) the designated office.

4. Study Proponent and Proponent's Study Director. HQDA ODCSLOG is the study proponent. Director of Transportation, Energy and Troop Support, ODCSLOG (DALO-TSP), will be the Proponent's study representative.

5. Study Agency. U. S. Army Concepts Analysis Agency (CAA).

6. Terms of Reference.

a. Statement of the Problem. Current Army transportation workload forecasting procedures result in unrealistic forecasts of Army lift requirements to MAC, MSC, and MTMC.

b. Purpose. To develop procedures to improve US Army transportation workload forecasting.

c. Scope. This study will focus on the long-range surface transportation workload forecast process and its impact on the Army budget and on transportation costs. Short-range forecasting will be examined to the extent that it impacts on or influences the long-range forecast.

d. Objectives. Determination of the nature and extent of the TWF problem, exploration of alternative solutions to the problem, evaluation of the alternative solutions in terms of cost and feasibility, and development of an outline plan to manage the TWF system improvements.

e. Tasks.

(1) Identify the nature and extent of U. S. Army transportation workload forecasting variances from actual lift.

(2) Determine the impact of long-range transportation workload forecasts on the Army budget, on the industrial funds of Military Sealift Command (MSC), the Military Airlift Command and Military Traffic Management Command (MTMC), and on rates established for Army second destination cargo movements.

(3) Examine feasible and cost effective methods for increasing accuracy in forecasting.

(4) Examine and evaluate alternative locations for forecasting responsibility.

(5) Recommend an operationally and cost effective transportation workload forecasting methodology.

f. Timeframe. Current.

g. Assumptions. Transportation workload forecasting requirements will remain unchanged for the duration of the study.

h. Essential Elements of Analysis (EEA).

(1) What are the recorded variances between long-range transportation workload forecasting and actual utilization of cargo shipping?

(2) Do systemic conditions exist which contribute to unrealistic forecasting? If so, what are they?

(3) What is the economic and operational impact of long-range forecasts which are at variance with actual utilization?

(4) Do short-range forecasts impact on long-range forecasting? If so how?

(5) What is the impact of the current separation of responsibility for long-range and short-range forecasting?

(6) What methodologies exist in the other services which could be applied to the resolution of the Army problem?

(7) What DARCOM activities affect major items of equipment planned for oversea distribution?

(8) What is the impact of the Total Army Equipment Distribution Program (TAEDP) on forecasting of requirements.

(9) What is the commodity impact of AAFES forecasting procedures?

(10) What are the feasible and cost effective methods for improving forecasting accuracy?

(11) What, if any, unique commodities are masked as general or special cargo?

7. Responsibilities.

a. The ODCSLOG will:

(1) Provide support as required for its areas of responsibility and interest.

(2) Prepare an evaluation of study results IAW AR 5-5.

(3) Establish and convene a Study Advisory Group (SAG) under provisions of AR 5-5.

b. CAA will:

(1) Establish a study team.

(2) Establish direct communications with ODCSLOG, D/TRETS, and other agencies as required for the conduct of the study.

(3) Provide periodic in-process reviews (IPR) and final study documentation to the study sponsor.

c. USAMSSA will: Provide ADP support as requested.

8. Literature Search.

a. Department of the Army, Office of the Comptroller of the Army, Report on the Army Transportation Study, May 1971.

b. Evaluation of Second Destination Transportation Funding, U. S. Army Logistics Evaluation Agency, 29 December 1978.

c. Defense Logistics Agency studies and reports.

d. MSC reports.

e. Army Inventory Management Agency studies.

f. USAF and USN transportation workload forecasting methodologies.

g. OSD transportation workload forecasting studies and reports.

9. References.

a. JCS Pub 15, dated 2 June 1975.

b. AR 55-23, dated 17 March 1978.

c. AR 55-30, dated 15 August 1982.

d. AR 55-133, dated 18 February 1977.

e. AR 59-8, dated 20 August 1982.

f. MECHTRAM Users Manual, dated June 1978.

g. AR 11-18, October 1975.

h. DA PAM, May 1976.

i. AR 11-28, December 1975.

10. Administration.

a. Support

(1) Funding for temporary duty (TDY) and travel associated with the study will be provided by each participating agency.

(2) Headquarters or agencies represented in the Study Advisory Group will provide own TDY, per diem, and travel funds.

b. Milestone Schedule

First IPR May 1983

DALO-TSP-C11
SUBJECT: Transportation Workload Forecasting

11 May 1983

Second IPR	September 1983
Third IPR	December 1983

c. Control Procedures

(1) Periodic IPRs will be provided to the study sponsor by the study team.

(2) Documentation required by AR 5-5, including DD Form 1498 and DD Form 1473, and a final report to include an Executive Summary will be submitted by CAA.

d. Coordination

(1) Direct coordination between CAA, DALO-TSP, and forecasting activities is authorized. For purposes of any possible data collection, coordination between CAA and the submitting activity is directed. Information copies of all data inputs should be provided to HQDA, DALO-TSP-C11.

(2) This study directive has been coordinated with CAA in accordance with AR 5-5.

FOR THE DEPUTY CHIEF OF STAFF FOR LOGISTICS:

JIMMY D. ROSS
Brigadier General, GS
Director of Transportation,
Energy and Troop Support

APPENDIX C

REFERENCES/BIBLIOGRAPHY

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1. Dry Cargo Sealift Movement Forecasting and Sizing of MSC Fleet Study, OSD Logistics System Analysis Office, 1982

2. Anderson, O. D, Time Series Analysis and Forecasting: The Box Jenkins Approach, Butterworth & Co., Ltd, London, England, 1977

3. Box, George E. P. and Gwilym M. Jenkins, Time Series Analysis: Forecasting and Control, Holden-Day Inc., San Francisco, CA, 1976

4. Dixon, W. J., et al., BMDP Statistical Software, University of California Press, Berkeley, CA, 1981

5. Makridakis, Spyros and Steven C. Wheelwright, Forecasting: Methods and Applications, John Wiley & Sons, New York, NY, 1978

6. Montgomery, Douglas C. and Lywood A. Johnson, Forecasting and Time Series Analysis, McGraw-Hill Book Company, New York, NY, 1976

7. Pindyck, Robert S. and Daniel L. Dubinfeld, Econometric Models and Economic Forecasts, McGraw-Hill Book Company, New York, NY, 1981

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DEPARTMENT OF DEFENSE

Department of Defense (DOD) Publications

DOD Directive 5160.10, Single Manager Assignment for Ocean Transportation

DOD Directive 5160.53, Single Manager Assignment for Military Traffic, Land Transportation, and Common-User Ocean Terminals

Joint Chiefs of Staff (JCS) Publications

JCS Publication 15, Mobility System Policies, Procedures and Considerations

DEPARTMENT OF THE ARMY

Department of the Army (DA) Publications

AR 55-23, Submission of Dry Cargo Requirements and the Assignment and Allocation of Sea Transportation Space

AR 55-30, Space Requirements and Performance Reports for Transportation Movements

AR 59-8, Military Airlift Command: Requirement, Submissions, Space Assignments, and Allocations and Priorities

Report on the Army Transportation Study, Department of the Army, Office of the Comptroller of the Army, 1971

Evaluation of Second Destination Transportation Funding, US Army Logistics Evaluation Agency, 1978

Deputy Chief of Staff for Logistics (DCSLOG)

Integrated Transportation Management Operating System (ITMIS) User's Manual

DEPARTMENT OF THE AIR FORCE

US Air Force Logistics Command (AFLC) Publication

AFLC Regulation 171-125, Surface Transportation Tonnage and Cost System (0027B)

US Air Force (USAF) Publication

AFR 75-15, Reports for Military Transportation Requirements.

DEPARTMENT OF THE NAVY

US Navy Supply Systems Command Publication

NAVSUPINST 4620.7D, Sealift Cargo Requirements and Reporting Instructions.

APPENDIX D

COMMODITY TIME SERIES DATA

D-1. GENERAL. The purpose of this appendix is to provide a list of the aggregate time series data that was used to build the forecasting models and test their accuracy.

D-2. COMMODITY DATA

a. Each figure contains three columns of data: (1) column 1 identifies the year and month, (2) column 2 depicts the amount of measurement tons that were lifted during the month, and (3) column 3 lists the number of records or shipments that were aggregated to develop the lift figure in column 2.

b. As discussed in paragraph 6-2, aggregate time series data was developed for each commodity over all routes as well as each commodity for a particular route. The data contained in this appendix is the commodity data for all routes combined. The specific route data (424 routes) is available upon request.

```
7610       914.43     32
7611      -446.00     53
7612       929.00     30
7701       773.05     34
7702      1092.00     25
7703       686.00     24
7704       888.50     27
7705      1049.00     28
7706      1569.00     31
7707      1244.00     34
7708      1280.00     37
7709      1536.33     41
7710      1241.68     29
7711      1420.68     37
7712      1034.00     49
7801       966.00     22
7802       665.00     17
7803       973.00     25
7804      1098.05     32
7805      1468.22     36
7806      1147.57     33
7807      1624.08     26
7808      1398.31     35
7809      1932.14     37
7810      1134.12     29
7811      1007.05     30
7812      1100.67     29
7901       679.54     22
7902       898.38     31
7903       803.69     37
7904       953.98     29
7905      1744.64     42
7906      1180.45     43
7907      1536.85     49
7908      1926.72     53
7909      1268.99     41
7910       753.78     33
7911      1781.41     58
7912       907.11     44
8001       962.50     32
8002      1370.28     31
8003       841.68     28
8004      1174.32     32
8005      2064.68     49
8006      1131.43     33
8007      2325.32     36
8008      1861.21     52
8009      1475.91     41
8010       736.55     42
8011      1601.66     50
8012       586.91     38
8101       956.52     47
8102       733.21     38
8103       780.88     45
8104      1111.18     38
8105      1065.04     43
8106      1126.30     37
8107      1462.26     33
8108      1579.98     37
8109      1305.40     52
8110      1029.26     38
8111      1088.42     35
8112      1075.72     50
8201       836.67     22
8202       776.65     24
8203      1258.34     34
8204      1852.16     33
8205      1612.27     37
8206      1083.50     33
8207       941.80     28
8208      1404.23     34
8209      1170.27     26
8210       405.76     21
8211      1199.56     27
8212      1002.46     25
8301      1004.83     27
8302       553.68     21
8303       993.29     24
8304      1160.93     27
8305      1079.12     27
8306      1504.68     27
```

Figure D-1. Chill Cargo Data

```
7610          1825.00          24
7611          1377.00          28
7612          1714.40          24
7701          1997.00          22
7702          1020.00          19
7703          1692.00          23
7704          1747.00          23
7705          2105.00          22
7706          2280.00          22
7707          1551.50          24
7708          2168.00          28
7709          2520.63          23
7710          1297.48          21
7711          1432.60          23
7712          3222.00          37
7801          1562.75          27
7802          1620.00          21
7803          2173.00          22
7804          2483.00          23
7805          2575.00          30
7806          2126.25          32
7807          2735.63          27
7808          2248.36          30
7809          2155.63          24
7810          1603.22          23
7811          2065.12          23
7812          2475.95          25
7901          1854.22          25
7902          2620.91          27
7903          1994.23          25
7904          2600.57          27
7905          2807.90          29
7906          2096.05          24
7907          2196.11          35
7908          2678.11          31
7909          1204.67          26
7910          1705.16          28
7911          2509.71          28
7912          1849.35          34
8001          2293.43          26
8002          1658.10          24
8003          2590.96          25
8004          2510.01          27
8005          2622.45          27
8006          2533.26          23
8007          2518.18          22
8008          1856.05          24
8009          2010.77          23
8010          2342.00          27
8011          2053.41          24
8012          1948.56          16
8101          2543.46          32
8102          2366.03          18
8103          2525.21          26
8104          2563.80          26
8105          3742.60          27
8106          2002.94          26
8107          2143.94          25
8108          3240.05          28
8109          2249.00          31
8110          3320.31          26
8111          2346.50          26
8112          2204.62          30
8201          3570.90          20
8202          2564.14          24
8203          3011.91          30
8204          3807.10          32
8205          4076.17          37
8206          2952.83          30
8207          3662.92          39
8208          2713.77          29
8209          2184.09          21
8210          2679.29          30
8211          2333.06          25
8212          2838.82          22
8301          3367.38          27
8302          2709.29          23
8303          3084.59          26
8304          3349.15          30
8305          3489.33          28
8306          1408.76          18
```

Figure D-2. Freeze Cargo Data

```
7610          61749.00          2
7611          39861.00          2
7612          58988.00          3
7701          21934.00          2
7702          42244.00          2
7703          55231.00          2
7704          39902.00          1
7705          40668.00          2
7706          58003.00          2
7707          60925.00          2
7708          59130.00          2
7709          19340.00          2
7710          30267.00          1
7711          18599.00          1
7712          20967.00          6
7801          32448.00          1
7802          17533.00          2
7803          35408.00          2
7804          40275.00          3
7805          41381.00          2
7806          63142.00          5
7807          16423.00          1
7808          17596.00          1
7809          14777.00          1
7810          20450.00          1
7811          21372.00          1
7812          22176.02          8
7901          21521.00          6
7902          45859.00          3
7903          44672.70          4
7904          55623.25          3
7905          56026.63          6
7906          57462.04          6
7907          60851.00          2
7908          56040.00          2
7909          19492.00          1
7910          21564.00          2
7911          42761.00          5
7912          46265.00          6
8001          40735.00          2
8002          41967.00          2
8003          43866.40          3
8004            911.99          4
8005          46137.80          6
8006          57750.40          5
8007          44276.00          3
8008          61943.00          3
8009          44779.00          2
8010          41780.00          3
8011          39949.00          2
8012          41578.00          2
8101          19639.00          1
8102          42924.40          3
8103          43059.73          4
8104          34307.00          2
8105          16040.00          3
8106          17952.00          1
8107          42153.00          4
8108          36490.00          2
8109          19255.00          1
8110          19888.00          4
8111          64116.00          4
8112          41776.00          4
8201          19028.00          1
8202          40916.00          3
8203          38147.00          1
8204          19197.00          1
8205          33085.00          2
8206          41567.00          2
8207          19103.00          1
8208          19405.00          1
8209          19712.00          2
8210          18858.00          1
8211          20783.00          2
8301              3.75          1
8302          42134.00          2
8303          42810.00          2
8304          37096.00          1
8305          42172.15          3
8306          59384.00          2
```

Figure D-3. Coal Cargo Data

```
7610          41821.00          661
7611          35966.00          561
7612          36005.45          559
7701          29064.00          477
7702          25607.34          405
7703          34811.90          444
7704          34059.68          459
7705          53170.56          579
7706          64770.59          608
7707          66293.50          685
7708          49268.87          637
7709          52133.99          600
7710          34352.50          523
7711          42229.51          623
7712          32394.77          961
7801          37390.59          494
7802          28335.40          457
7803          30829.73          492
7804          37085.44          509
7805          43438.15          540
7806          48713.32          579
7807          57841.56          742
7808          54899.44          690
7809          37034.26          570
7810          40010.71          590
7811          34677.62          527
7812          34208.30          538
7901          30187.86          542
7902          28548.93          448
7903          35251.63          488
7904          36773.68          517
7905          42298.38          525
7906          57765.56          648
7907          47143.98          742
7908          51880.17          645
7909          37408.39          540
7910          35868.76          573
7911          36811.15          598
7912          34736.91          770
8001          30050.56          466
8002          30936.04          442
8003          38732.92          439
8004          37293.05          435
8005          53344.70          573
8006          70839.85          618
8007          54640.66          642
8008          49141.86          593
8009          39196.46          589
8010          31053.24          495
8011          37337.96          580
8012          32077.74          547
8101          28986.22          549
8102          25622.64          442
8103          34327.40          424
8104          38185.57          553
8105          38301.51          575
8106          60539.24          721
8107          52705.90          667
8108          52652.01          651
8109          38700.91          618
8110          33664.01          626
8111          42015.68          702
8112          35020.40          857
8201          30798.75          476
8202          27999.89          369
8203          38213.67          411
8204          40310.56          451
8205          47200.96          507
8206          57071.23          519
8207          61344.41          547
8208          51192.28          501
8209          45420.13          510
8210          44899.97          504
8211          42950.14          531
8212          40307.49          512
8301          38289.44          495
8302          33096.79          431
8303          36512.30          439
8304          38640.73          483
8305          52182.91          521
8306          52566.11          389
```

Figure D-4. POV Cargo Data

7610	25277.00	77
7611	16605.38	48
7612	5857.00	32
7701	8430.00	35
7702	21607.00	52
7703	15348.00	40
7704	6696.00	34
7705	14505.00	39
7706	19595.00	43
7707	19071.00	47
7708	11319.05	35
7709	24709.00	51
7710	18633.00	26
7711	7990.00	34
7712	21955.00	82
7801	11073.77	34
7802	12196.40	42
7803	11516.35	43
7804	16017.36	49
7805	16719.70	40
7806	16951.41	36
7807	15443.58	41
7808	14800.04	36
7809	10445.10	42
7810	9797.31	38
7811	16870.93	63
7812	9093.68	32
7901	15901.03	35
7902	19502.37	45
7903	27913.04	62
7904	18948.87	73
7905	39409.91	70
7906	20607.57	34
7907	30392.92	68
7908	19885.99	56
7909	30817.66	75
7910	9624.08	67
7911	9872.81	40
7912	17939.59	79
8001	8619.23	45
8002	515.37	37
8003	6482.14	44
8004	11686.72	54
8005	23455.11	63
8006	16020.10	66
8007	12359.52	47
8008	25878.58	36
8009	22490.53	39
8010	13486.95	49
8011	1627.89	35
8012	9108.96	52
8101	1235.15	35
8102	10908.02	34
8103	5540.86	43
8104	6186.03	54
8105	22260.45	49
8106	24613.14	52
8107	7073.32	47
8108	23843.03	62
8109	27333.09	63
8110	662.05	45
8111	17557.01	51
8112	5482.24	53
8201	6456.22	49
8202	7392.55	49
8203	21027.41	60
8204	17228.07	67
8205	17218.66	63
8206	42902.71	55
8207	20341.87	68
8208	10394.07	51
8209	12649.19	51
8210	4855.21	41
8211	13602.41	54
8212	5045.79	40
8301	6207.98	41
8302	19933.54	51
8303	1578.10	34
8304	23499.36	40
8305	17038.42	46
8306	5246.68	17

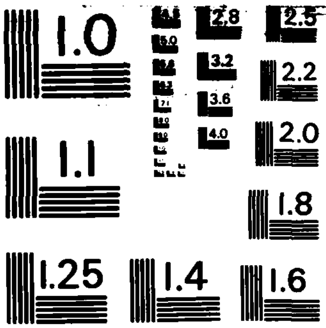
Figure D-5. Ammunition Cargo Data

```
7610          169685.38          929
7611          136598.20          906
7612          137157.17          804
7701          118389.04          798
7702          119138.13          789
7703          156793.38          826
7704          155416.55          861
7705          149079.38          828
7706          151319.13          844
7707          153615.98          915
7708          164439.95          919
7709          175531.69          987
7710          102835.28          731
7711          152121.67          895
7712          155614.20         1492
7801          131867.87          775
7802          127959.98          701
7803          170993.59          746
7804          184455.30          768
7805          195278.54          765
7806          185624.84          836
7807          192765.97          866
7808          183700.29          837
7809          172309.79          701
7810          159271.08          693
7811          152886.07          697
7812          141442.29          694
7901          136876.47          775
7902          132237.18          777
7903          191265.90          841
7904          171987.31          776
7905          163200.71          836
7906          190869.50          807
7907          194245.59         1017
7908          191258.98          945
7909          157422.38          933
7910          146030.71          875
7911          160887.98         1021
7912          162211.08         1272
8001          141571.69          744
8002          140556.16          659
8003          153689.79          732
8004          158969.70          731
8005          171530.99          788
8006          169789.05          772
8007          167376.09          832
8008          171133.33          824
8009          145800.95          728
8010          163019.89          822
8011          130670.76          745
8012          130638.09          810
8101          117417.46          730
8102          136109.29          753
8103          157627.35          879
8104          159745.58          809
8105          164352.00          919
8106          151871.78          845
8107          147996.56          769
8108          153975.55          766
8109          157746.08          910
8110          148297.50          858
8111          148662.02          892
8112          152260.93         1086
8201          141734.41          626
8202          145632.93          583
8203          177477.21          640
8204          207666.50          684
8205          184058.04          703
8206          185248.45          637
8207          190531.74          709
8208          171823.35          624
8209          168166.05          651
8210          163430.32          737
8211          166049.06          690
8212          146563.08          671
8301          165732.53          663
8302          166667.72          600
8303          168058.87          672
8304          170752.73          635
8305          172529.14          593
8306          146634.14          477
```

Figure D-6. General Cargo Data

AD-A139 872 TRANSPORTATION WORKLOAD FORECASTING (TWF) STUDY(U) ARMY 2/4
CONCEPTS ANALYSIS AGENCY BETHESDA MD J N KEENAN ET AL.
JAN 84 CAA-SR-84-2

UNCLASSIFIED F/G 15/5 NL



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

7610	6921.13	264
7611	5181.63	238
7612	6843.00	195
7701	9356.00	207
7702	7583.00	179
7703	8284.00	172
7704	7325.00	191
7705	10120.00	215
7706	8517.52	212
7707	11202.84	250
7708	9764.90	257
7709	12922.03	278
7710	51504.44	396
7711	49633.62	479
7712	52162.62	564
7801	13149.16	269
7802	5261.56	186
7803	5141.90	183
7804	4355.41	176
7805	5928.59	201
7806	24223.30	362
7807	38029.99	477
7808	30135.99	451
7809	14979.32	301
7810	8249.93	233
7811	5444.69	231
7812	7036.35	240
7901	5884.55	220
7902	5931.01	183
7903	5718.59	197
7904	7249.50	209
7905	6477.25	184
7906	11968.71	278
7907	13788.33	317
7908	18869.97	338
7909	11953.09	308
7910	7961.36	293
7911	5658.74	271
7912	7884.78	286
8001	5729.89	233
8002	5618.19	228
8003	8103.18	199
8004	5106.35	198
8005	8828.87	225
8006	12187.71	238
8007	13564.19	234
8008	15455.52	297
8009	5887.34	258
8010	7383.61	242
8011	5425.80	208
8012	5455.39	242
8101	12359.36	303
8102	4676.94	197
8103	6081.80	254
8104	5092.21	230
8105	5337.28	223
8106	8152.05	234
8107	10326.22	264
8108	9874.07	264
8109	7502.37	307
8110	6401.19	277
8111	7367.61	254
8112	8732.26	302
8201	6216.15	130
8202	6482.44	191
8203	5433.68	186
8204	4988.23	185
8205	6247.31	197
8206	9819.27	213
8207	10179.44	233
8208	8307.99	255
8209	7502.69	245
8210	6446.26	225
8211	6141.86	225
8212	6296.87	220
8301	7079.59	214
8302	5458.20	191
8303	8368.62	197
8304	6458.20	200
8305	6250.06	192
8306	3572.82	121

Figure D-7. HHG Cargo Data

```
7610          4566.00          9
7611          4797.00         10
7612          4085.00         10
7701          3435.00         13
7702          3035.00          6
7703          4619.00         12
7704          5403.00         13
7705          6925.00         18
7706          2740.00         18
7707          3436.00         16
7708          5423.00         22
7709          4585.00         22
7710          5332.00         29
7711          7500.00         42
7712          4809.00         40
7801          3008.38         17
7802          4484.00         20
7803          4955.17         23
7804          5312.19         21
7805          4517.80         23
7806          4776.16         22
7807          6890.31         35
7808          4529.79         27
7809          3040.79         17
7810          4992.09         32
7811          4708.84         20
7812          2458.71         20
7901          3536.08         17
7902          4139.14         25
7903          6303.43         30
7904          4566.99         15
7905          5076.56         17
7906          2809.66         20
7907          6961.60         40
7908          6608.23         36
7909          5319.78         27
7910          5151.74         25
7911          5069.07         30
7912          3194.80         38
8001          3464.81         15
8002          3706.79         15
8003          5634.30         11
8004          4547.11         15
8005          5267.77         16
8006          4601.18         15
8007          6358.49         20
8008          6241.42         18
8009          5169.60         16
8010          6699.15         12
8011          6624.96         13
8012          6570.70         11
8101          4320.55         15
8102          5564.29         14
8103          6165.83         19
8104          6695.59         23
8105          6718.39         18
8106          6840.74         13
8107          7962.13         25
8108          6188.26         15
8109          5583.56         28
8110          5967.83         26
8111          5619.88         25
8112          6305.61         24
8201          4289.05         11
8202          5414.74         11
8203          6717.58         14
8204          5628.13         13
8205          6042.79         12
8206          5378.95         10
8207          7499.49         12
8208          8432.05         13
8209          7172.74         12
8210          7097.94         10
8211          7240.69         10
8212          6174.71         18
8301          4912.16         10
8302          4756.71         11
8303          7660.25         13
8304          6166.17         11
8305          7150.32         14
8306          7339.53         10
```

Figure D-8. CONEX Cargo Data

```
7610        103157.00        167
7611         58871.00        122
7612         39460.00        116
7701         26477.00        114
7702         39854.00        131
7703         31793.00        102
7704         41171.00        113
7705         43139.75        135
7706         63514.19        142
7707         71288.75        157
7708         90143.13        151
7709         67335.08        160
7710         81170.00        108
7711         35116.90        136
7712         35683.00        212
7801         35545.37        138
7802         39076.19        114
7803         46139.50        128
7804         39683.84        139
7805         45772.92        133
7806         47049.17        152
7807         48994.29        144
7808         71461.20        146
7809         34868.92        117
7810         86150.90        139
7811         47392.79        110
7812         92161.79        128
7901         61218.57        109
7902         75766.21        116
7903         89700.76        135
7904         71410.28        157
7905         97975.18        141
7906         60328.28        147
7907         51095.70        184
7908         54659.18        156
7909         64187.00        164
7910         34199.90        119
7911         68929.19        180
7912         50715.55        156
8001         62835.93        117
8002         41753.65         94
8003         48868.54        117
8004         35981.60        112
8005         42740.18        103
8006         45385.89        123
8007         79021.29        144
8008         54166.92        106
8009         51748.36        121
8010         72327.59        142
8011         46773.28        110
8012         77300.46        134
8101         39046.16        112
8102         52046.25        105
8103         41809.62        125
8104         64555.04        140
8105         57810.41        115
8106         43339.49         90
8107         40229.12        120
8108         60673.97        119
8109         42064.65        128
8110         91382.88        153
8111         41020.93        110
8112         32728.10        131
8201         21858.81         60
8202         17823.79         52
8203         23526.04         76
8204         24994.10         78
8205         25399.55         71
8206         30089.88         80
8207         44222.43         95
8208         70003.35         73
8209         66826.87         79
8210         56958.69         91
8211         41928.63         84
8212         37710.32         86
8301         33987.13         97
8302         13157.70         60
8303         28412.73         95
8304         40297.05         77
8305         32096.73         76
8306         17622.00         44
```

Figure D-9. Special Cargo Data

APPENDIX E

BOX-JENKINS METHODOLOGY

E-1. GENERAL

a. Box-Jenkins models are a flexible class of stable linear statistical models that are used to model stochastic time series data. The models are first fitted to historical time series data using parametric estimates. The fitted model is then used to provide forecasts of future observations.

b. This appendix will discuss:

(1) Stochastic properties of time series models and the principle of stationarity.

(2) Basic model autocorrelation and partial autocorrelation functions.

(3) Seasonal models.

(4) The backshift operator.

(5) Model diagnostic checks.

E-2. STOCHASTIC PROPERTIES AND STATIONARITY

a. The assumption of a historical stochastic time series differentiates Box-Jenkins models from other time series models. Some time series models are simple extrapolation formulas which fail to account for the stochastic properties of time series. Box-Jenkins models assume that the historical data evolves stochastically and attempt to model the stochastic properties of the time series for forecasting purposes.[5]

b. A stochastic process assumes that each observation $x_1, x_2, \ldots x_t$ is randomly drawn from a probability distribution. Using Box-Jenkins techniques, an attempt is made to duplicate the stochastic process in hopes of understanding the probability distributions of future observed values and providing accurate predictions of the future. A perfect duplication of the stochastic process is practically impossible. This would require a joint distribution of all possible combinations of time series values $x_1, x_2 \ldots x_t$. If the time series is large, one can quickly see that the resulting probability distribution function would be immense. In view of this impossible task, the next best thing is to model the characteristics of the stochastic process. If the characteristics can be identified, then the randomness of the series can be approximated and used to predict future values.[6]

c. Stochastic properties of time series data affect model development through the principle of stationarity. Stationary data are data whose stochastic processes remain constant over time. If the stochastic process is constant over time, i.e., stationarity exists, then coefficients similar to those used in regression analysis can be estimated to model the data. One of the critical assumptions of regression analysis is the assumption of a constant linear relationship between two variables. If the relationship remains linear over time, then the process is stationary, and the model is adequate. If not, then the process is nonstationary and the model is not correct.

d. The principal of stationarity assumes that the stochastic properties of the data are invariant with respect to time. The data are invariant in that the stochastic processes of the data are constant throughout all intervals of time. The stochastic processes are assumed to be in equilibrium, and any variance from a constant mean is assumed to be the same at any point in time.

e. As mentioned earlier, a stochastic process assumes that each observation is randomly drawn. Future predictions of the stochastic process would be based on the conditional probability distribution for the series. Thus, prediction of x_{T+1} would be made given the probability distribution of the series $x_1 \ldots x_T$. In mathematical terms, this conditional probability would be expressed as:

$$p\ (x_T + 1 \mid x_1,\ x_2 \ldots x_T)$$

If the time series is stationary, the joint distribution and conditional distribution will remain constant throughout time. Thus,

$$p(x_t, \ldots, x_{t+n}) = p(x_{t+m}, \ldots, x_{t+n+m})$$

$$p(x_t) = p(x_{t+m})$$

Finally, if the series is stationary, the mean, variance, and covariance of the data will remain constant over time.[6]

f. The autocorrelation function is a statistical tool that is used in Box-Jenkins models to describe the stochastic process of a time series and provides an understanding of the probability distributions of the time series. The autocorrelation function ρ_k is defined as:

$$\rho_k = \frac{E\left[(x_t - \mu_x)(x_{t+k} - \mu_x)\right]}{\sqrt{E\left[(x_t - \mu_x)^2\right] E\left[(x_{t+k} - \mu_x)^2\right]}} = \frac{\mathrm{COV}(x_t,\ x_{t+k})}{\sigma_{x_t}\ \sigma_{x_{t+k}}}$$

If a stochastic process consists of independently distributed random variables with a mean of zero, then the autocorrelation function for $\rho_0 = 1$ and $\rho_k = 0$ for all lags $k > 0$. This process indicates the existence of white noise, which means that the forecast of $x_{T+l} = 0$ for all $l > 0$. When white noise is achieved, random errors of the modeling process have been eliminated since the predicted value of the error term equals zero.

g. As in other statistical models, Box-Jenkins uses a sample of time series to make predictions about the population. Thus, the sample autocorrelation function $\hat{\rho}_k$ is defined as:

$$\hat{\rho}_k = \frac{\sum_{t=1}^{T-k} (x_t - \bar{x})(x_{t+k} - \bar{x})}{\sum_{t=1}^{T} (x_t - \bar{x})^2}$$

This statistic is used on Box-Jenkins models to compute the autocorrelation function for different values of lag k. If the data are generated by a stationary process, the autocorrelation function estimates $\hat{\rho}_k$ should fall to zero quickly as k increases. A failure of $\hat{\rho}_k$ to drop off quickly to zero indicates the existence of nonstationary data. To test whether successive coefficients of the autocorrelation function are equal to zero, i.e., generated by white noise, one would employ the Bartlett test. Bartlett determined that if the series was generated by white noise, the sample autocorrelation coefficients are approximately distributed with a normal distribution of mean of zero and standard deviation $1/\sqrt{T}$, where T equals the number of observations in the series. Thus, if the sample coefficients fall within the confidence interval, the sample coefficients are assumed to be zero.[6]

h. Finally, if the data are not generated by a stationary process, a technique known as differencing will help achieve stationary data. Differencing is defined as:

$$w_t = x_t - x_{t-1}$$

where the new series w_t is then analyzed for stationarity. If the data do not exhibit stationarity with first order differencing, the series w_t can be differenced again. Additionally, if the variance of the data does not remain constant over time, logarithm transformations of the data and possible differencing of the transformed data should be attempted to achieve stationarity.

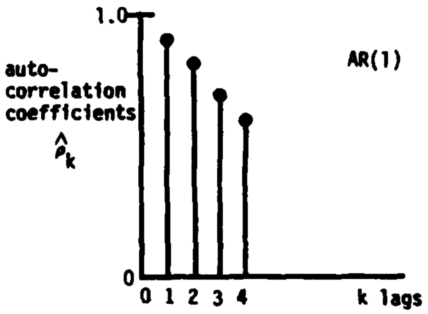
E-3. AUTOCORRELATION AND PARTIAL AUTOCORRELATION FUNCTIONS

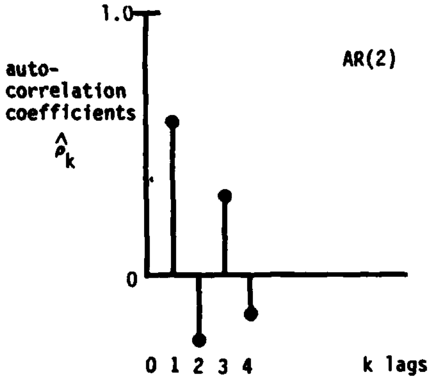
a. Autoregressive (AR) models attempt to describe the process x_t with a weighted sum of past values of the series x_{t-n} and a random disturbance term, ϵ_t.

$$x_t = \phi_1 x_{t-1} + \phi_2 x_{t-2} + \dots + \phi_n x_{t-n} + \delta + \epsilon_t$$

where ϕ_n are the AR parameters δ is the mean of the series.

The autocorrelation function for the AR models is used to help determine the number of lags in the model:





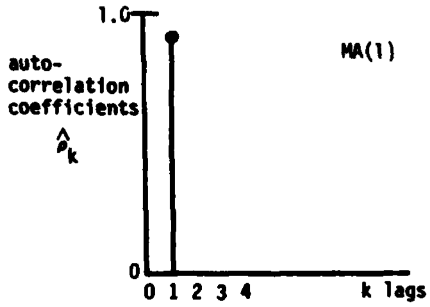
An AR(1) process depicts a function that declines geometrically from $\rho_0 = 1$. An AR(2) process can be portrayed as an oscillating or sinusoidal function that dampens geometrically. The partial autocorrelation functions for AR models closely resemble the pattern for MA model autocorrelation function and vice versa. Thus, to confirm the existence of an AR(1) model, one would expect to find a partial autocorrelation function with a significant coefficient at lag 1 and zeros for all coefficients with lags $k > 1$. Similarly, the AR(2) partial autocorrelation function would depict two significant coefficients and then zeros for all lags $k > 2$.[2]

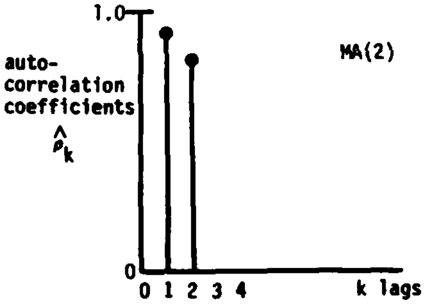
b. Moving average (MA) models attempt to describe the process x_t by a weighted sum of current and lagged disturbance terms, ϵ_{t-n}.

$$x_t = \mu + \epsilon_t - \theta_1 \epsilon_{t-1} - \theta_2 \epsilon_{t-2} - \dots - \theta_n \epsilon_{t-n}$$

where μ is the mean of the series and θ_n are the MA parameters.

The autocorrelation function for MA models will depict how many disturbance terms should be used in the model:





Autocorrelation functions for MA models will portray significant coefficients which correspond to the number of disturbance terms to include in the model. Successive coefficients should decline to zero rapidly. The partial autocorrelation functions for MA models will depict coefficients that dampen exponentially to zero or dampen in an oscillating manner to zero.

c. Autoregressive-moving average (ARMA) models are mixed models which attempt to describe the process x_t as a function of past values, lagged random disturbances, and a current disturbance term.

$$x_t = \phi_1 x_{t-1} + \phi_2 x_{t-2} + \dots + \phi_n x_{t-n} + \delta + \epsilon_t - \theta_1 \epsilon_{t-1} - \theta_2 \epsilon_{t-2} - \dots - \theta_n \epsilon_{t-n}$$

The autocorrelation and partial autocorrelation functions for ARMA models can be depicted in many combinations. For more information, reference Box-Jenkins' "Time Series Analysis"[2] for a complete description of possible function portrayals.

E-4. BACKSHIFT OPERATOR

a. The "backshift operator" is the use of a mathematical concept to simplify model building. The backshift operator B is defined as:

$$B x_t = x_{t-1}$$

In more general terms, the backshift operator is defined as $B^n x_t$, where n relates to the number of past values used.[4] The following will explain the use of the backshift operator:

$$x_{t-1} = Bx_t$$

$$x_{t-2} = B^2x_t$$

$$x_{t-3} = B^3x_t$$

$$\vdots \qquad \vdots$$

$$x_{t-n} = B^nx_t$$

b. All ARMA models can be expressed using the backshift operator. For example, an AR(1) model is depicted as follows:

$$x_t = \phi_1 x_{t-1} + \epsilon_t$$

since $Bx_t = x_{t-1}$ the equation can be written as:

$$x_t = \phi_1 Bx_t + \epsilon_t$$

$$x_t - \phi_1 Bx_t = \epsilon_t$$

$$(1 - \phi_1 B)x_t = \epsilon_t$$

Similarly, an MA model is depicted as follows:

$$x_t = \epsilon_t - \theta_1 \epsilon_{t-1}$$

since $B\epsilon_t = \epsilon_{t-1}$, the equation can be written as:

$$x_t = \epsilon_t - \theta_1 B\epsilon_t$$

$$x_t = (1 - \theta_1 B)\epsilon_t$$

c. A more complex model such as an AR(2) is rewritten as follows:

$$x_t = \phi_1 x_{t-1} + \phi_2 x_{t-2} + \epsilon_t$$

since $Bx_t = x_{t-1}$ and $x_{t-2} = Bx_{t-1} = B^2x_t$, the equation can now be written as:

$$x_t = \phi_1 Bx_t + \phi_2 B^2x_t + \epsilon_t$$

$$x_t - \phi_1 Bx_t - \phi_2 B^2x_t = \epsilon_t$$

$$(1 - \phi_1 B - \phi_2 B^2)\, x_t = \epsilon_t$$

Similarly, an MA(2) model is depicted as:

$$x_t = (1 - \theta_1 B - \theta_2 B^2)\epsilon_t$$

The use of the backshift operator is especially useful in expressing seasonal models. This will be explained in the next section.

E-5. SEASONAL MODELS

a. Seasonal Box-Jenkins models are a particular class of models which incorporate multiplicative properties. Seasonal data are identified through autocorrelation analysis of the time series data. If seasonality exists, autocorrelation coefficients will peak at lags 12, 24, and 36 and should be correlated with each other. The existence of seasonality in the data violates the principle of stationarity and must be removed through differencing. In this case, the resulting series w_t is a seasonally adjusted series:

$$w_t = x_t - x_{t-12}$$

If the series w_t is stationary, it is modeled, and if it is nonstationary, the series w_t is differenced.

b. Once stationary data is achieved, two distinct models are combined. One model is a seasonal model which captures the seasonal correlation between observations a year apart. The second model is a nonseasonal model which explains the dependency of observations within a given year. The following equations illustrate this process.

(1) A seasonal AR model is described as follows:

$$x_t = \phi_{12} x_{t-12} + \alpha_t$$

$$x_t = \phi_{12} B x_{t-11} + \alpha_t$$

$$\begin{matrix} \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \end{matrix}$$

$$x_t = \phi_{12} B^{12} x_t + \alpha_t$$

$$x_t - \phi_{12} B^{12} x_t = \alpha_t$$

$$(1 - \varphi_{12} B^{12}) x_t = \alpha_t \qquad \text{(E-1)}$$

(2) Likewise, a seasonal MA model is constructed as follows:

$$x_t = \alpha_t - \theta_{12}\alpha_{t-12}$$

$$x_t = \alpha_t - \theta_{12}B\alpha_{t-11}$$

$$\begin{matrix} \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \end{matrix}$$

$$x_t = \alpha_t - \theta B^{12}\alpha_t$$

$$x_t = (1 - \theta_{12}B^{12})\alpha_t \qquad \text{(E-2)}$$

c. The two seasonal models above now explain the relationship between the observations separated by a year (i.e., October 1978, October 1979). However, a nonseasonal relationship exists between the months within a year (i.e., October 1978, November 1978). Thus, the error term α_t in the seasonal model would not be totally independent. A relationship exists between the seasonal model error terms that must also be explained in order to completely analyze the data. Nonseasonal MA or AR models are used to explain this relationship.

$$(1 - \phi_1 B)\alpha_t = \epsilon_t \qquad \text{(E-3) AR nonseasonal model}$$

$$\alpha_t = (1 - \theta_1 B)\epsilon_t \qquad \text{(E-4) MA nonseasonal model}$$

Combining seasonal (E-1) and nonseasonal (E-3) components provides the following:

$$(1 - \phi_1 B)(1 - \phi_{12}B^{12})x_t = \epsilon_t$$

where seasonal (E-2) and nonseasonal (E-4) components are AR.

$$x_t = (1 - \theta_1 B)(1 - \theta_{12}B^{12})\epsilon_t$$

where seasonal and nonseasonal components are MA. Models may also be mixed where the seasonal and nonseasonal components are opposite.

$$(1 - \phi_{12}B^{12})\ x_t = (1 - \theta_1 B)\epsilon_t \qquad \text{seasonal AR, nonseasonal MA}$$

$$(1 - \phi_1 B)\ x_t = (1 - \theta_{12}B^{12})\epsilon_t \qquad \text{seasonal MA, nonseasonal AR}$$

E-6. MODEL DIAGNOSTICS

a. The next-to-last step in model building is diagnostic checks on the fit of the model. There are two basic diagnostic checks that are performed once the Box-Jenkins model is estimated.

b. The first test involves a visual comparison of the autocorrelation function of the model to the autocorrelation function of the original series. This particular check is a very subjective test. If the autocorrelation functions are similar, then the model is assumed to be valid. If the autocorrelation functions are different, then the model adequacy is suspect.

c. The second test involves a quantitative analysis of the residuals of the model. Box-Jenkins model building assumes that the error terms are normally distributed with a mean of zero and a variance 1/T. If the residuals of the model are characterized by those properties, the residuals closely resemble the properties of white noise. Statistical results by G. E. P. Box and D. A. Pierce have developed the Box-Pierce statistic Q:

$$Q = T \sum_{k=1}^{K} \hat{\rho}_k^{\,2}$$

where T is the number of observations, k is the number of lags, and $\hat{\rho}_k$ is the estimated residual at each lag k. The statistic is approximately distributed as a chi-square distribution with k - p - q degrees of freedom (p is the AR order and q is the MA order). Although any lag greater than 5 is sufficient for this test, the normal rule of thumb is to include enough lags to have at least 20 degrees of freedom.[6]

d. The null hypothesis H_0 for the Box-Pierce statistic is that the residuals are not correlated with each other, have a mean of zero and a variance 1/T, i.e., the properties of the residuals resemble white noise. Once calculated, the Q statistic is compared to values of a chi-square distribution for a given number of degrees of freedom. If the Q statistic is less than the value in the chi-square table, the null hypothesis is not rejected for a given significance level. If the Q statistic is greater than the chi-square value, the null hypothesis is rejected for a given significance level. For example, if the Q statistic is 11.1 for 20 degrees of freedom, then the null hypothesis would not be rejected at the 95 percent confidence level, since 11.1 is less than 12.4.

APPENDIX F

BOX-JENKINS COMMODITY ANALYSIS

F-1. GENERAL. The purpose of this appendix is to detail the steps of analysis that were performed during the Box-Jenkins model development for each commodity. The analysis discussion will consist of: (1) a visual examination of the raw data patterns and moving average patterns, (2) the achievement of stationarity through differencing or transformations, (3) an identification of model type through analysis of the autocorrelation and partial autocorrelation functions, (4) the estimation of model parameters, and (5) the verification of model fit for each commodity. The analysis discussion of commodities appears in this appendix as follows:

a. POV, pp F-1 through F-14.

b. General cargo, pp F-15 through F-29.

c. HHG, pp F-30 through F-42.

d. Coal, pp F-43 through F-65.

e. Ammunition, pp F-66 through F-79.

f. Special, pp F-80 through F-93.

g. Cargo trailer/CONEX, pp F-94 through F-106.

h. Freeze, pp F-107 through F-121.

i. Chill, pp F-122 through F-134.

F-2. POV

a. The raw data for POVs is depicted in Figure F-1. In its raw form, the series exhibits a seasonal trend with the peaks occurring in the summer months (June-July) and the troughs occurring in the winter months (January-February). This pattern is more pronounced in the 3-month and 6-month moving average schematics (Figures F-2 and F-3). However, the mean of the series is fairly constant over time as displayed in Figure F-4.

b. Autocorrelation function analysis of the raw series confirms the seasonality of the series as noted by the large autocorrelation coefficients at lags 6, 12, 18, 24, 30, and 36 (Figures F-5 and F-6). The strong seasonal trend violates the principle of data stationarity; therefore, the series was differenced at a lag of 12 months to eliminate the seasonal trend. Figure F-7 depicts the seasonally adjusted series.

c. The autocorrelation function of the seasonally differenced series is depicted in Figure F-8. Aside from the high autocorrelation coefficients at lags 12 and 24, the series exhibits random behavior and is considered to be stationary. The significant autocorrelation coefficients at lags 12 and 24 suggest an MA seasonal model. Examination of the partial autocorrelation function (Figure F-9) identifies a possible AR nonseasonal model. Again, without considering the autocorrelation coefficients at lags 12 and 24, the autocorrelation pattern is similar to an AR process. In sum, the specific model applicable to the POV seasonally adjusted series is a nonseasonal ARIMA (2,0,0) model and a seasonal ARIMA (0,1,1) model:

$$(1 - \phi_1 B - \phi_2 B^2)(1 - B^{12}) X_t = (1 - \theta_{12} B^{12})\epsilon_t$$

d. The results of this model (Figure F-10) are as follows:

$$\underset{(.19)}{(1 - .0221B} - \underset{(3,05)}{.3554 B^2)}(1 - B^{12}) X_t = (1 - \underset{(16.77)}{.8581} B^{12})\epsilon_t$$

$$\chi^2 (3,20) = 16.35$$

The results indicate that all the estimated parameters of the model, except ϕ_1 are significant at the 5 percent significance level. Verification of the model's adequacy using the Box-Pierce test indicates that the autocorrelations of the estimated model residuals are not significantly different from zero at the 32 percent significance level (Figure F-11). Thus, the null hypothesis, residuals are uncorrelated, should not be rejected at the 32 percent significance level.

e. However, the significant autocorrelation coefficent at lag 24 of the estimated autocorrelation function suggests that the model is not correctly specified. Attempts to adjust the seasonal model to an ARIMA (0,1,2) resulted in a nonstationary model since $\theta_1 > 1.0$. Adding another seasonal model to the original model resulted in the following:

$$(1 - \phi_1 B - \phi_2 B^2)(1 - B^{12}) X_t = (1 - \theta_{12} B^{12})(1 - \theta_{24} B^{24})\epsilon_t$$

This model eliminated the significant coefficient at lag 24, however this model is more restrictive and the MSE of the FY 82 forecast was larger than the (2,0,0) x (0,1,1) seasonal model. These model adjustments should be tracked during future forecasts to determine if they are warranted.

f. Using this model to forecast FY 82 resulted in a forecast of 501.37 K/MTON versus an actual shipment of 510.252 K/MTON. The MSE of the POV forecast for FY 82 was 8.54 (Figure F-12), and the annual forecast error is -1.7 percent.

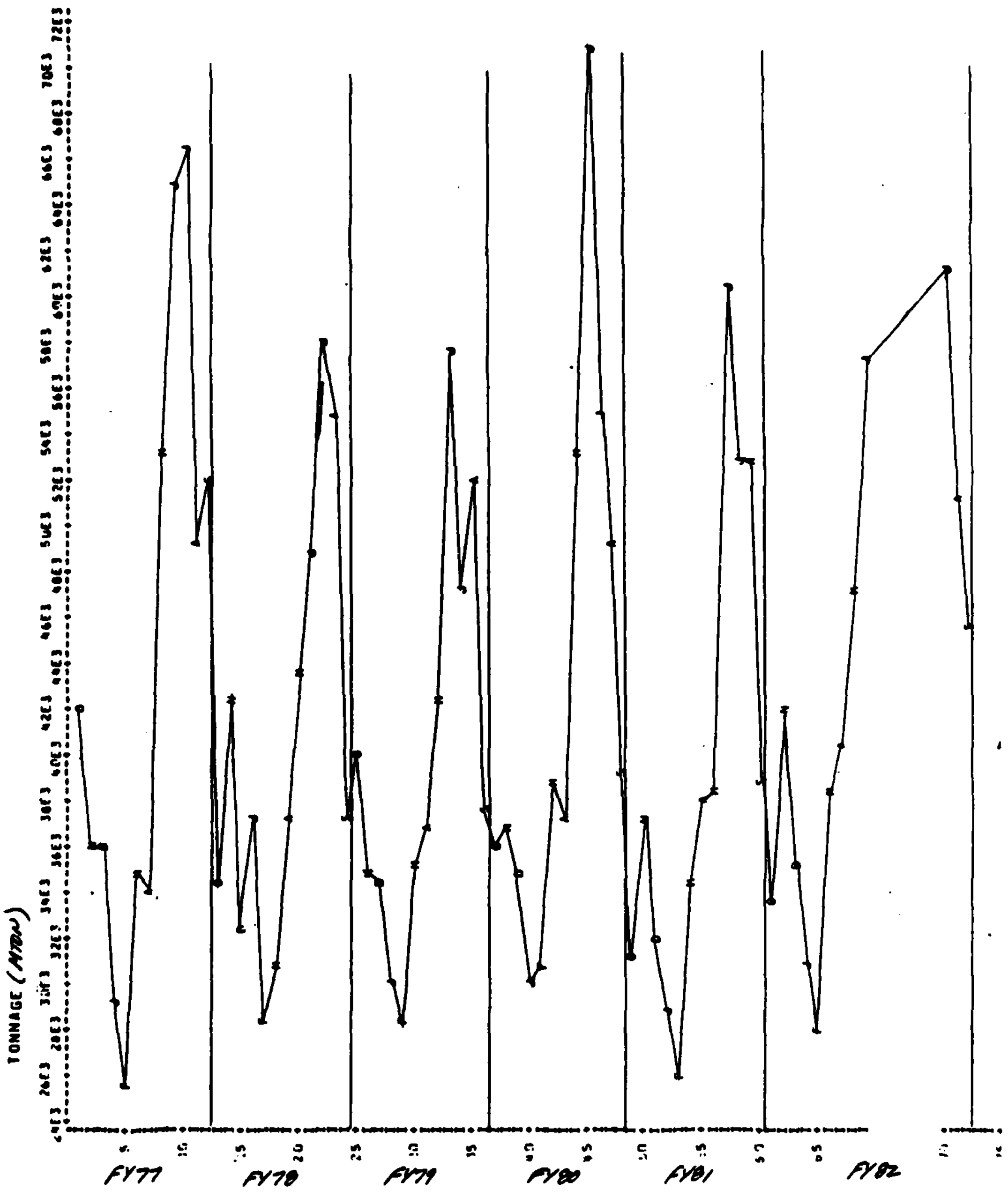
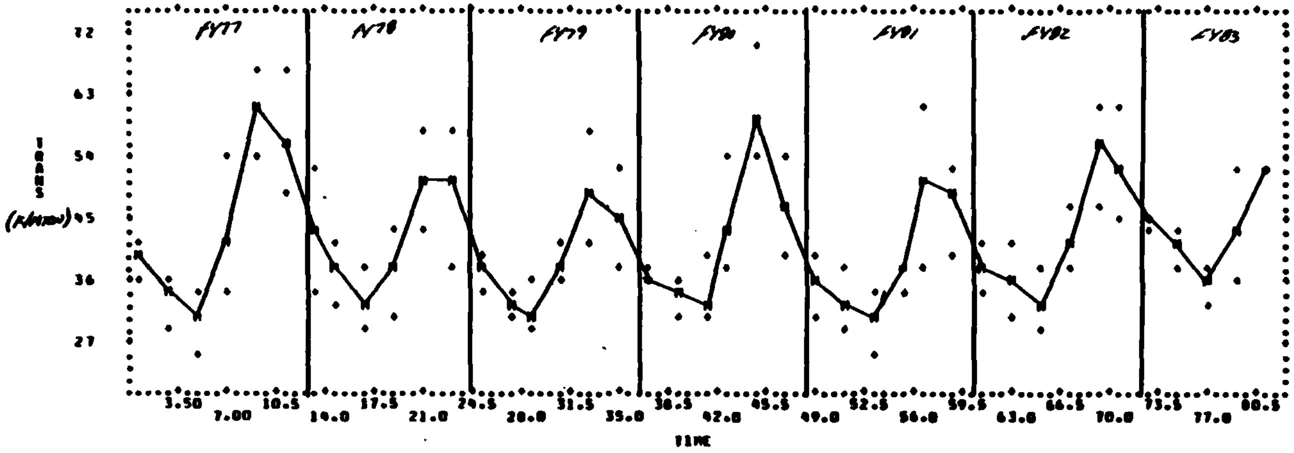
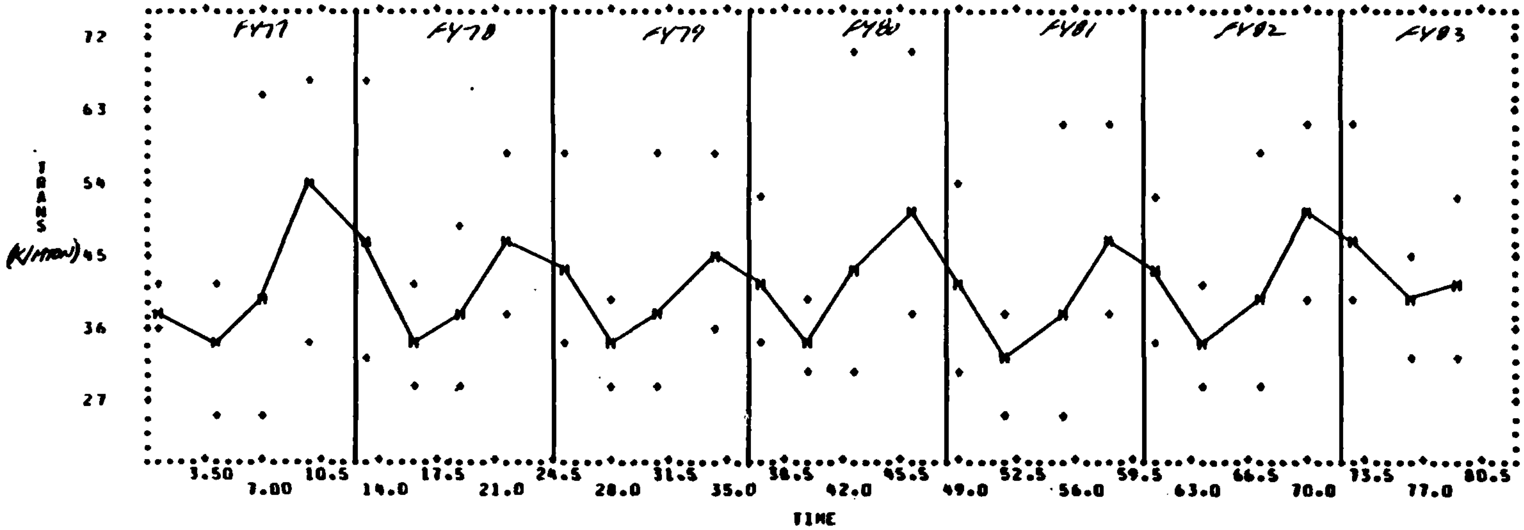


Figure F-1. POV Cargo, FY 77 - FY 82



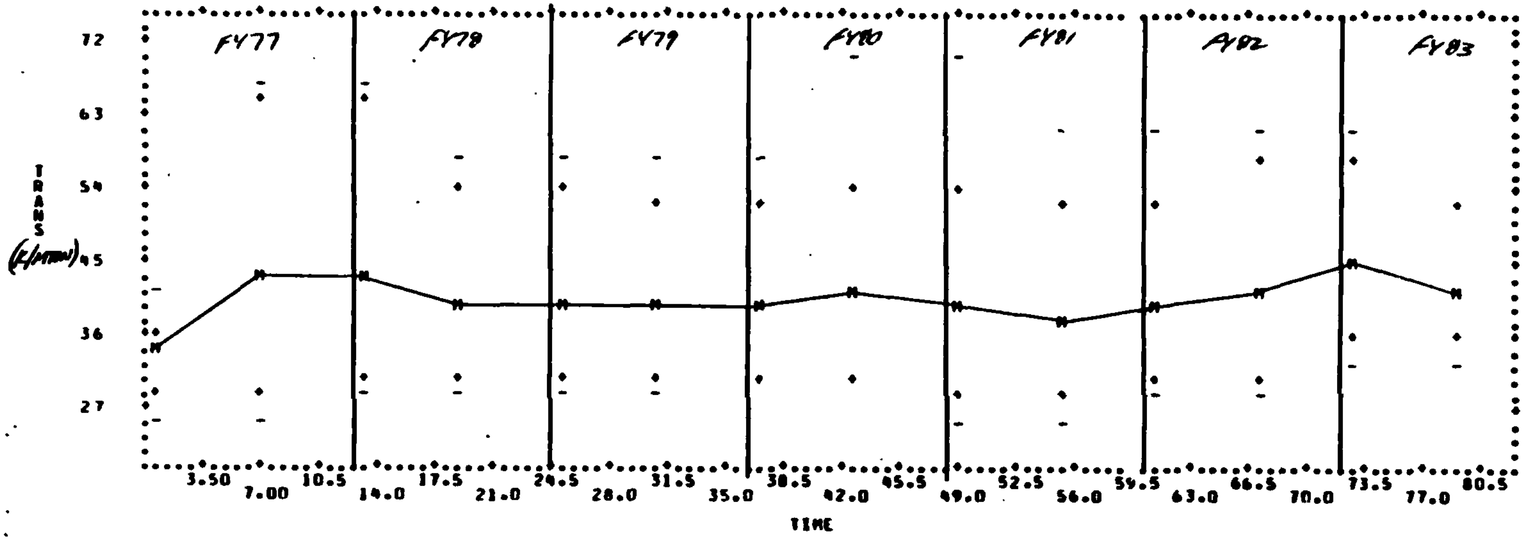
```
TIME      NO. OF    MINIMUM              MAXIMUM

VALUE     CASES      VALUE      MEAN      VALUE
   1.000    2       35.9660   38.8935   41.8210
   3.000    3       29.0690   33.6185   36.0059
   5.000    3       25.6073   29.8277   34.0119
   7.000    3       34.0597   40.6007   53.1706
   9.000    3       53.1706   61.4115   66.2935
  11.000    3       44.2689   55.0900   66.2935
  13.000    3       34.3525   42.9053   52.1348
  15.000    3       32.3948   37.3303   43.2295
  17.000    3       28.3354   32.1852   37.3906
  19.000    3       30.4297   37.1170   43.4381
  21.000    3       43.4381   49.9917   57.8416
  23.000    3       37.0343   49.9251   57.8416
  25.000    3       34.6776   37.2409   40.0107
  27.000    3       30.1879   33.0246   34.6776
  29.000    3       28.5489   31.3295   35.2516
  31.000    3       35.2516   38.1080   42.2984
  33.000    3       42.2984   49.0693   57.7656
  35.000    3       37.4084   45.4775   51.8802
  37.000    3       35.8888   36.7028   37.4084
  39.060    3       30.0506   33.8662   36.8111
  41.000    3       30.0506   33.2398   38.7329
  43.000    3       37.2930   43.1236   53.3447
  45.000    3       53.3447   59.6089   70.8398
  47.000    3       39.1965   47.6597   59.6407
  49.000    3       31.0532   35.0626   39.1965
  51.000    3       28.9862   32.8006   37.3380
  53.000    3       25.8226   29.7121   34.3274
  55.000    3       34.3274   36.9382   38.3015
  57.000    3       38.3015   50.5155   60.5392
  59.000    3       38.7009   48.0196   52.7059
  61.000    3       33.4449   38.1269   42.0157
  63.000    3       30.7987   35.9449   42.0157
  65.000    3       27.9999   32.3374   38.2117
  67.000    3       38.2117   41.9084   47.7009
  69.000    3       47.7009   55.2855   61.3444
  71.000    3       45.4201   52.6523   61.3444
  73.000    3       42.9501   44.4234   45.4201
  75.000    3       38.2094   40.5157   42.9501
  77.000    3       33.0960   35.9662   38.2094
  79.000    3       36.5123   42.4453   52.1829
  81.000    2       52.1829   52.3745   52.5661
```

Figure F-2. Three-month Moving Average - POV



```
TIME      NO. OF    MINIMUM               MAXIMUM

VALUE     CASES      VALUE      MEAN       VALUE
   1.000      3     35.9660   37.9300    41.8210
   4.000      6     25.6073   33.8793    41.8210
   7.000      6     25.6073   40.2473    64.7706
  10.000      6     34.0597   53.2829    66.2935
  13.000      6     32.3948   46.1122    66.2935
  16.000      6     28.3354   34.2554    42.2295
  19.000      6     28.3354   37.6321    48.7133
  22.000      6     37.0343   46.5020    57.8416
  25.000      6     34.2083   43.1120    57.8416
  28.000      6     28.5489   33.8142    40.0107
  31.000      6     28.5489   38.4710    57.7656
  34.000      6     36.7739   45.5451    57.7656
  37.000      6     34.7369   40.6449    51.8802
  40.000      6     30.0506   34.5261    38.7329
  43.000      6     30.0506   43.5329    70.8398
  46.000      6     37.2930   50.7428    70.8398
  49.000      6     31.0532   40.5747    54.6407
  52.000      6     25.8226   31.6009    37.3380
  55.000      6     25.8226   37.6938    60.5392
  58.000      6     38.1856   46.8475    60.5392
  61.000      6     33.6640   42.4598    52.7059
  64.000      6     27.9999   34.6187    42.0157
  67.000      6     27.9999   40.2658    57.0712
  70.000      6     40.3106   50.4232    61.3444
  73.000      6     40.3075   47.6857    61.3444
  76.000      6     33.0968   39.3427    44.9000
  79.000      6     33.0968   41.8814    52.5661
```

Figure F-3. Six-month Moving Average - POV

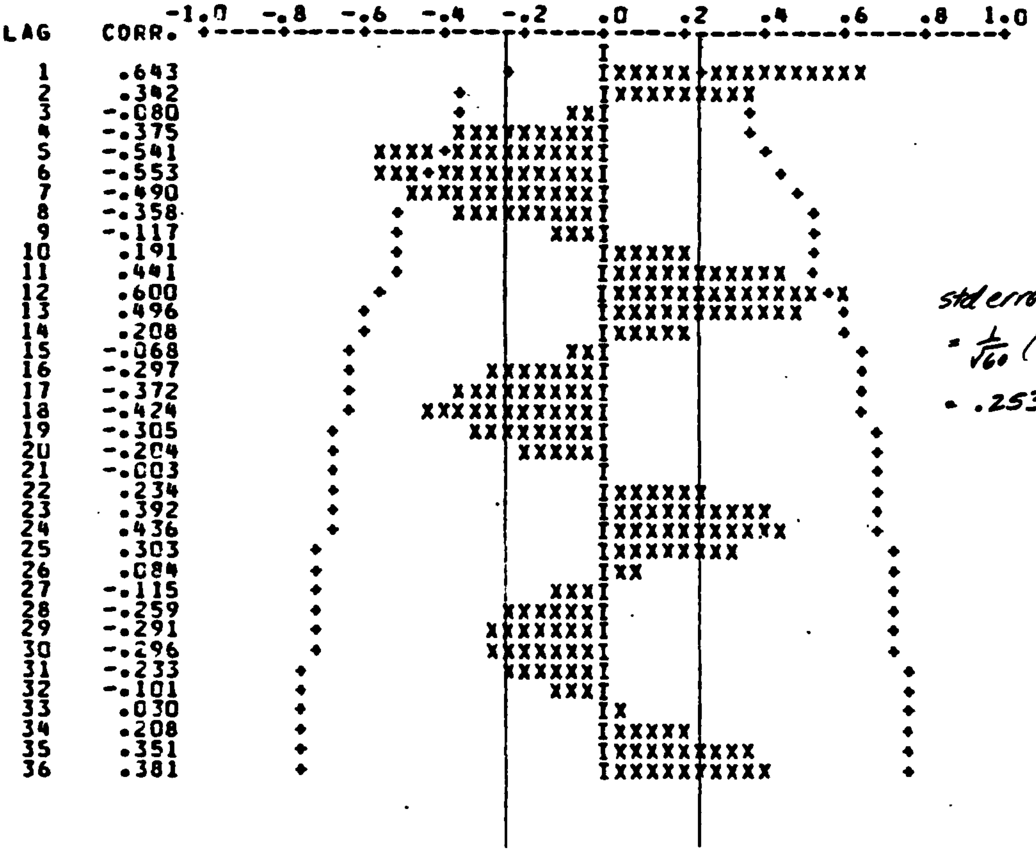


```
TIME       NO. OF     MINIMUM   TRIMMED   TRIMMED   TRIMMED   MAXIMUM
VALUE      CASES       VALUE    MINIMUM    MEAN     MAXIMUM    VALUE
  1.000        6      25.6073   29.0640   33.9618   36.0054   41.8210
  7.000       12      25.6073   29.0640   43.1072   64.7706   66.2935
 13.000       12      28.3354   30.8297   43.0601   64.7706   66.2935
 19.000       12      28.3354   30.8297   39.8368   54.8994   57.8416
 25.000       12      28.5489   30.1879   39.5507   54.8994   57.8416
 31.000       12      28.5489   30.1879   38.9841   51.8802   57.7656
 37.000       12      30.0506   30.9360   39.2611   51.8802   57.7656
 43.000       12      30.0506   30.9360   41.0722   54.6407   70.8398
 49.000       12      25.8226   28.9862   39.7399   54.6407   70.8398
 55.000       12      25.8226   28.9862   38.4328   52.7059   60.5392
 61.000       12      27.9999   30.7987   40.0258   52.7059   60.5392
 67.000       12      27.9999   30.7987   42.0908   57.0712   61.3444
 73.000       12      33.0968   36.5123   44.9154   57.0712   61.3444
 79.000        9      33.0968   36.5123   41.9690   52.1829   52.5661
```

Figure F-4. Twelve-month Moving Average - POV

```
AUTOCORRELATIONS

  1- 12      .64  .34 -.08 -.37 -.54 -.55 -.49 -.36 -.12  .19  .44  .60
  ST.E.      .13  .17  .19  .19  .20  .22  .24  .26  .27  .27  .27  .28

 13- 24      .50  .21 -.07 -.30 -.37 -.42 -.31 -.20  0.0  .23  .39  .44
  ST.E.      .30  .32  .32  .32  .32  .33  .34  .34  .35  .35  .35  .36

 25- 36      .30  .08 -.12 -.26 -.29 -.30 -.23 -.10  .03  .21  .35  .38
  ST.E.      .36  .37  .37  .37  .37  .38  .38  .38  .38  .38  .38  .39
```

PLOT OF AUTOCORRELATIONS



std error

$= \frac{1}{\sqrt{60}} (1.96)$

$= .253$

Figure F-5. ACF - Raw Data - POV

```
PARTIAL AUTOCORRELATIONS

  1- 12       .64 -.12 -.43 -.23 -.15 -.15 -.25 -.28 -.07  .13  .06  .09
   ST.E.      .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 13- 24      -.14 -.29 -.04 -.01  .03 -.23 -.01 -.01  .02  .05 -.10 -.11
   ST.E.      .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 25- 36      -.13 -.02  .07 -.05 -.09 -.09 -.05  .04 -.08 -.13  .07  .08
   ST.E.      .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

PLOT OF PARTIAL AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1    .643                    +     IXXXXX+XXXXXXXXXX
  2   -.122                    +  XXXI     +
  3   -.430               XXXXX+XXXXXI     +
  4   -.231                    XXXXXXI     +
  5   -.147                    + XXXXI     +
  6   -.150                    + XXXXI     +
  7   -.254                    XXXXXXI     +
  8   -.275                   X+XXXXXI     +
  9   -.065                    +   XXI     +
 10    .130                    +     IXXX  +
 11    .063                    +     IXX   +
 12    .091                    +     IXX   +
 13   -.137                    +  XXXI     +
 14   -.286                   X+XXXXXI     +
 15   -.038                    +    XI     +
 16   -.007                    +     I     +
 17    .027                    +     IX    +
 18   -.235                    XXXXXXI     +
 19   -.013                    +     I     +
 20   -.012                    +     I     +
 21    .017                    +     I     +
 22    .054                    +     IX    +
 23   -.096                    +   XXI     +
 24   -.106                    +  XXXI     +
 25   -.129                    +  XXXI     +
 26   -.025                    +    XI     +
 27    .072                    +     IXX   +
 28   -.048                    +    XI     +
 29   -.092                    +   XXI     +
 30   -.090                    +   XXI     +
 31   -.049                    +    XI     +
 32    .042                    +     IX    +
 33   -.080                    +   XXI     +
 34   -.134                    +  XXXI     +
 35    .068                    +     IXX   +
 36    .082                    +     IXX   +
```

Figure F-6. PACF - Raw Data - POV

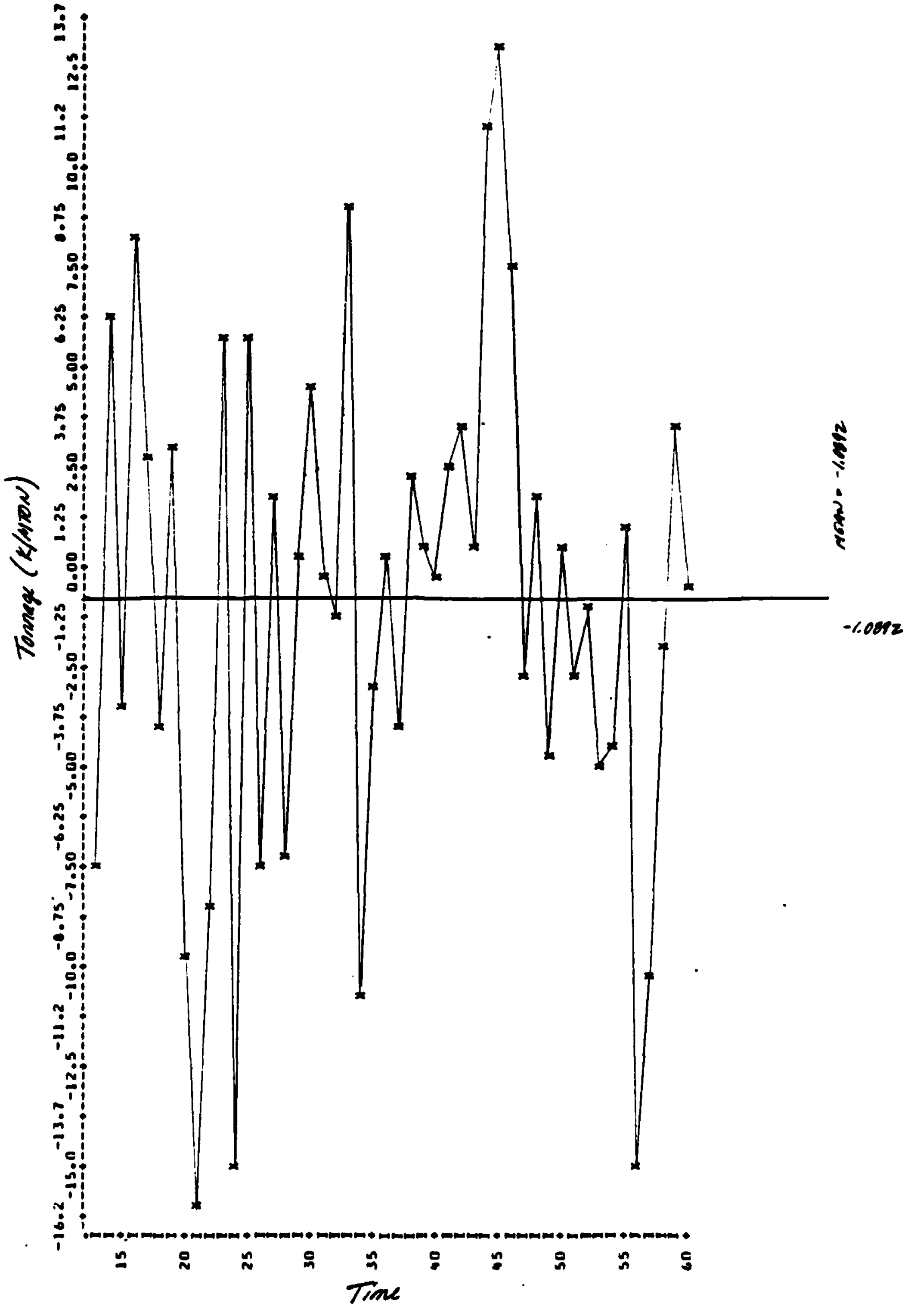


Figure F-7. Differenced Series (12-month lag) - POV

```
AUTOCORRELATIONS

  1- 12      .07  .22  .10  .02 -.11  .04 -.05 -.02 -.10 -.17 -.10 -.27
  ST.E.      .14  .15  .15  .15  .15  .15  .16  .16  .16  .16  .16  .16

 13- 24      .11  .04  .05  0.0 -.02 -.18  .07 -.18 -.06  0.0 -.12 -.26
  ST.E.      .17  .17  .17  .17  .17  .17  .18  .18  .18  .18  .18  .18

 25- 36     -.05 -.05  .02  .11  .11  .11 -.03  .11 -.01  .06  .06  .16
  ST.E.      .19  .19  .19  .19  .19  .19  .19  .20  .20  .20  .20  .20

PLOT OF AUTOCORRELATIONS

               -1.0 -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG     CORR.   +----+----+----+----+----+----+----+----+----+----+
                                         I
  1      .068                     +      IXX    +
  2      .223                     +      IXXXXXX+
  3      .096                     +      IXX    +
  4      .023                    +       IX      +
  5     -.108                    +    XXXI       +
  6      .045                    +       IX      +
  7     -.051                    +      XI       +
  8     -.020                    +      XI       +
  9     -.097                    +     XXI       +
 10     -.167                    +   XXXXI       +
 11     -.100                    +     XXI       +
 12     -.268                    +XXXXXXXI       +
 13      .106                    +       IXXX    +
 14      .040                    +       IX      +
 15      .045                    +       IX      +
 16      .002                    +       I       +
 17     -.016                    +       I       +
 18     -.184                    +  XXXXXI       +
 19      .068                   +        IXX      +
 20     -.179                   +    XXXXI        +
 21     -.063                   +      XXI        +
 22      .002                   +        I        +
 23     -.120                   +     XXXI        +
 24     -.261                   + XXXXXXXI        +
 25     -.046                   +       XI        +
 26     -.050                   +       XI        +
 27      .018                   +        I        +
 28      .110                   +        IXXX     +
 29      .106                   +        IXXX     +
 30      .105                   +        IXXX     +
 31     -.026                  +        XI         +
 32      .111                  +         IXXX      +
 33     -.013                  +         I         +
 34      .055                  +         IX        +
 35      .062                  +         IXX       +
 36      .162                  +         IXXXX     +
```

Std error

$= \frac{1}{\sqrt{48}}(1.96)$

$= .283$

Figure F-8. ACF - Lagged 12 Months

```
PARTIAL AUTOCORRELATIONS

  1- 12     .07  .22  .07 -.04 -.15  .05  .01 -.02 -.10 -.18 -.03 -.20
  ST.E.     .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14

 13- 24     .21  .14 -.01 -.10 -.14 -.14  .13 -.13 -.15 -.04 -.10 -.28
  ST.E.     .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14

 25- 36     .07  .14  .02 -.03 -.08 -.05 -.01  .02 -.09 -.01 -.07  0.0
  ST.E.     .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14

PLOT OF PARTIAL AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1    .068                   +      IXX    +
  2    .220                   +      IXXXXX +
  3    .073                   +      IXX    +
  4   -.035                   +     XI      +
  5   -.153                   +  XXXXI      +
  6    .054                   +      IX     +
  7    .006                   +      I      +
  8   -.015                   +      I      +
  9   -.104                   +   XXXI      +
 10   -.179                   +  XXXXI      +
 11   -.033                   +     XI      +
 12   -.199                   + XXXXXI      +
 13    .210                   +      IXXXXX +
 14    .140                   +      IXXXX  +
 15   -.014                   +      I      +
 16   -.103                   +   XXXI      +
 17   -.141                   +  XXXXI      +
 18   -.141                   +  XXXXI      +
 19    .128                   +      IXXX   +
 20   -.133                   +   XXXI      +
 21   -.154                   +  XXXXI      +
 22   -.038                   +     XI      +
 23   -.104                   +   XXXI      +
 24   -.275                   XXXXXXXI      +
 25    .069                   +      IXX    +
 26    .143                   +      IXXXX  +
 27    .024                   +      IX     +
 28   -.032                   +     XI      +
 29   -.081                   +    XXI      +
 30   -.051                   +     XI      +
 31   -.013                   +      I      +
 32    .021                   +      IX     +
 33   -.086                   +    XXI      +
 34   -.012                   +      I      +
 35   -.066                   +    XXI      +
 36    .001                   +      I      +
```

Figure F-9. PACF - Lagged 12 Months

```
ESTIMATION BY BACKCASTING METHOD

RELATIVE CHANGE IN RESIDUAL SUM OF SQUARES LESS THAN  .1000-004


SUMMARY OF THE MODEL

OUTPUT VARIABLE -- TRANS
INPUT VARIABLES -- NOISE

VARIABLE  VAR. TYPE  MEAN      TIME     DIFFERENCES
                                                12
TRANS      RANDOM             1-  60  (1-B   )

PARAMETER VARIABLE   TYPE  FACTOR  ORDER ESTIMATE         ST. ERR.  T-RATIO
     1   TRANS        MA      1      12     .8581            .0512    16.77
     2   TRANS        AR      1       1     .2208-001        .1159      .19
     3   TRANS        AR      1       2     .3554            .1165     3.05

RESIDUAL SUM OF SQUARES  =       806.252357 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM       =               43
RESIDUAL MEAN SQUARE     =        18.750055
```

Figure F-10. Model Parameters - POV

```
AUTOCORRELATIONS

  1- 12     -.02 -.03  .12 -.02 -.20  .05  .07 -.06 -.07 -.04 -.20 -.18
  ST.E.      .13  .13  .13  .13  .13  .14  .14  .14  .14  .14  .14  .14

 13- 24      .16  .04  .13  .05 -.03 -.12  .10 -.10 -.06  .17 -.10 -.27
  ST.E.      .15  .15  .15  .15  .15  .15  .15  .15  .16  .16  .16  .16

 25- 36      .02 -.07 -.03  .12  .13  .01 -.02  .14 -.02  .01  .13  .11
  ST.E.      .17  .17  .17  .17  .17  .17  .17  .17  .17  .17  .17  .17

PLOT OF AUTOCORRELATIONS

           -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG    CORR. +----+----+----+----+----+----+----+----+----+----+
                                      I
  1    -.015                    +     I     +
  2    -.026                    +    XI     +
  3     .121                    +     IXXX  +
  4    -.017                    +     I     +
  5    -.202                    +XXXXXI     +
  6     .055                   +      IX     +
  7     .067                   +      IXX    +
  8    -.062                   +    XXI      +
  9    -.066                   +    XXI      +
 10    -.038                   +     XI      +
 11    -.199                   + XXXXXI      +
 12    -.179                   +  XXXXI      +
 13     .164                   +      IXXXX  +
 14     .037                   +      IX     +
 15     .128                   +      IXXX   +
 16     .053                   +      IX     +
 17    -.035                   +     XI      +
 18    -.120                   +   XXXI      +
 19     .103                  +       IXXX    +
 20    -.101                  +    XXXI       +
 21    -.061                  +     XXI       +
 22     .170                  +       IXXXX   +
 23    -.103 272(40)=1635     +    XXXI       +
 24    -.266                  +XXXXXXXI       +
 25     .024                  +       IX      +
 26    -.067                  +     XXI       +
 27    -.027                  +      XI       +
 28     .121                  +       IXXX    +
 29     .130                  +       IXXX    +
 30     .005                  +       I       +
 31    -.025                  +      XI       +
 32     .137                  +       IXXX    +
 33    -.023                  +      XI       +
 34     .007                  +       I       +
 35     .126                  +       IXXX    +
 36     .113                 +        IXXX     +
```

Figure F-11. Estimated Residuals - POV

```
 FORECAST ON VARIABLE TRANS    FROM TIME PERIOD    61

PERIOD            FORECASTS       ST.  ERR.      ACTUAL    |   ERROR
  61              35.36769         6.27085       33.664    |   -1.703
  62              37.17831         6.27237       42.016    |    4.838
  63              33.60430         6.65760       35.02     |    1.416
  64              30.18449         6.65832       30.799    |     .615
  65              26.42352         6.70566       28.0      |    1.577
  66              34.95272         6.70587       38.214    |    3.262
  67              35.44728         6.71187       40.311    |    4.864
  68              49.08484         6.71192       47.201    |   -1.883
  69              62.68552         6.71269       57.071    |   -5.614
  70              60.19025         6.71269       61.344    |    1.154
  71              50.49294         6.71279       51.192    |     .7
  72              45.75998         6.71279       45.420    |    -.339
STANDARD ERROR =  6.27085        (BY CONDITIONAL METHOD  )

                  501.37                         510.26       MSE = 8.54
```

Figure F-12. Forecast FY 82 - POV

F-3. GENERAL CARGO

a. The raw data for general cargo is depicted in Figure F-13. The raw data appears to follow a seasonal pattern which falls in the early part of the fiscal year and rises at the end of the fiscal year. This seasonal pattern is more clearly manifested in the 3-month and 6-month moving average diagrams (Figures F-14 and F-15). However, it should be noted that the seasonal pattern is not repeated regularly and that a general trend exists in the data. This fact is verified by the 12-month moving average diagram (Figure F-16) which depicts a possible 5-year cycle in the data. Currently, there is not enough data to confirm the existence of this cycle throughout time; thus, this hypothesis requires continued analysis.

b. Autocorrelation function analysis of the data confirms the existence of seasonality in the data (Figures F-17 and F-18) as noted by the large autocorrelation coefficients at lags 6, 12, 18, 24, 30, and 36. To eliminate seasonality in the data, the raw series was differenced at a lag of 12 months. The plot of the new series is shown in Figure F-19. It is readily obvious that this series is not stationary, as noted by the downward trend of observations over time. Nonstationarity in the data is more clearly evidenced by the autocorrelation function (Figure F-20) which fails to fall quickly to zero. In an effort to achieve stationarity, the seasonally adjusted series was differenced at a lag of 1 month. The resulting autocorrelation function (Figure F-21) indicates that a weak stationary series has been generated.

c. Analysis of the autocorrelation function identifies a possible mixed ARMA nonseasonal model and a possible MA seasonal model. The nonseasonal mixed ARMA model is suggested based upon the gradual decline (except lag 3) of the autocorrelation and partial autocorrelation coefficients (Figures F-21 and F-22). The autocorrelation function suggests a MA seasonal process as manifested by the gradual decay of autocorrelations at lags 12 and 24. Thus, the data suggest a multiplicative seasonal with a mixed ARIMA nonseasonal (1,1,1) model and a seasonal ARIMA (0,1,1) model:

$$(1 - \phi_1 B)(1 - B^{12})(1 - B) X_t = (1 - \theta_1 B)(1 - \theta_{12} B^{12}) \epsilon_t$$

d. The results of the model (Figure F-23) are as follows:

$$(1 - \underset{(2.5)}{.3579} B)(1 - B^{12})(1 - B) X_t = (1 - \underset{(8.31)}{.7962} B)(1 - \underset{(13.43)}{.7753} B^{12}) \epsilon_t$$

$$x^2 (3,20) = 12.8$$

The results indicate that all of the estimated parameters are signficant of the 5 percent significance level. The Q statistic for 20 degrees of freedom is 12.8 (Figure F-24). Thus, the null hypothesis, estimated model residuals are uncorrelated, should not be rejected at the 13 percent significance level.

e. The general cargo seasonal model forecasted that 1856.61 K/MTON would be transported during FY 82 versus an actual shipment of 2021.55 K/MTON The MSE of the general cargo forecast for FY 82 was 318.54 (Figure F-25), and the annual forecast error was -8.2 percent. As stated in paragraph 6-7, another model for general cargo forecasted FY 82 shipments with a -4.6 percent error. Both models should be tracked into the future for forecasting accuracy and model fit.

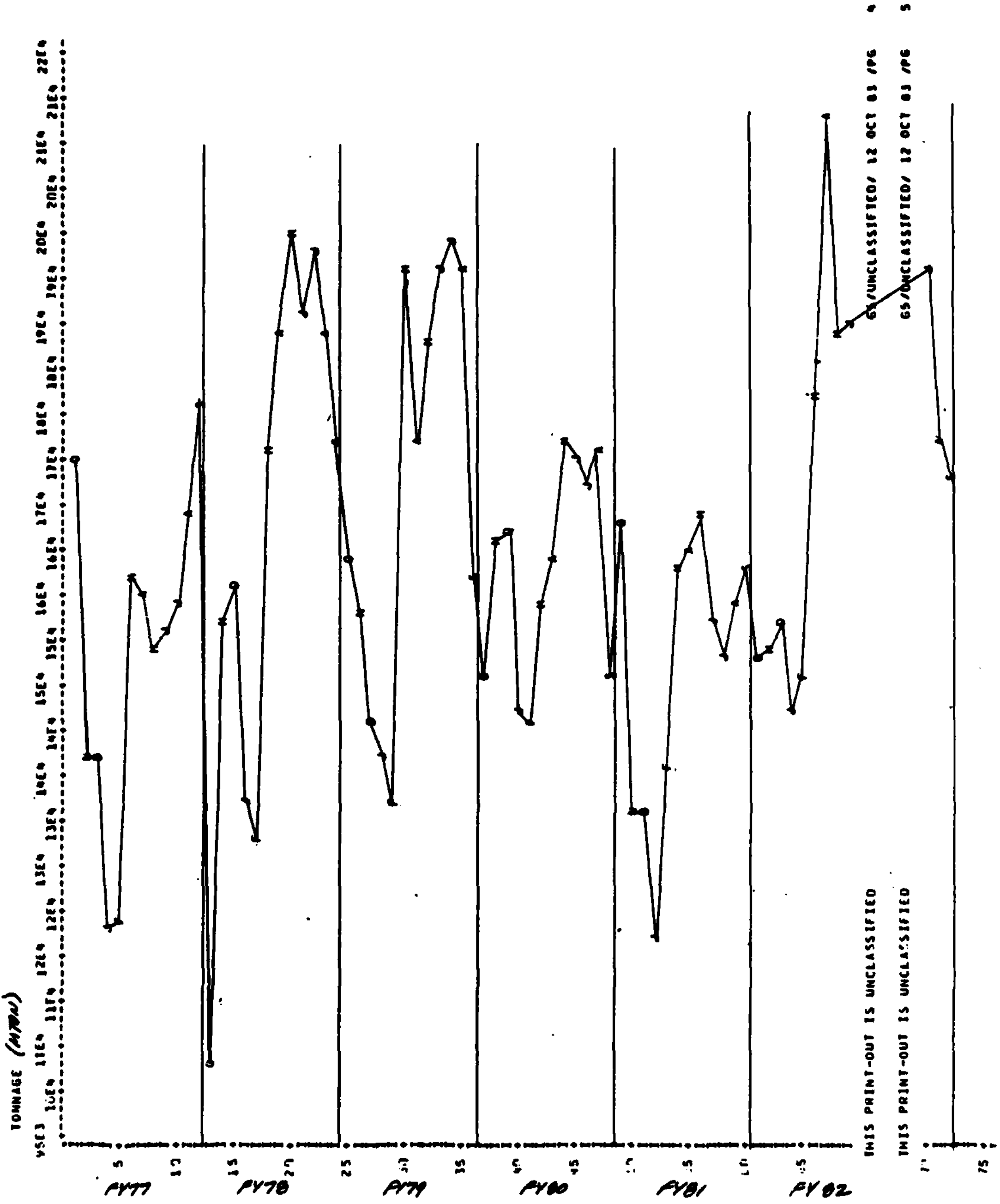
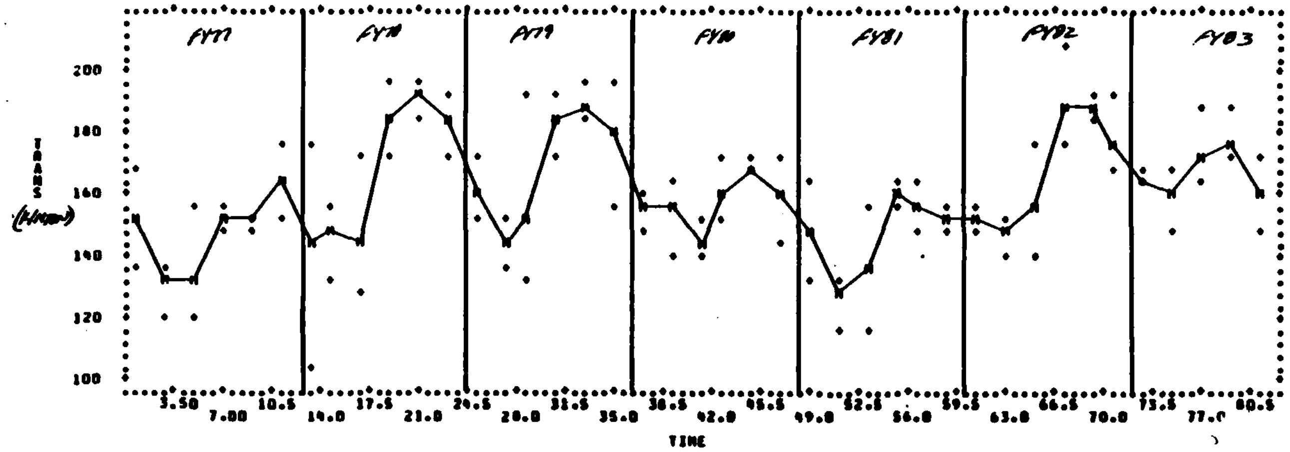
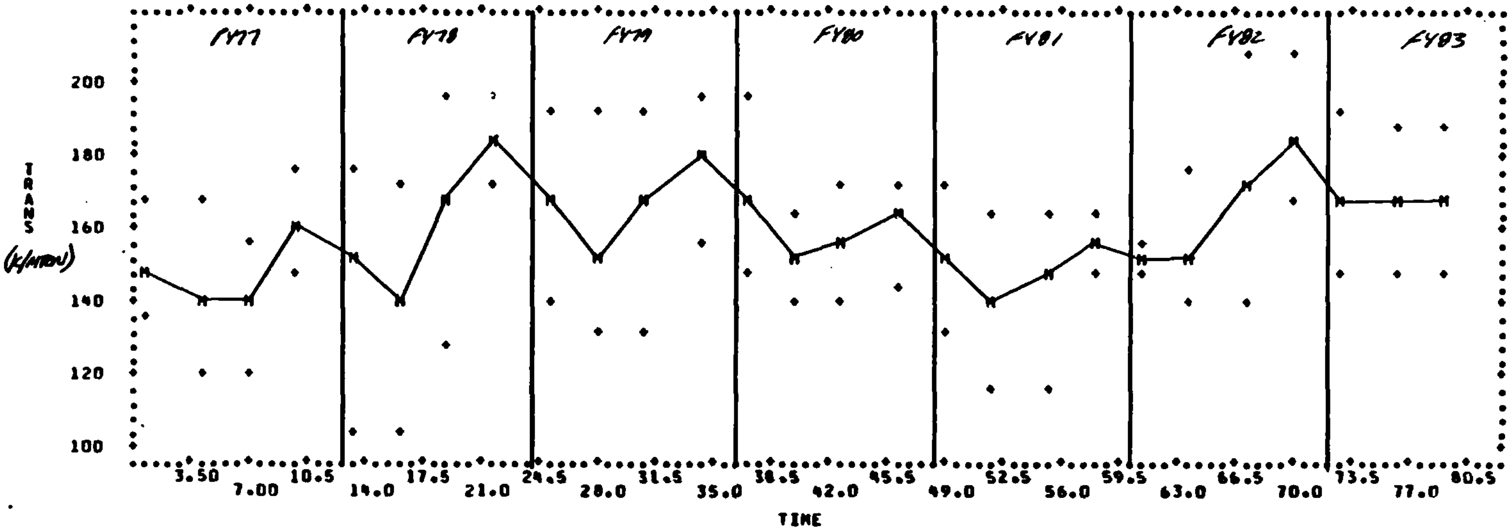


Figure F-13. General Cargo, FY 77 - FY 82



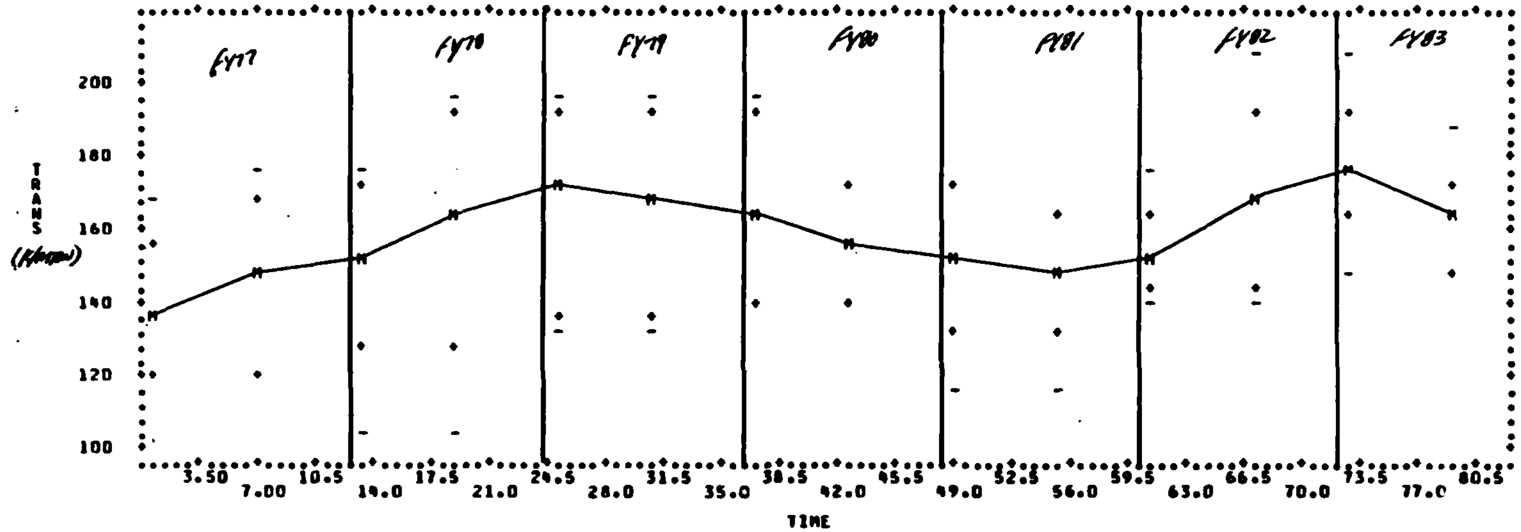
```
TIME      NO. OF    MINIMUM               MAXIMUM
VALUE     CASES      VALUE      MEAN       VALUE
  1.000       2    136.5982  153.1918  169.6855
  3.000       3    118.3090  130.7198  137.1572
  5.000       3    118.3090  131.4402  156.7934
  7.000       3    149.0794  153.7631  156.7934
  9.000       3    149.0794  151.3382  153.6160
 11.000       3    153.6160  164.5297  175.5317
 13.000       3    102.8353  143.4963  175.5317
 15.000       3    131.8679  146.5346  155.6142
 17.000       3    127.9600  143.6071  170.9936
 19.000       3    170.9936  183.5750  195.2785
 21.000       3    185.6248  191.2231  195.2785
 23.000       3    172.3098  182.9253  192.7660
 25.000       3    152.8061  161.4890  172.3098
 27.000       3    136.8765  143.7349  152.8061
 29.000       3    132.2372  153.4594  191.2659
 31.000       3    171.9873  182.1513  191.2659
 33.000       3    183.2007  189.4386  194.2456
 35.000       3    157.4224  180.9756  194.2456
 37.000       3    146.0307  155.7809  160.0000
 39.000       3    141.5717  155.8902  162.2111
 41.000       3    140.5562  145.2725  153.6098
 43.000       3    153.6098  161.3968  171.5310
 45.000       3    167.3161  169.5659  171.5310
 47.000       3    145.8009  161.4368  171.1333
 49.000       3    130.6708  146.4977  163.0198
 51.000       3    117.4175  126.2421  130.6708
 53.000       3    117.4175  137.0519  157.6273
 55.000       3    157.6273  160.5750  164.3520
 57.000       3    147.9966  154.7401  164.3520
 59.000       3    147.9966  153.2394  157.7461
 61.000       3    148.2975  151.5685  157.7461
 63.000       3    141.7344  147.5524  152.2679
 65.000       3    141.7344  154.9482  177.4772
 67.000       3    177.4772  189.7339  207.6665
 69.000       3    184.0580  186.6127  190.5317
 71.000       3    168.1660  176.8404  190.5317
 73.000       3    163.4303  165.8818  168.1660
 75.000       3    146.5631  159.4482  166.0991
 77.000       3    165.7325  173.4964  188.0579
 79.000       3    170.7527  177.1136  188.0579
 81.000       2    146.6341  159.5816  172.5291
```

Figure F-14. Three-month Moving Average - General



```
TIME      NO. OF   MINIMUM             MAXIMUM

VALUE     CASES     VALUE      MEAN     VALUE
   1.000      3    136.5982  147.8136  169.6854
   4.000      6    118.3890  139.6269  169.6854
   7.000      6    118.3890  141.6893  156.7934
  10.000      6    149.0794  158.2338  175.5317
  13.000      6    102.8353  150.6932  175.5317
  16.000      6    102.8353  140.2321  170.9936
  19.000      6    127.9600  166.0300  195.2785
  22.000      6    172.3098  185.6891  195.2785
  25.000      6    141.4423  167.0626  192.7660
  28.000      6    132.2372  152.3298  191.2659
  31.000      6    132.2372  167.7395  191.2659
  34.000      6    157.4224  181.4974  194.2456
  37.000      6    146.0307  168.6761  194.2456
  40.000      6    140.5562  150.8246  162.2111
  43.000      6    140.5562  156.0179  171.5310
  46.000      6    145.8009  164.1000  171.5310
  49.000      6    130.6381  151.4398  171.1333
  52.000      6    117.4175  139.2471  163.0109
  55.000      6    117.4175  147.8539  164.3520
  58.000      6    147.9966  155.9479  164.3520
  61.000      6    147.9966  151.4899  157.7461
  64.000      6    141.7344  152.3442  177.4772
  67.000      6    141.7344  173.6363  207.6665
  70.000      6    168.1660  184.5824  207.6665
  73.000      6    146.5631  167.7606  190.5317
  76.000      6    146.5631  166.0836  188.0589
  79.000      6    146.6341  168.3959  188.0589
```

Figure F-15. Six-month Moving Average - General



```
  TIME     NO. OF    MINIMUM  TRIMMED  TRIMMED  TRIMMED   MAXIMUM
  VALUE    CASES      VALUE   MINIMUM   MEAN    MAXIMUM    VALUE
    1.000     6     118.3890 119.1381 137.4217 156.7934 169.6854
    7.000    12     118.3890 119.1381 149.3243 169.6854 175.5317
   13.000    12     102.8353 127.9600 151.2428 170.9936 175.5317
   19.000    12     102.8353 127.9600 165.7414 192.7660 195.2785
   25.000    12     132.2372 136.8765 170.0598 192.7660 195.2785
   31.000    12     132.2372 136.8765 167.6481 191.2659 194.2456
   37.000    12     140.5562 141.5717 165.9130 191.2590 194.2456
   43.000    12     140.5562 141.5717 157.7460 171.1333 171.5310
   49.000    12     117.4175 130.6381 153.1134 171.1333 171.5310
   55.000    12     117.4175 130.6381 148.9401 163.0199 164.3520
   61.000    12     141.7344 145.6329 153.0541 164.3520 177.4772
   67.000    12     141.7344 145.6329 167.2158 193.5317 207.6665
   73.000    12     146.5631 163.4303 174.9766 190.5317 207.6665
   79.000     9     146.5631 146.6341 164.5472 172.5291 188.0589
```

Figure F-16. Twelve-month Moving Average - General

```
AUTOCORRELATIONS

  1- 12      .65  .36  .08 -.11 -.23 -.31 -.25 -.09  .06  .22  .39  .47
   ST.E.     .13  .17  .19  .19  .19  .19  .20  .21  .21  .21  .21  .22

 13- 24      .27  .10 -.09 -.30 -.42 -.46 -.30 -.19 -.04  .04  .19  .24
   ST.E.     .24  .24  .24  .24  .25  .26  .28  .28  .28  .28  .28  .29

 25- 36      .09 -.03 -.15 -.30 -.30 -.34 -.24 -.13 -.04  .05  .09  .10
   ST.E.     .29  .29  .29  .29  .30  .30  .31  .31  .31  .31  .31  .31

PLOT OF AUTOCORRELATIONS

           -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR.  +----+----+----+----+----+----+----+----+----+----+
                                      I
   1   .645                     +     IXXXXX+XXXXXXXXXX
   2   .358                  +        IXXXXXXXXX
   3   .083                  +        IXX      +
   4  -.111                  +     XXXI        +
   5  -.225                  +  XXXXXXI        +
   6  -.313                  +XXXXXXXXI        +
   7  -.251                 +   XXXXXXI         +
   8  -.088                 +       XXI         +
   9   .062                 +         IXX       +
  10   .216                 +         IXXXXX    +
  11   .387                 +         IXXXXXXXXXX
  12   .469                +          IXXXXXXXXXX+X
  13   .270               +           IXXXXXXX    +
  14   .099               +           IXX         +
  15  -.091               +         XXI           +
  16  -.303               +   XXXXXXXXI           +
  17  -.420               + XXXXXXXXXXI           +
  18  -.458              + XXXXXXXXXXXI            +
  19  -.296              +     XXXXXXXI            +
  20  -.194             +        XXXXXI             +
  21  -.039             +            XI             +
  22   .043             +             IX            +
  23   .189             +             IXXXXX        +
  24   .236             +             IXXXXXX       +
  25   .092             +             IXX           +
  26  -.032             +            XI             +
  27  -.148             +         XXXXI             +
  28  -.302             +     XXXXXXXXI             +
  29  -.300             +      XXXXXXXI             +
  30  -.343            +     XXXXXXXXXI              +
  31  -.239            +        XXXXXXI              +
  32  -.126            +           XXXI              +
  33  -.037            +             XI              +
  34   .046            +              IX             +
  35   .092            +              IXX            +
  36   .095            +              IXX            +
```

std error

$= \frac{1}{\sqrt{60}}(1.96)$

$= .253$

Figure F-17. ACF - Raw Data - General

```
PARTIAL AUTOCORRELATIONS

  1- 12      .65 -.10 -.18 -.11 -.08 -.15  .07  .14  .04  .12  .25  .13
  ST.E.      .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 13- 24     -.30  .03 -.03 -.29 -.09  .02  .05 -.27  .12 -.12 -.03  .06
  ST.E.      .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 25- 36     -.07 -.10  .07 -.04  .08 -.18  .01  .03 -.18 -.06 -.09 -.04
  ST.E.      .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

PLOT OF PARTIAL AUTOCORRELATIONS

             -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG     CORR.  +----+----+----+----+----+----+----+----+----+----+
                                        I
   1      .645                    +     IXXXXX+XXXXXXXXXX
   2     -.100                    +  XXXI     +
   3     -.184                    +XXXXXI     +
   4     -.108                    +  XXXI     +
   5     -.080                    +   XXI     +
   6     -.148                    + XXXXI     +
   7      .067                    +     IXX   +
   8      .141                    +     IXXXX +
   9      .043                    +     IX    +
  10      .117                    +     IXXX  +
  11      .248                    +     IXXXXXX
  12      .126                    +     IXXX  +
  13     -.295                   X+XXXXXI     +
  14      .032                    +     IX    +
  15     -.030                    +    XI     +
  16     -.286                   X+XXXXXI     +
  17     -.086                    +   XXI     +
  18      .024                    +     IX    +
  19      .048                    +     IX    +
  20     -.267                   X+XXXXXI     +
  21      .119                    +     IXXX  +
  22     -.121                    +  XXXI     +
  23     -.034                    +    XI     +
  24      .056                    +     IX    +
  25     -.067                    +   XXI     +
  26     -.097                    +   XXI     +
  27      .069                    +     IXX   +
  28     -.037                    +    XI     +
  29      .078                    +     IXX   +
  30     -.180                    + XXXXI     +
  31      .007                    +     I     +
  32      .026                    +     IX    +
  33     -.175                    + XXXXI     +
  34     -.064                    +   XXI     +
  35     -.087                    +   XXI     +
  36     -.041                    +    XI     +
```

Figure F-18. PACF - Raw Data - General

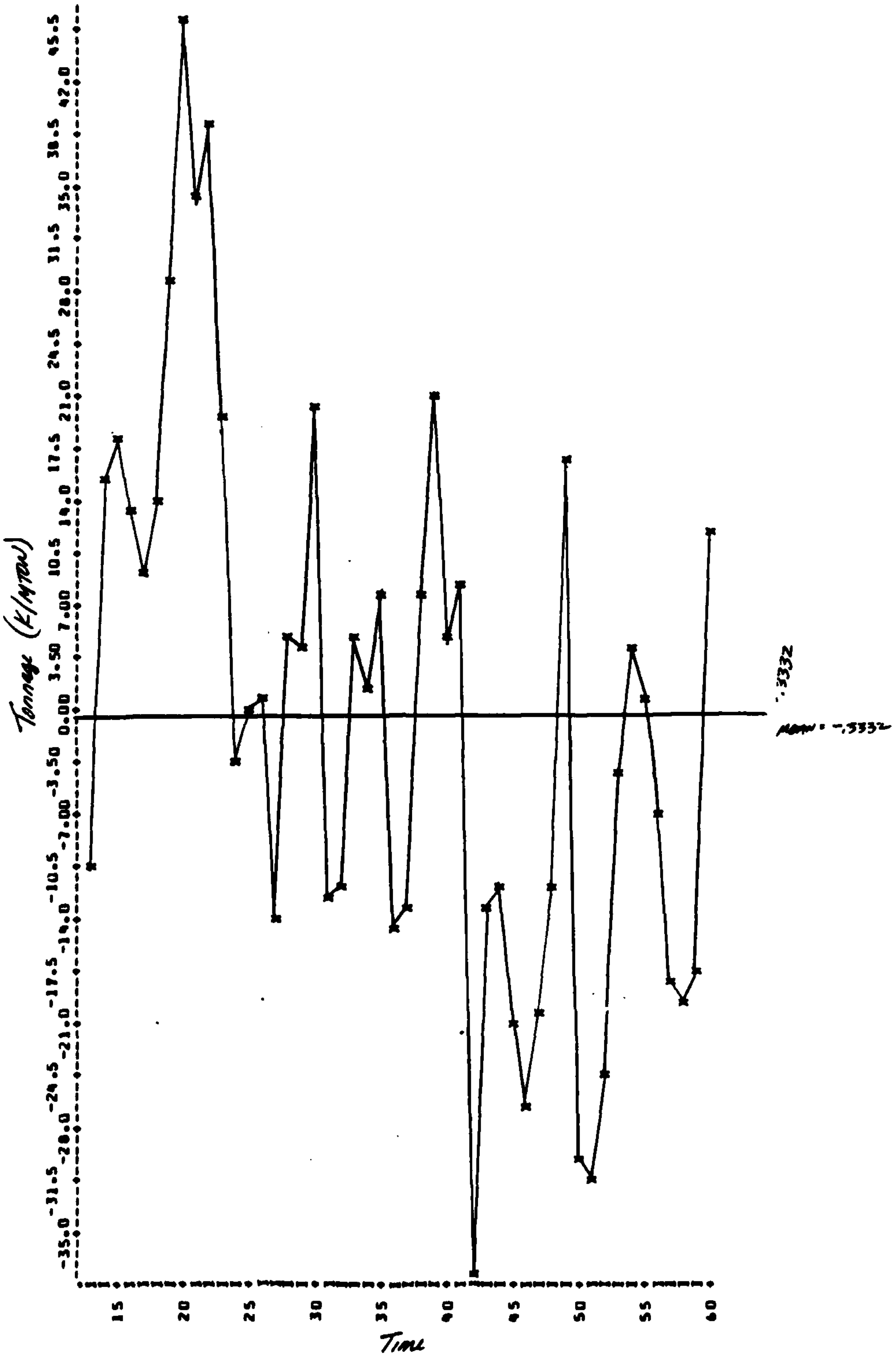


Figure F-19. Differenced Series (12-month lag) - General

```
AUTOCORRELATIONS

  1- 12     .59  .35  .20  .26  .34  .27  .10  .18  .11  .12  .08 -.09
 ST.E.      .14  .19  .20  .21  .21  .22  .23  .23  .23  .23  .24  .24

 13- 24    -.01  .07  .10  .03 -.07 -.02  .11 -.03 -.06 -.21 -.18 -.17
 ST.E.      .24  .24  .24  .24  .24  .24  .24  .24  .24  .24  .24  .25

 25- 36    -.17 -.18 -.18 -.26 -.22 -.23 -.23 -.16 -.10 -.07 -.12 -.21
 ST.E.      .25  .25  .25  .26  .26  .27  .27  .27  .28  .28  .28  .28

PLOT OF AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2  .0   .2   .4   .6   .8   1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1    .586                   +      IXXXXXX+XXXXXXXX
  2    .355                 +        IXXXXXXXXX
  3    .204                +         IXXXXX    +
  4    .259                +         IXXXXXX   +
  5    .339                +         IXXXXXXXX +
  6    .275               +          IXXXXXXX   +
  7    .103               +          IXXX       +
  8    .176               +          IXXXX      +
  9    .105               +          IXXX       +
 10    .119               +          IXXX       +
 11    .083              +           IXX         +
 12   -.086              +         XXI           +
 13   -.006              +           I           +
 14    .075              +           IXX         +
 15    .095              +           IXX         +
 16    .028              +           IX          +
 17   -.068              +         XXI           +
 18   -.022              +          XI           +
 19    .107              +           IXXX        +
 20   -.026              +          XI           +
 21   -.060              +          XI           +
 22   -.208              +      XXXXXI           +
 23   -.176              +       XXXXI           +
 24   -.168              +       XXXXI           +
 25   -.166              +       XXXXI           +
 26   -.182              +      XXXXXI           +
 27   -.183              +      XXXXXI           +
 28   -.260             +     XXXXXXXI            +
 29   -.222             +      XXXXXXI            +
 30   -.231             +      XXXXXXI            +
 31   -.232             +      XXXXXXI            +
 32   -.162             +        XXXXI            +
 33   -.104            +          XXXI             +
 34   -.068            +           XXI             +
 35   -.118            +          XXXI             +
 36   -.213            +        XXXXXI             +
```

std error

$= \frac{1}{\sqrt{48}}(1.96)$

$= .283$

Figure F-20. ACF - Lagged 12 Months

```
AUTOCORRELATIONS

  1- 12      -.18 -.09 -.26 -.04  .18  .14 -.28  .19 -.09  .05  .10 -.28
   ST.E.      .15  .15  .15  .16  .16  .16  .17  .18  .18  .18  .18  .18

 13- 24       .01  .07  .12  .03 -.16 -.10  .28 -.11  .12 -.21  .03  .01
   ST.E.      .19  .19  .19  .19  .19  .20  .20  .21  .21  .21  .21  .21

 25- 36       .02  0.0  .08 -.12  .02 -.02 -.07  .01  .04  .09  .06 -.15
   ST.E.      .21  .21  .21  .21  .22  .22  .22  .22  .22  .22  .22  .22

PLOT OF AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1   -.179                   +  XXXXI      +
  2   -.094                   +    XXI      +
  3   -.256                   +XXXXXXI      +
  4   -.045                  +      XI       +
  5    .175                  +       IXXXX   +
  6    .141                  +       IXXXX   +
  7   -.280                  +XXXXXXXI       +
  8    .187                 +        IXXXXX   +
  9   -.090                 +      XXI        +
 10    .047                 +        IX       +
 11    .103                 +        IXXX     +
 12   -.278                 + XXXXXXXI        +
 13    .007                 +        I        +
 14    .071                 +        IXX      +
 15    .117                 +        IXXX     +
 16    .026                +         IX        +
 17   -.161                +     XXXXI         +
 18   -.103                +      XXXI         +
 19    .281                +         IXXXXXXX  +
 20   -.107                +      XXXI         +
 21    .123                +         IXXX      +
 22   -.206                +    XXXXXI         +
 23    .032                +         IX        +
 24    .011                +         I         +
 25    .016                +         I         +
 26   -.003                +         I         +
 27    .078                +         IXX       +
 28   -.124               +       XXXI          +
 29    .024               +          IX         +
 30   -.023               +         XI          +
 31   -.074               +        XXI          +
 32    .005               +          I          +
 33    .041               +          IX         +
 34    .095               +          IXX        +
 35    .062               +          IXX        +
 36   -.152               +      XXXXI          +
```

std error

$= \frac{1}{\sqrt{47}}(1.96)$

$= .286$

Figure F-21. ACF - Lagged 12 Months and 1 Month

```
PARTIAL AUTOCORRELATIONS

  1- 12    -.18 -.13 -.31 -.21  .04  .10 -.29  .19  .02 -.09  .16 -.22
  ST.E.     .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15

 13- 24    -.11 -.03  .13 -.12 -.11  .07  .12 -.12  .15 -.04 -.02 -.09
  ST.E.     .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15

 25- 36    -.06  .03 -.02  .03 -.16 -.01 -.07 -.17  .10 -.03  .06 -.10
  ST.E.     .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15

PLOT OF PARTIAL AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1   -.179                   +  XXXXI      +
  2   -.130                   +   XXXI      +
  3   -.313                  X+XXXXXXI      +
  4   -.211                   + XXXXXI      +
  5    .036                   +      IX     +
  6    .099                   +      IXX    +
  7   -.293                   XXXXXXXI      +
  8    .188                   +      IXXXXX +
  9    .024                   +      IX     +
 10   -.090                   +    XXI      +
 11    .158                   +      IXXXX  +
 12   -.218                   + XXXXXI      +
 13   -.112                   +   XXXI      +
 14   -.026                   +     XI      +
 15    .132                   +      IXXX   +
 16   -.123                   +   XXXI      +
 17   -.114                   +   XXXI      +
 18    .074                   +      IXX    +
 19    .124                   +      IXXX   +
 20   -.116                   +   XXXI      +
 21    .147                   +      IXXXX  +
 22   -.043                   +     XI      +
 23   -.020                   +      I      +
 24   -.093                   +    XXI      +
 25   -.064                   +    XXI      +
 26    .033                   +      IX     +
 27   -.020                   +     XI      +
 28    .033                   +      IX     +
 29   -.160                   +  XXXXI      +
 30   -.013                   +      I      +
 31   -.072                   +    XXI      +
 32   -.166                   +  XXXXI      +
 33    .097                   +      IXX    +
 34   -.026                   +     XI      +
 35    .062                   +      IXX    +
 36   -.099                   +    XXI      +
```

Figure F-22. PACF - Lagged 12 Months and 1 Month

```
ESTIMATION BY BACKCASTING METHOD

RELATIVE CHANGE IN RESIDUAL SUM OF SQUARES LESS THAN  .1000-004


SUMMARY OF THE MODEL

OUTPUT VARIABLE -- TRANS
INPUT VARIABLES -- NOISE

VARIABLE  VAR. TYPE  MEAN      TIME      DIFFERENCES
                                             12       1
TRANS       RANDOM            1-  60  (1-B   ) (1-B   )

PARAMETER VARIABLE    TYPE  FACTOR  ORDER ESTIMATE         ST. ERR.  T-RATIO
     1    TRANS        MA      1       1     .7962            .0959      8.31
     2    TRANS        MA      2      12     .7753            .0577     13.43
     3    TRANS        AR      1       1     .3579            .1432      2.50
RESIDUAL SUM OF SQUARES  =       6104.701843 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM       =                43
RESIDUAL MEAN SQUARE     =        141.969809
```

Figure F-23. Model Parameters - General

```
AUTOCORRELATIONS
  1- 12      0.0  .06 -.14  .04  .01  .15 -.11  .14 -.08 -.05  .05 -.12
  ST.E.      .13  .13  .13  .13  .13  .13  .14  .14  .14  .14  .14  .14

 13- 24     -.14  .03  .04 -.06 -.13 -.06  .15 -.04  .13 -.12  .07 -.20
  ST.E.      .14  .15  .15  .15  .15  .15  .15  .15  .15  .15  .16  .16

 25- 36     -.07 -.03  .07 -.16  .04 -.12 -.09  0.0  .02  .08  .01 -.18
  ST.E.      .16  .16  .16  .16  .16  .16  .17  .17  .17  .17  .17  .17

PLOT OF AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1    .004                    +     I     +
  2    .059                    +     IX    +
  3   -.137                    +  XXXI     +
  4    .043                   +      IX     +
  5    .010                   +      I      +
  6    .153                   +      IXXXX  +
  7   -.112                   +   XXXI      +
  8    .144                   +      IXXXX  +
  9   -.081                   +    XXI      +
 10   -.045                   +     XI      +
 11    .052                   +      IX     +
 12   -.119                   +   XXXI      +
 13   -.145                   +  XXXXI      +
 14    .033                   +      IX     +
 15    .043                   +      IX     +
 16   -.058                   +     XI      +
 17   -.128                   +   XXXI      +
 18   -.058                   +     XI      +
 19    .154                   +      IXXXX  +
 20   -.037                   +     XI      +
 21    .131                   +      IXXX   +
 22   -.117                  +    XXXI       +
 23    .065 .213(60) = 12.8  +       IXX     +
 24   -.197                  +  XXXXXI       +
 25   -.071                  +     XXI       +
 26   -.030                  +      XI       +
 27    .071                  +       IXX     +
 28   -.158                  +   XXXXI       +
 29    .045                  +       IX      +
 30   -.119                  +    XXXI       +
 31   -.088                  +     XXI       +
 32   -.002                  +       I       +
 33    .024                  +       IX      +
 34    .082                  +       IXX     +
 35    .009                  +       I       +
 36   -.182                  +  XXXXXI       +
```

Figure F-24. Estimated Residuals - General

```
 FORECAST ON VARIABLE TRANS    FROM TIME PERIOD    61
PERIOD          FORECASTS         ST.  ERR.         ACTUAL          ERROR
  61            149.60000         15.16543          148.297        -1.303
  62            140.33198         17.39390          146.662         6.331
  63            142.79956         18.44542          152.261         9.462
  64            127.50204         19.18827          141.734        14.232
  65            131.17248         19.82463          145.633        14.461
  66            164.52803         20.41488          177.477        12.949
  67            164.28495         20.97950          207.666        43.382
  68            167.88490         21.52618          184.059        16.174
  69            165.61838         22.05823          185.248        19.63
  70            166.36350         22.57737          190.532        24.168
  71            170.92077         23.08469          171.823          .903
  72            165.60065         23.58106          168.166         2.566
STANDARD ERROR =  15.1654     (BY CONDITIONAL METHOD  )

                1856.61                             2021.55     MSE = 318.54
```

Figure F-25. Forecast FY 82 - General

F-4. HHG

a. The raw series for HHG shipments is depicted in Figure F-26. The raw data depicts the volatility of HHG shipments when MSC is required to transport normal Code 4 shipments. During FY 78 HHG shipments by MSC were more than three-times as large as any other fiscal year in the data set. Due to this distortion in the data, only data from October 1978 through September 1981 was used to develop the models. The HHG time series has only 36 observations, much less than is normally required to achieve satisfactory results from time series analysis.

b. Aside from the distortion during FY 78, the raw data depict a seasonal trend with peaks during the summmer months and troughs during the winter months. Evidence of seasonality in the data is also seen in the 6-month moving average (Figure F-27). However, the 12-month moving average (Figure F-28) suggests that the mean of the series is fairly constant over the latter years and appears to exhibit a slight downtrend.

c. Autocorrelation function analysis (Figures F-29 and F-30) confirms the existence of seasonality in the data as manifested by the significant autocorrelation coefficient at lags 12 and 24. The series was differenced at a lag of 12 months to eliminate the seasonality and achieve stationary data. The plot of the seasonally adjusted series is depicted in Figure F-31. Autocorrelation and partial autocorrelation function analysis of the data (Figures F-32 and F-33) indicate that stationarity has been achieved.

d. Analysis of Figures F-32 and F-33 suggest that the data be modeled with a seasonal and nonseasonal model. In contrast to all of the other models, the seasonal model for HHG was AR in nature. This was discovered after comparing the results of AR and MA seasonal models. The nonseasonal model was identified as an MA process. The resulting model was a nonseasonal ARIMA (0,0,1) model and a seasonal ARIMA (1,1,0) model:

$$(1-\phi_{12}B^{12})(1-B^{12})X_t = \mu + (1-\theta_4 B^4)\epsilon_t$$

The nonseasonal model was built with only one parameter rather than four since the first three coefficients lacked any statistical significance. Also, the mean of the seasonally adjusted series was significant at the 6 percent significance level.

e. The results of the model (Figure F-34) were as follows:

$$(1+\underset{(-2.33)}{.3198}B^{12})(1-B^{12})X_t = \underset{(-3.67)}{-1.163} + (1-\underset{(1.88)}{.3397}B^4)\epsilon_t$$

$$\chi^2(2,20) = 6.26$$

All of the estimated parameters except θ_4, are significant at the 5 percent significance level. θ_4 is significant at the 7 percent significance level. Verification of the model's adequacy, using the Box-Pierce test with 20 degrees of freedom, indicates that the null hypothesis (uncorrelated residuals) should not be rejected at the .5 percent significance level (Figure F-35).

f. This model forecasted FY 82 HHG shipments to be 80.2 K/MTON versus an actual lift of 87.7 K/MTON (Figure F-36). The MSE of the HHG forecast was 5.24 percent, and the annual forecast error was -8.5 percent.

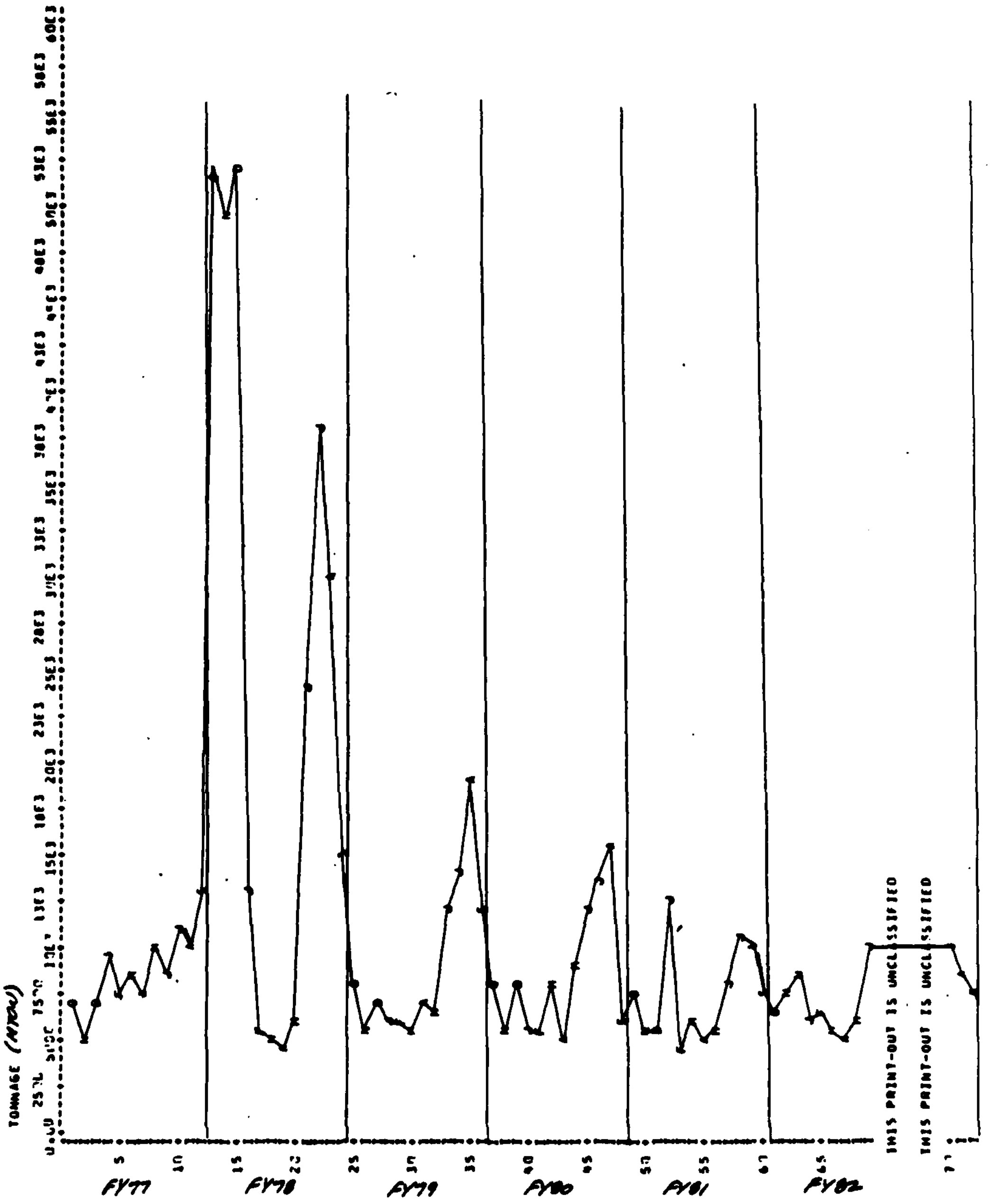
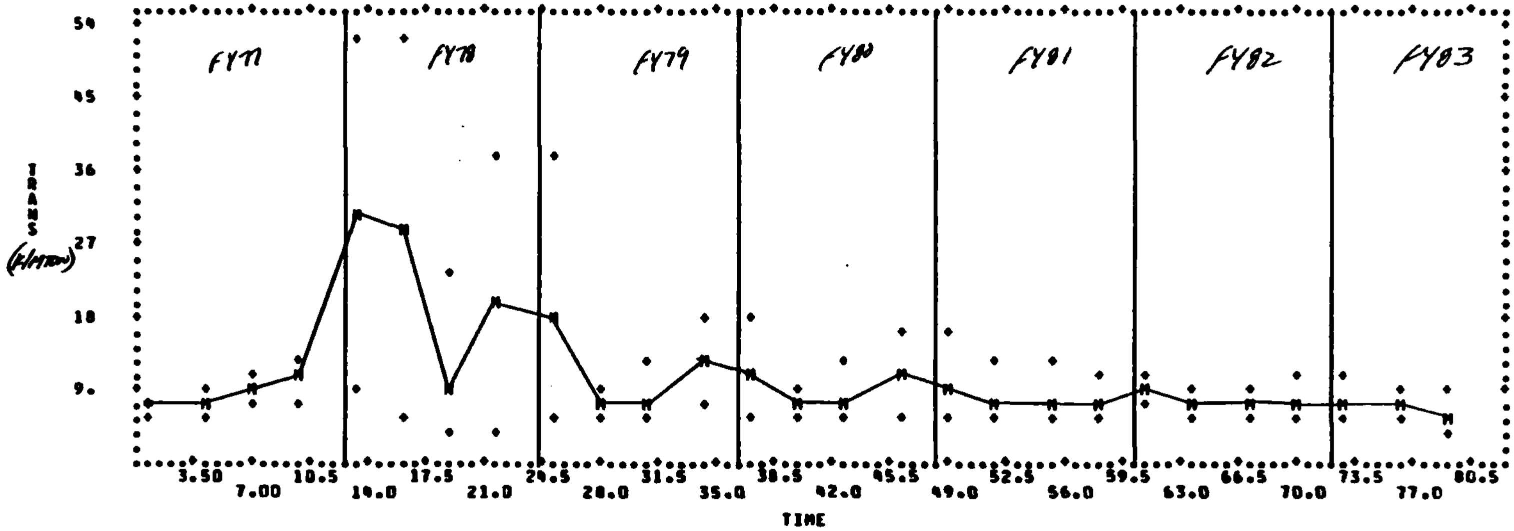
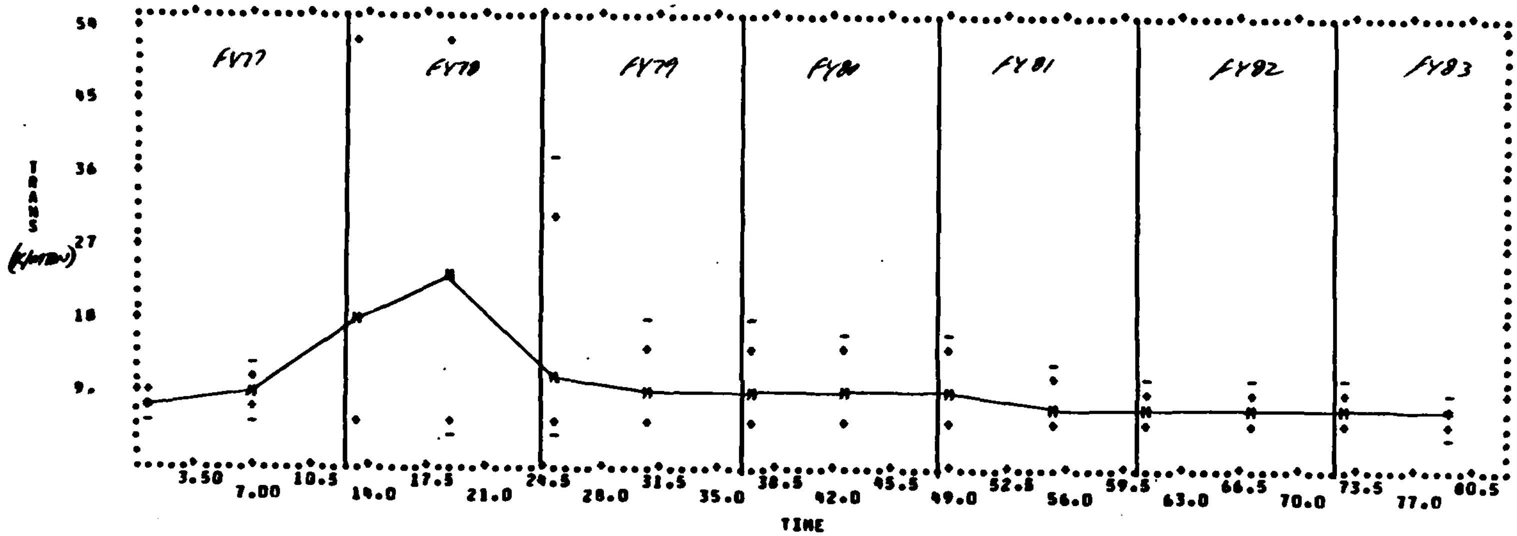


Figure F-26. HHG Cargo, FY 77 - FY 82



```
TIME      NO. OF    MINIMUM              MAXIMUM

VALUE     CASES      VALUE      MEAN      VALUE
    1.000     3      5.1816    6.3153    6.9211
    4.000     6      5.1816    7.3615    9.3560
    7.000     6      7.3250    8.5309   10.1200
   10.000     6      7.3250    9.9759   12.9220
   13.000     6      9.7649   31.1989   52.1626
   16.000     6      5.1419   29.4756   52.1626
   19.000     6      4.3554    9.6767   24.2233
   22.000     6      4.3554   19.6088   38.0300
   25.000     6      5.4447   17.3077   38.0300
   28.000     6      5.4447    6.3725    8.2499
   31.000     6      5.7186    7.2049   11.9687
   34.000     6      6.4772   11.7178   18.8700
   37.000     6      5.6587   11.0194   18.8700
   40.000     6      5.6182    6.8260    8.1032
   43.000     6      5.1063    7.5957   12.1877
   46.000     6      5.1063   10.1717   15.4558
   49.000     6      5.4258    8.8620   15.4558
   52.000     6      4.6769    6.8971   12.3594
   55.000     6      4.6769    6.9499   12.3594
   58.000     6      5.0922    7.7140   10.3262
   61.000     6      6.4012    8.3673   10.3262
   64.000     6      5.4337    6.7722    8.7323
   67.000     6      4.9882    6.5312    9.8193
   70.000     6      4.9882    7.8408   10.1794
   73.000     6      6.1419    7.4792   10.1794
   76.000     6      5.4582    6.6319    8.3686
   79.000     6      3.5728    6.1979    8.3686
```

Figure F-27. Six-month Moving Average - HHG



TIME VALUE	NO. OF CASES	MINIMUM VALUE	TRIMMED MINIMUM	TRIMMED MEAN	TRIMMED MAXIMUM	MAXIMUM VALUE
1.000	6	5.1816	6.8930	7.9078	8.2850	9.3560
7.000	12	3.1816	6.8930	8.5917	11.2028	12.9220
13.000	12	5.1419	5.2616	17.9401	51.5044	52.1626
19.000	12	4.3554	5.1419	23.7988	51.5044	52.1626
25.000	12	4.3554	5.4447	11.3502	30.1360	38.0300
31.000	12	5.4447	5.7186	8.4227	13.7883	18.8700
37.000	12	5.6182	5.6587	8.6775	13.7883	18.8700
43.000	12	5.1063	5.6182	8.1424	13.5642	15.4558
49.000	12	4.6769	5.1063	8.2280	13.5642	15.4558
55.000	12	4.6769	5.0922	7.0631	13.3262	12.3594
61.000	12	5.0922	5.3373	7.1499	9.8741	10.3262
67.000	12	4.9882	5.4337	7.2511	9.8193	10.1794
73.000	12	4.9882	5.4582	7.1669	9.8193	10.1794
79.000	9	3.5728	5.4582	6.3044	7.0796	8.3686

Figure F-28. Twelve-month Moving Average - HHG

```
AUTOCORRELATIONS

  1- 12      .54   .24  -.14  -.30  -.29  -.38  -.30  -.31  -.21   .12   .31   .51
   ST.E.     .17   .21   .22   .22   .23   .24   .26   .27   .28   .28   .28   .29

 13- 24      .26   .09  -.11  -.18  -.15  -.22  -.21  -.19  -.16   .02   .15   .26
   ST.E.     .31   .32   .32   .32   .33   .33   .33   .33   .34   .34   .34   .34

 25- 33      .16   .10   .03   .02  -.02  -.02  -.04  -.03  -.04
   ST.E.     .35   .35   .35   .35   .35   .35   .35   .35   .35

PLOT OF AUTOCORRELATIONS

             -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG     CORR.  +----+----+----+----+----+----+----+----+----+----+
                                        I
  1      .537                   +       IXXXXXXX+XXXXX
  2      .237                 +         IXXXXXX   +
  3     -.135                +       XXXI          +
  4     -.305                +  XXXXXXXXI          +
  5     -.288                +   XXXXXXXI          +
  6     -.376               +  XXXXXXXXXI           +
  7     -.305              +    XXXXXXXXI            +
  8     -.309              +    XXXXXXXXI            +
  9     -.213             +        XXXXXI             +
 10      .116             +             IXXX          +
 11      .313             +             IXXXXXXXX     +
 12      .509             +             IXXXXXXXXXXXXX+
 13      .258            +              IXXXXXX        +
 14      .086           +               IXX             +
 15     -.111           +            XXXI               +
 16     -.179           +           XXXXI               +
 17     -.147           +           XXXXI               +
 18     -.221           +         XXXXXXI               +
 19     -.205           +          XXXXXI               +
 20     -.188           +          XXXXXI               +
 21     -.160          +            XXXXI                +
 22      .018          +                I                +
 23      .150          +                IXXXX            +
 24      .257          +                IXXXXXX          +
 25      .158          +                IXXXX            +
 26      .097          +                IXX              +
 27      .027          +                IX               +
 28      .017          +                I                +
 29     -.017          +                I                +
 30     -.021          +               XI                +
 31     -.036          +               XI                +
 32     -.028          +               XI                +
 33     -.040          +               XI                +
```

std error $= \frac{1}{\sqrt{36}} (1.96)$

$= .326$

Figure F-29. ACF - Raw Data - HHG

```
PARTIAL AUTOCORRELATIONS

  1- 12      .54 -.07 -.33 -.13  .02 -.32 -.13 -.20 -.19  .24  .09  .10
  ST.E.      .17  .17  .17  .17  .17  .17  .17  .17  .17  .17  .17  .17

 13- 24     -.28 -.02 -.07  .01 -.04 -.12 -.05  .03 -.19 -.19  .01 -.09
  ST.E.      .17  .17  .17  .17  .17  .17  .17  .17  .17  .17  .17  .17

 25- 33     -.10  0.0 -.09 -.05 -.08  .03 -.03  .08 -.01
  ST.E.      .17  .17  .17  .17  .17  .17  .17  .17  .17

PLOT OF PARTIAL AUTOCORRELATIONS

            -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR.  +----+----+----+----+----+----+----+----+----+----+
                                      I
  1     .537                  +       IXXXXXXX+XXXXX
  2    -.071                  +     XXI       +
  3    -.329                  XXXXXXXXI       +
  4    -.129                  +    XXXI       +
  5     .024                  +       IX      +
  6    -.325                  XXXXXXXXI       +
  7    -.129                  +    XXXI       +
  8    -.196                  +  XXXXXI       +
  9    -.189                  +  XXXXXI       +
 10     .243                  +       IXXXXXX +
 11     .086                  +       IXX     +
 12     .100                  +       IXX     +
 13    -.282                  +XXXXXXXI       +
 14    -.020                  +       I       +
 15    -.070                  +     XXI       +
 16     .014                  +       I       +
 17    -.040                  +      XI       +
 18    -.117                  +    XXXI       +
 19    -.054                  +      XI       +
 20     .029                  +       IX      +
 21    -.195                  +  XXXXXI       +
 22    -.192                  +  XXXXXI       +
 23     .013                  +       I       +
 24    -.092                  +     XXI       +
 25    -.097                  +     XXI       +
 26     .001                  +       I       +
 27    -.090                  +     XXI       +
 28    -.047                  +      XI       +
 29    -.076                  +     XXI       +
 30     .032                  +       IX      +
 31    -.031                  +      XI       +
 32     .080                  +       IXX     +
 33    -.005                  +       I       +
```

Figure F-30. PACF - Raw Data - HHG

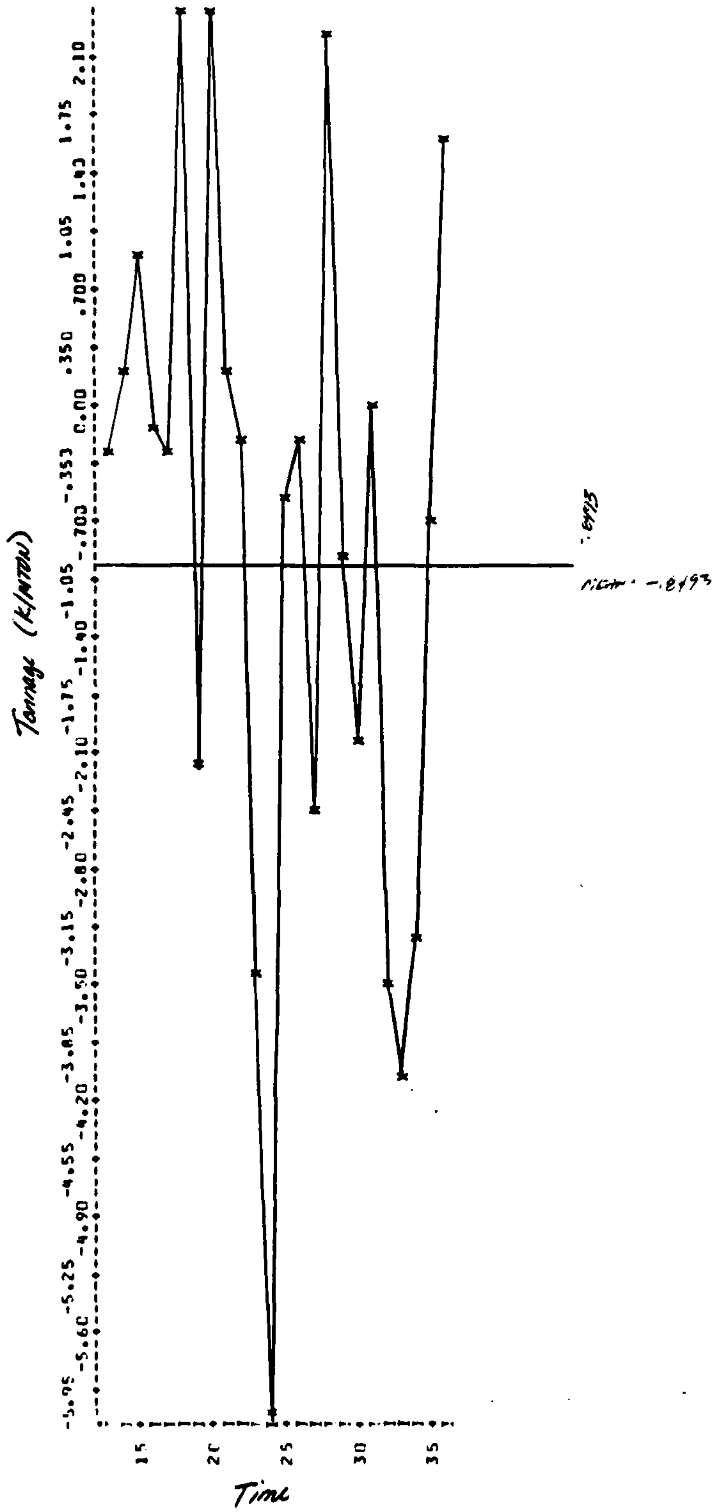


Figure F-31. Differenced Series (12-month lag) - HHG

```
AUTOCORRELATIONS

 1- 12        .18  .03  .02 -.30 -.05 -.11 -.02  .22 -.02  .20  .04 -.29
 ST.E.        .20  .21  .21  .21  .23  .23  .23  .23  .24  .24  .25  .25

 13- 22      -.09 -.08 -.05 -.03 -.10 -.01 -.07 -.02  .03  .03
 ST.E.        .26  .26  .26  .26  .26  .26  .26  .27  .27  .27

PLOT OF AUTOCORRELATIONS

               -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG    CORR.     +----+----+----+----+----+----+----+----+----+----+
                                          I
  1    .177                      +         IXXXX     +
  2    .034                      +         IX        +
  3    .020                      +         I         +
  4   -.302                      + XXXXXXXXI         +
  5   -.046                     +         XI          +
  6   -.110                     +       XXXI          +
  7   -.022                     +         XI          +
  8    .219                     +          IXXXXX     +
  9   -.020                    +           I           +
 10    .196                    +           IXXXXX      +
 11    .040                    +           IX          +
 12   -.293                    +    XXXXXXXI           +
 13   -.089                   +          XXI            +
 14   -.080                   +          XXI            +
 15   -.051                   +           XI            +
 16   -.032                   +           XI            +
 17   -.100                   +          XXI            +
 18   -.014                   +            I            +
 19   -.071                   +          XXI            +
 20   -.022                   +           XI            +
 21    .029                   +            IX           +
 22    .025                   +            IX           +
```

std error

$= \frac{1}{\sqrt{24}}(1.96)$

$= .400$

Figure F-32. ACF - Lagged 12 Months

```
PARTIAL AUTOCORRELATIONS

 1- 12       .18  0.0  .01 -.32  .07 -.12  .06  .13 -.08  .18 -.07 -.23
 ST.E.       .20  .20  .20  .20  .20  .20  .20  .20  .20  .20  .20  .20

13- 22      -.05  .10 -.05 -.18 -.08 -.10 -.07  .02 -.05  .10
 ST.E.       .20  .20  .20  .20  .20  .20  .20  .20  .20  .20

PLOT OF PARTIAL AUTOCORRELATIONS

           -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG    CORR. +----+----+----+----+----+----+----+----+----+----+
                                      I
  1     .177                +         IXXXX     +
  2     .003                +         I         +
  3     .014                +         I         +
  4    -.318                + XXXXXXXXI         +
  5     .072                +         IXX       +
  6    -.121                +      XXXI         +
  7     .035                +         IX        +
  8     .134                +         IXXX      +
  9    -.080                +       XXI         +
 10     .184                +         IXXXXX    +
 11    -.068                +       XXI         +
 12    -.227                +   XXXXXXI         +
 13    -.048                +        XI         +
 14     .097                +         IXX       +
 15    -.048                +        XI         +
 16    -.181                +    XXXXXI         +
 17    -.078                +       XXI         +
 18    -.103                +      XXXI         +
 19    -.065                +       XXI         +
 20     .022                +         IX        +
 21    -.051                +        XI         +
 22     .098                +         IXX       +
```

Figure F-33. PCAF - Lagged 12 Months

```
ESTIMATION BY BACKCASTING METHOD
RELATIVE CHANGE IN RESIDUAL SUM OF SQUARES LESS THAN  .1000-004


SUMMARY OF THE MODEL

OUTPUT VARIABLE -- TRANS
INPUT VARIABLES -- NOISE

VARIABLE  VAR. TYPE  MEAN      TIME     DIFFERENCES
                                            12
TRANS       RANDOM            1-  36  (1-B  )

PARAMETER VARIABLE    TYPE  FACTOR  ORDER ESTIMATE        ST. ERR.  T-RATIO
      1   TRANS        MA     1       4      .3397          .1811      1.86
      2   TRANS        AR     1      12    -.3198          .1371     -2.33
      3   TRANS       TRND    1       0    -1.163          .3173     -3.67

RESIDUAL SUM OF SQUARES   =        24.269138 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM        =                9
RESIDUAL MEAN SQUARE      =         2.696571
```

Figure F-34. Model Parameters - HHG

```
AUTOCORRELATIONS

  1- 12     .16  .03 -.02 -.02 -.10 -.13 -.10  .10 -.09  .15 -.02 -.10
 ST.E.      .17  .17  .17  .17  .17  .17  .18  .18  .18  .18  .18  .18

 13- 24    -.12 -.10 -.14 -.05 -.02 -.05 -.10 -.01  .02  0.0  .02  .02
 ST.E.      .18  .19  .19  .19  .19  .19  .19  .19  .19  .19  .19  .19

 25- 33     0.0  .03  .05  .03  .01  .01  .01  0.0  0.0
 ST.E.      .19  .19  .19  .19  .19  .19  .19  .19  .19

PLOT OF AUTOCORRELATIONS

              -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG      CORR.  +----+----+----+----+----+----+----+----+----+----+
                                         I
  1       .163                   +       IXXXX   +
  2       .031                   +       IX      +
  3      -.016                   +       I       +
  4      -.018                   +       I       +
  5      -.102                   +    XXXI       +
  6      -.132                   +    XXXI       +
  7      -.096                  +      XXI        +
  8       .099                  +        IXX      +
  9      -.088                  +      XXI        +
 10       .147                  +        IXXXX    +
 11      -.019                  +        I        +
 12      -.097                  +      XXI        +
 13      -.122                  +     XXXI        +
 14      -.097                  +      XXI        +
 15      -.138                  +     XXXI        +
 16      -.045                  +       XI        +
 17      -.022                  +       XI        +
 18      -.050                  +       XI        +
 19      -.105                  +     XXXI        +
 20      -.014                  +        I        +
 21       .018                  +        I        +
 22       .003 (.173)36=6.26    +        I        +
 23       .022                  +        IX       +
 24       .024                  +        IX       +
 25       .005                  +        I        +
 26       .035                  +        IX       +
 27       .050                  +        IX       +
 28       .032                 +         IX        +
 29       .009                 +         I         +
 30       .012                 +         I         +
 31       .013                 +         I         +
 32       .003                 +         I         +
 33      -.003                 +         I         +
```

Figure F-35. Estimated Residuals - HHG

```
 FORECAST ON VARIABLE TRANS     FROM TIME PERIOD      37
PERIOD              FORECASTS         ST.  ERR.     ACTUAL       ERROR
  37                 7.32353          1.71159        6.401        -.922
  38                 5.03787          1.71159        7.368        2.33
  39                 5.27541          1.71159        8.732        3.456
  40                 5.86943          1.71159        6.216         .346
  41                 3.81461          1.80766        6.482        2.667
  42                 5.56495          1.80766        5.434        -.131
  43                 3.93335          1.80766        4.988        1.055
  44                 5.29067          1.80766        6.247         .956
  45                 8.27946          1.80766        9.819        1.539
  46                10.19849          1.80766       10.179        -.019
  47                13.80086          1.80766        8.308       -5.492
  48                 5.82243          1.80766        7.503        1.681
STANDARD ERROR =  1.71159        (BY CONDITIONAL METHOD   )

                    80.19                          87.68      MSE = 5.24
```

Figure F-36. Forecast FY 82 - HHG

F-5. COAL

a. The raw series for commodity coal is depicted in Figure F-37. The raw data do not depict a recurring pattern or seasonal trend. Examination of the 3-month and 6-month moving average diagrams (Figures F-38 and F-39) affirms the absence of a predictable pattern. The 12-month moving average diagram (Figure F-40) suggests the possibility of a 5-year cycle; however, there is not enough data to verify this hypothesis.

b. Autocorrelation function analysis of the data confirms the absence of seasonality in the data (see Figures F-41 and F-42). However, the autocorrelation function of the raw series indicates that a trend does exist in the data and that stationarity is not present. To achieve stationarity, the raw series was differenced at a lag of one month. The plot of the differenced series is illustrated in Figure F-43. Figures F-44 and F-45 depict the autocorrelation and partial autocorrelation functions of the differenced series. These functions as well as a visual examination of the plot of the differenced series indicate the existence of stationary data.

c. The autocorrelation and partial autocorrelation functions of the differenced series suggest that the data could be modeled using an ARIMA (0,1,1) process. Only the first lag of the autocorrelation function is significant, and the remaining coefficients are distributed randomly within the 95 percent confidence interval. The partial autocorrelations decay exponentially to zero as the lags increase. Besides an ARIMA (0,1,1) model, the data could also be modeled using an ARIMA (1,1,1) model. Thus, the appropriate models are:

$$(1 - B)\, X_t = (1 - \theta_1)\epsilon_t$$

or

$$(1 - \phi_1 B)\,(1 - B)\, X_t = (1 - \theta_1)\epsilon_t$$

d. Test of both models indicated that the ARIMA (1,1,1) model was the most appropriate model. Thus, the resulting forecast model (Figure 6-46) is:

$$\underset{(9.46)}{(1 - .3461B)}\,(1 - B)\, X_t = \underset{(2.06)}{(1 - .859B)}\epsilon_t$$

$$x^2\ (2,20) = 10.87$$

e. All of the estimated parameters were significant at the 5 percent significance level. The model was verified using the Box-Pierce test and a visual examination of the estimated residuals of the model. The Q statistic test is 10.87, which indicates that the null hypothesis, uncorrelated residuals, should not be rejected at the 5 percent significance level (Figure F-47). Also, all of the estimated residuals fall within the 95 percent confidence interval and do not depict any noticeable trend or pattern.

f. The ARIMA (1,1,1) model forecasted the FY 82 coal tonnage shipped to be 406.51 K/MTON (Figure F-48) as compared to the historical FY 82 lift of 375.94 K/MTON and the actual FY 82 DLA coal contract of 440.67 K/MTON. The MSE of the coal forecast was 192.60, and the annual forecast error was -.6 percent (actual FY 82) and 15.2 percent (DLA).

g. As discussed earlier, several external factors have affected coal shipments during October 1977 to September 1981. A close examination of the raw data indicates that contract negotiation delays have seriously affected coal shipments and that a detailed adjustment of coal data is needed to develop an accurate forecasting model. The need for data adjustment is clearly identified by the large outlier observations contained in the differenced series (Figure F-43).

h. In particular, the data point for April 1980 is a large outlier that affects the model-building process. The observation for April 1980 was adjusted to the average shipment for April during the 5-year period. The autocorrelation and partial autocorrelation functions (Figures F-49 and F-50) of the adjusted series again depict a trend in the data. Also, it should be noted that almost all of the autocorrelation coefficients for the adjusted data are greater than the autocorrelation coefficients for the original series (Figure F-41). Thus, the data are very sensitive to data manipulation, and further data adjustments should be done with extreme caution.

i. The differenced adjusted series is illustrated in Figure F-51. The autocorrelation and partial autocorrelation functions (Figures F-52 and F-53) indicate the existence of weak stationarity in the data. Again, it should be noted that although the autocorrelation function of the differenced adjusted series indicates a possible ARIMA (1,1,1) model, the function varies from the differenced unadjusted series. In particular, lags 10, 17, and 24 are more significant than before. This would suggest that additional parameters need to be added to the original model. To retain some parsimony in the model only one parameter was added. The form of the model is:

$$(1 - \phi_1 B)(1 - B) X_t = (1 - \theta_1 B - \theta_{10} B^{10})\epsilon_t$$

j. The results of the model (Figure F-54) are as follows:

$$\begin{array}{c} (1 - \underset{(1.46)}{.2168}B)(1 - B) X_t = (1 - \underset{(9.69)}{.7693}B + \underset{(-3.8)}{.2705}B^{10})\epsilon_t \\ \chi^2 (3,20) = 10.51 \end{array}$$

All of the estimated parameters are significant at the 5 percent significance level except $_1$. The Q statistic indicates a good fit for the model, thus the null hypothesis should not be rejected at the 5 percent significance level (Figure F-55). It should be noted that the "goodness of fit" test accounts for the significant residual coefficient at lag 17. Attempts to reduce the significance of this coefficient added further complication and restriction to the original model. Also, until all of the data are adjusted correctly, additional modifications to the original model should not be attempted.

k. The adjusted model forecasted that 398.80 K/MTON of coal would be shipped during FY 82 (Figure 6-56) which corresponds to an annual forecast error of 6.1 percent.

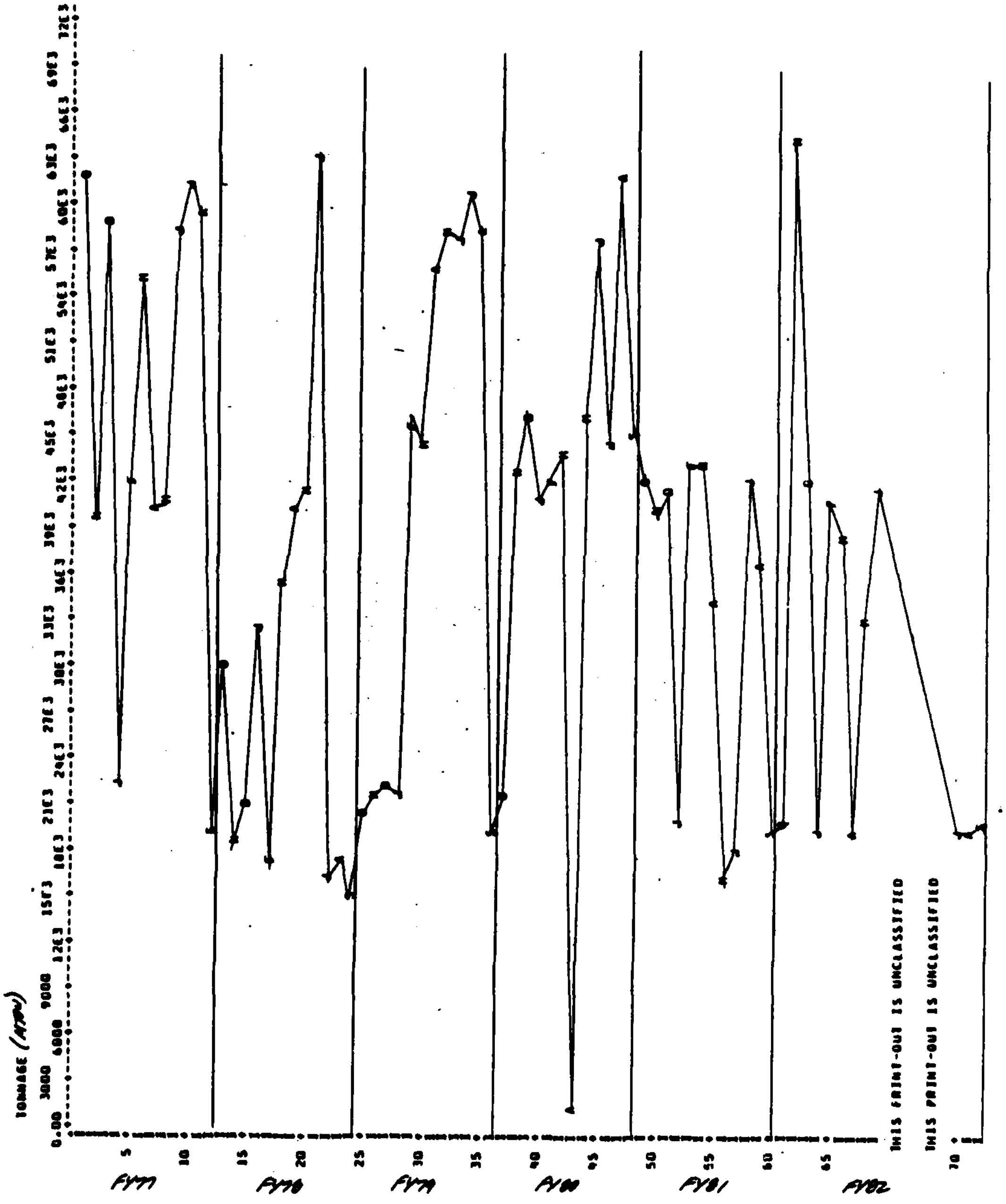
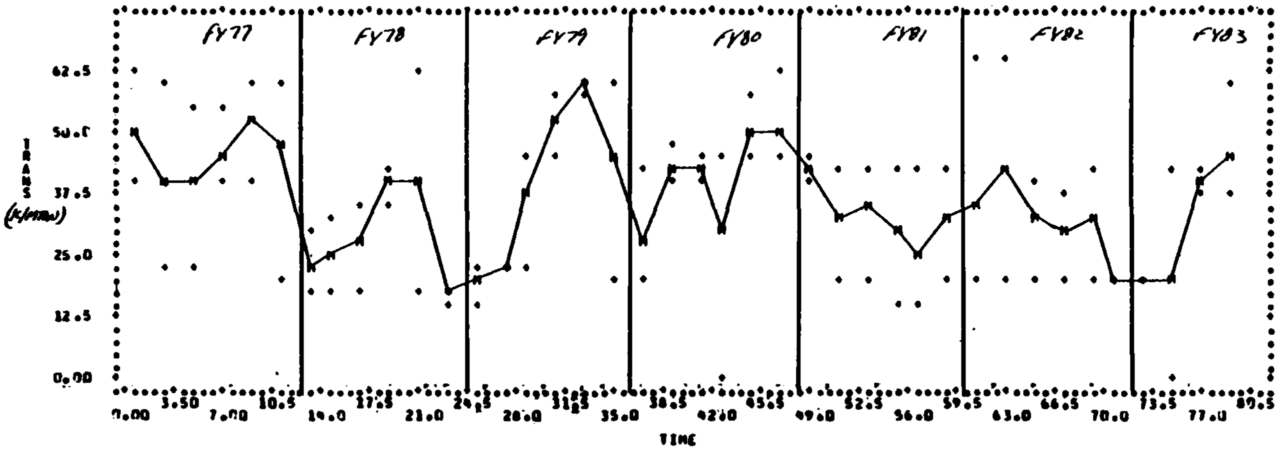
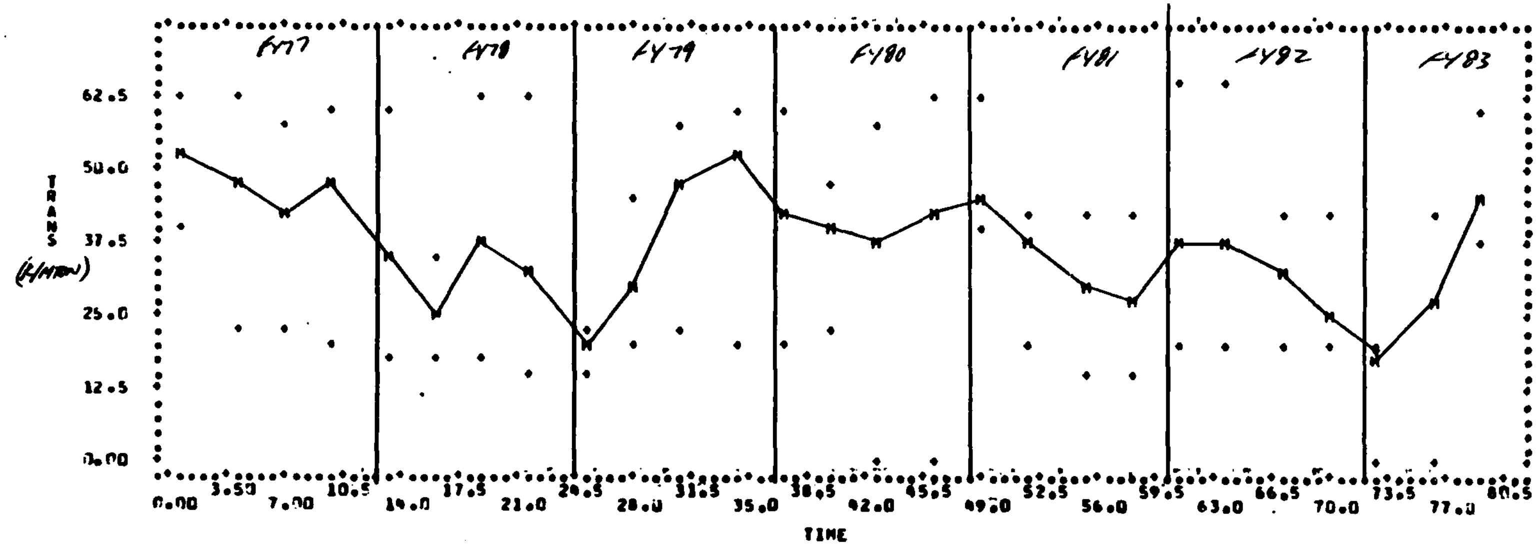


Figure F-37. Coal Cargo FY 77 - FY 82



```
TIME       NO. OF     MINIMUM              MAXIMUM
VALUE      CASES       VALUE      MEAN      VALUE
  1.000       2       39.8610   50.8050   61.7490
  3.000       3       21.9340   40.2610   58.9880
  5.000       3       21.9340   39.8030   55.2310
  7.000       3       39.9026   45.2670   55.2310
  9.000       3       40.6680   53.1987   60.9250
 11.000       3       19.3400   46.9650   60.9250
 13.000       3       18.5990   22.7353   30.2670
 15.000       3       18.5990   24.0047   32.4460
 17.000       3       17.5330   28.4610   35.4080
 19.000       3       35.4080   39.0213   41.3010
 21.000       3       16.9730   40.3123   61.1920
 23.000       3       14.7770   16.2653   17.5960
 25.000       3       14.7770   18.8663   21.3120
 27.000       3       21.3720   21.6097   22.1160
 29.000       3       21.5210   37.3509   45.8590
 31.000       3       44.6727   52.7742   58.0266
 33.000       3       57.4627   58.7799   60.8510
 35.000       3       19.4920   46.1277   60.8510
 37.000       3       19.4920   27.9390   42.7610
 39.000       3       40.7350   43.2537   46.2650
 41.000       3       40.7350   42.1895   43.8664
 43.000       3         .9120   30.3754   46.1370
 45.000       3       44.2760   49.3081   57.7554
 47.000       3       44.2760   50.3327   61.9430
 49.000       3       39.9990   42.1693   44.7790
 51.000       3       19.6390   33.7220   41.5780
 53.000       3       19.6390   35.2077   41.0597
 55.000       3       16.0470   31.1356   43.0597
 57.000       3       16.0470   25.3817   42.1530
 59.000       3       19.2550   32.6327   42.1530
 61.000       3       19.2550   34.4197   44.1160
 63.000       3       19.0280   41.6430   64.1160
 65.000       3       19.0280   32.6970   43.9160
 67.000       3       19.1970   30.1430   38.1970
 69.000       3       19.1030   31.2517   41.5670
 71.000       3       19.1030   19.4167   19.7120
 73.000       3       18.0580   19.7843   20.7850
 75.000       3         .0037   27.9736   42.7340
 77.000       3       37.1960   40.6800   42.0170
 79.000       3       37.1960   46.2174   59.3840
```

Figure F-38. Three-month Moving Average - Coal



```
TIME       NO. OF     MINIMUM               MAXIMUM

VALUE      CASES       VALUE      MEAN       VALUE
   1.000       3      39.8610   53.5327    61.7490
   4.000       6      21.9340   46.6678    61.7490
   7.000       6      21.9340   42.9970    58.0030
  10.000       6      19.3400   46.3280    60.9250
  13.000       6      18.5990   34.8713    60.9250
  16.000       6      17.5330   25.8703    35.4080
  19.000       6      17.5330   38.3645    63.1920
  22.000       6      14.7770   32.2657    63.1920
  25.000       6      14.7770   18.7997    22.1760
  28.000       6      20.4530   29.3418    45.8590
  31.000       6      21.5210   47.1941    58.0266
  34.000       6      19.4920   51.5825    60.8510
  37.000       6      19.4920   41.4955    60.8510
  40.000       6      21.5640   39.5264    46.2650
  43.000       6        .9120   38.5614    57.7574
  46.000       6        .9120   42.6330    61.9430
  49.000       6      39.9490   45.7175    61.9430
  52.000       6      19.6390   38.1550    43.0597
  55.000       6      16.0400   28.9870    43.0597
  58.000       6      16.0470   27.6995    42.1530
  61.000       6      19.2550   37.2797    64.1160
  64.000       6      19.0280   37.3118    64.1160
  67.000       6      19.0280   31.9930    41.5670
  70.000       6      19.1030   25.3448    41.5670
  73.000       6        .0037   16.3108    20.7810
  76.000       6        .0037   26.9475    42.8100
  79.000       5      37.0960   44.7192    59.3840
```

Figure F-39. Six-month Moving Average - Coal

```
TIME      NO. OF    MINIMUM    TRIMMED    TRIMMED    TRIMMED    MAXIMUM
VALUE     CASES      VALUE     MINIMUM     MEAN      MAXIMUM     VALUE
   1.000     6      21.9340    39.8610    49.0810    58.9880    61.7490
   7.000    12      19.3400    21.9340    47.6886    60.9250    61.7490
  13.000    12      17.5330    18.5990    35.4732    59.1300    60.9250
  19.000    12      14.7770    16.4230    27.0897    41.3810    63.1420
  25.000    12      14.7770    16.4230    29.1726    45.8590    63.1420
  31.000    12      19.4920    20.4530    40.5203    58.0400    60.8510
  37.000    12      19.4920    21.5640    46.6310    58.0400    60.8510
  43.000    12        .9120    21.5640    43.0102    57.7504    61.9430
  49.000    12        .9120    19.6390    42.1873    57.7504    61.9430
  55.000    12      16.0400    17.9520    33.6027    42.9244    43.0597
  61.000    12      16.0400    17.9520    30.9912    42.1530    64.1160
  67.000    12      19.0280    19.1030    29.2796    41.7760    64.1160
  73.000    12        .0037    18.8580    27.0940    42.1340    42.8100
  79.000     8        .0037    18.8580    33.9755    42.8100    59.3840
```

Figure F-40. Twelve-month Moving Average - Coal

```
AUTOCORRELATIONS

  1- 12     .34  .16  .07 -.07 -.07 -.14 -.15 -.06 -.06  .06 -.05  0.0
  ST.E.     .13  .14  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15

 13- 24     .08  .02 -.06 -.15 -.22 -.13 -.09  0.0 -.11 -.21 -.08  .04
  ST.E.     .15  .15  .15  .15  .16  .16  .16  .16  .16  .17  .17  .17

 25- 36    -.10 -.01 -.09  .06  .12  .04  .03  .06  .02  .03  .01  .03
  ST.E.     .17  .17  .17  .17  .17  .17  .17  .18  .18  .18  .18  .18

PLOT OF AUTOCORRELATIONS

              -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG      CORR.  +----+----+----+----+----+----+----+----+----+----+
                                         I
  1       .341                     +     IXXXXX+XXX
  2       .156                    +      IXXXX  +
  3       .069                    +      IXX    +
  4      -.065                    +    XXI      +
  5      -.069                    +    XXI      +
  6      -.140                    +  XXXXI      +
  7      -.150                    +  XXXXI      +
  8      -.060                    +     XI      +
  9      -.059                    +     XI      +
 10       .057                   +       IX      +
 11      -.051                   +      XI       +
 12       .005                   +       I       +
 13       .076                   +       IXX     +
 14       .021                   +       IX      +
 15      -.055                   +      XI       +
 16      -.148                   +   XXXXI       +
 17      -.223                   + XXXXXXI       +
 18      -.132                   +    XXXI       +
 19      -.068                   +     XXI       +
 20       .004                   +       I       +
 21      -.108                   +    XXXI       +
 22      -.214                   +  XXXXXI       +
 23      -.080                   +     XXI       +
 24       .039                   +       IX      +
 25      -.096                   +     XXI       +
 26      -.013                   +       I       +
 27      -.092                   +     XXI       +
 28       .057                   +       IX      +
 29       .120                   +       IXXX    +
 30       .035                  +        IX       +
 31       .029                  +        IX       +
 32       .061                  +        IXX      +
 33       .024                  +        IX       +
 34       .035                  +        IX       +
 35       .009                  +        I        +
 36       .026                  +        IX       +
```

std error

$= \frac{1}{\sqrt{60}} (1.96)$

$= .253$

Figure F-41. ACF - Raw Data - Coal

```
PARTIAL AUTOCORRELATIONS

  1- 12     .34  .05  0.0 -.11 -.02 -.11 -.07  .03 -.03  .09 -.13  .04
  ST.E.     .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 13- 24     .05 -.02 -.10 -.13 -.14 -.01  .01  .04 -.17 -.26 -.03  .11
  ST.E.     .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 25- 36    -.17 -.03 -.19  .06  .07 -.04 -.06 -.04 -.14 -.04  .11 -.02
  ST.E.     .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

PLOT OF PARTIAL AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1    .341                    +     IXXXXX+XXX
  2    .045                    +     IX    +
  3    .003                    +     I     +
  4   -.109                    +  XXXI     +
  5   -.023                    +    XI     +
  6   -.108                    +  XXXI     +
  7   -.067                    +   XXI     +
  8    .029                    +     IX    +
  9   -.030                    +    XI     +
 10    .086                    +     IXX   +
 11   -.126                    +  XXXI     +
 12    .036                    +     IX    +
 13    .054                    +     IX    +
 14   -.018                    +     I     +
 15   -.101                    +  XXXI     +
 16   -.126                    +  XXXI     +
 17   -.142                    + XXXXI     +
 18   -.011                    +     I     +
 19    .009                    +     I     +
 20    .043                    +     IX    +
 21   -.172                    + XXXXI     +
 22   -.258                    XXXXXXI     +
 23   -.033                    +    XI     +
 24    .108                    +     IXXX  +
 25   -.174                    + XXXXI     +
 26   -.030                    +    XI     +
 27   -.187                    +XXXXXI     +
 28    .057                    +     IX    +
 29    .066                    +     IXX   +
 30   -.040                    +    XI     +
 31   -.061                    +   XXI     +
 32   -.040                    +    XI     +
 33   -.144                    + XXXXI     +
 34   -.040                    +    XI     +
 35    .115                    +     IXXX  +
 36   -.022                    +    XI     +
```

Figure F-42. PACF - Raw Data - Codl

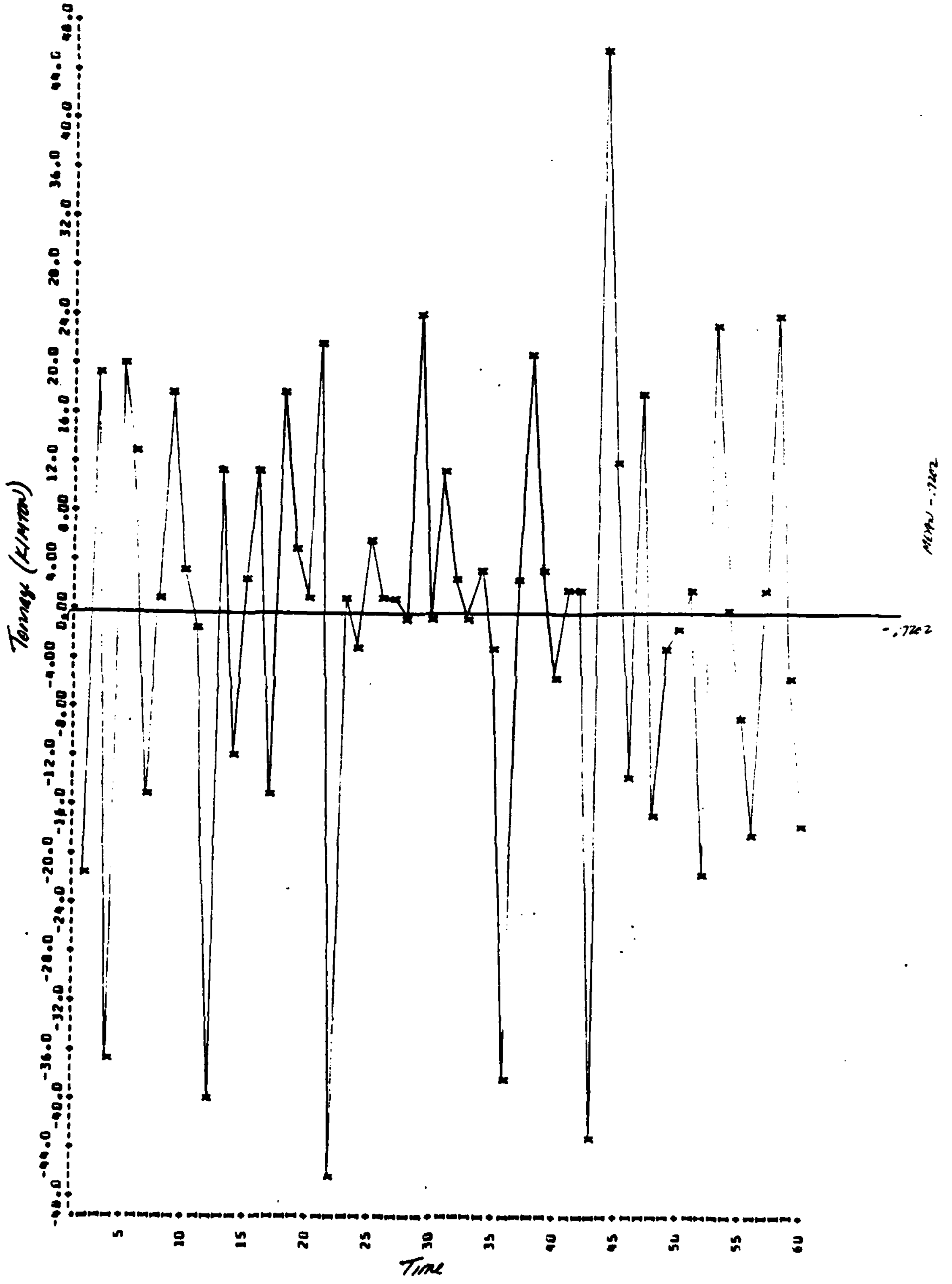


Figure F-43. Differenced Series (1-month lag) - Coal

```
AUTOCORRELATIONS

  1- 12     -.33 -.10  .06 -.13  .05 -.02 -.08  .02 -.07  .18 -.08 -.02
  ST.E.      .13  .14  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15

 13- 24      .14  0.0  .01 -.01 -.20  .08 -.04  .13  .06 -.19 -.01  .19
  ST.E.      .15  .16  .16  .16  .16  .16  .16  .16  .16  .16  .17  .17

 25- 36     -.14  .13 -.18  .04  .12 -.09 -.03  .03 -.04  .03  .01 -.02
  ST.E.      .17  .17  .17  .18  .18  .18  .18  .18  .18  .18  .18  .18

PLOT OF AUTOCORRELATIONS

             -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG    CORR.   +----+----+----+----+----+----+----+----+----+----+
                                        I
  1     -.333                  XX+XXXXXI     +
  2     -.097                   +    XXI      +
  3      .061                   +      IXX    +
  4     -.134                   +   XXXI      +
  5      .055                   +      IX     +
  6     -.021                   +     XI      +
  7     -.081                   +    XXI      +
  8      .024                   +      IX     +
  9     -.074                   +    XXI      +
 10      .178                   +      IXXXX  +
 11     -.076                   +    XXI      +
 12     -.024                  +      XI       +
 13      .136                  +       IXXX    +
 14     -.005                  +       I       +
 15      .013                  +       I       +
 16     -.005                  +       I       +
 17     -.204                  +  XXXXXI       +
 18      .075                  +       IXX     +
 19     -.042                  +      XI       +
 20      .132                  +       IXXX    +
 21      .060                  +       IXX     +
 22     -.195                  +  XXXXXI       +
 23     -.007                  +       I       +
 24      .193                  +       IXXXXX  +
 25     -.136                  +    XXXI       +
 26      .132                  +       IXXX    +
 27     -.184                 +   XXXXXI        +
 28      .038                 +        IX       +
 29      .117                 +        IXXX     +
 30     -.069                 +      XXI        +
 31     -.034                 +       XI        +
 32      .029                 +        IX       +
 33     -.044                 +       XI        +
 34      .030                 +        IX       +
 35      .014                 +        I        +
 36     -.020                 +       XI        +
```

std error

$= \frac{1}{\sqrt{59}} (1.96)$

$= .255$

Figure F-44. ACF - Lagged 1 Month

```
PARTIAL AUTOCORRELATIONS

  1- 12      -.33 -.23 -.07 -.19 -.08 -.09 -.16 -.13 -.21  .03 -.09 -.08
   ST.E.      .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 13- 24       .05  .11  .12  .11 -.11 -.04 -.09  .11  .19 -.04 -.18  .07
   ST.E.      .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 25- 36      -.07  .08 -.15 -.08  .05  .01 -.08  .02 -.09 -.23 -.06 -.07
   ST.E.      .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

PLOT OF PARTIAL AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1   -.333                  XX+XXXXXI     +
  2   -.234                    XXXXXXI     +
  3   -.068                    +   XXI     +
  4   -.166                    +XXXXXI     +
  5   -.076                    +   XXI     +
  6   -.094                    +   XXI     +
  7   -.156                    + XXXXI     +
  8   -.135                    +  XXXI     +
  9   -.212                    +XXXXXI     +
 10    .029                    +     IX    +
 11   -.067                    +   XXI     +
 12   -.083                    +   XXI     +
 13    .052                    +     IX    +
 14    .109                    +     IXXX  +
 15    .117                    +     IXXX  +
 16    .108                    +     IXXX  +
 17   -.109                    +  XXXI     +
 18   -.038                    +    XI     +
 19   -.090                    +   XXI     +
 20    .108                    +     IXXX  +
 21    .166                    +     IXXXXX+
 22   -.039                    +    XI     +
 23   -.178                    + XXXXI     +
 24    .074                    +     IXX   +
 25   -.069                    +   XXI     +
 26    .077                    +     IXX   +
 27   -.152                    + XXXXI     +
 28   -.085                    +   XXI     +
 29    .052                    +     IX    +
 30    .008                    +     I     +
 31   -.060                    +   XXI     +
 32    .017                    +     I     +
 33   -.093                    +   XXI     +
 34   -.231                    XXXXXXI     +
 35   -.057                    +    XI     +
 36   -.075                    +   XXI     +
```

Figure F-45. PACF - Lagged 1 Month

```
ESTIMATION BY BACKCASTING METHOD
RELATIVE CHANGE IN RESIDUAL SUM OF SQUARES LESS THAN  .1000-004

SUMMARY OF THE MODEL
OUTPUT VARIABLE -- TRANS
INPUT VARIABLES -- NOISE
VARIABLE  VAR. TYPE  MEAN       TIME     DIFFERENCES
                                                1
TRANS       RANDOM              1-  60  (1-B   )

PARAMETER VARIABLE   TYPE  FACTOR  ORDER ESTIMATE         ST. ERR.  T-RATIO
      1  TRANS        MA     1       1      .8590          .0908      9.46
      2  TRANS        AR     1       1      .3461          .1677      2.06

RESIDUAL SUM OF SQUARES  =      13820.113403 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM       =                56
RESIDUAL MEAN SQUARE     =        246.787739
```

Figure F-46. Model Parameters - Coal

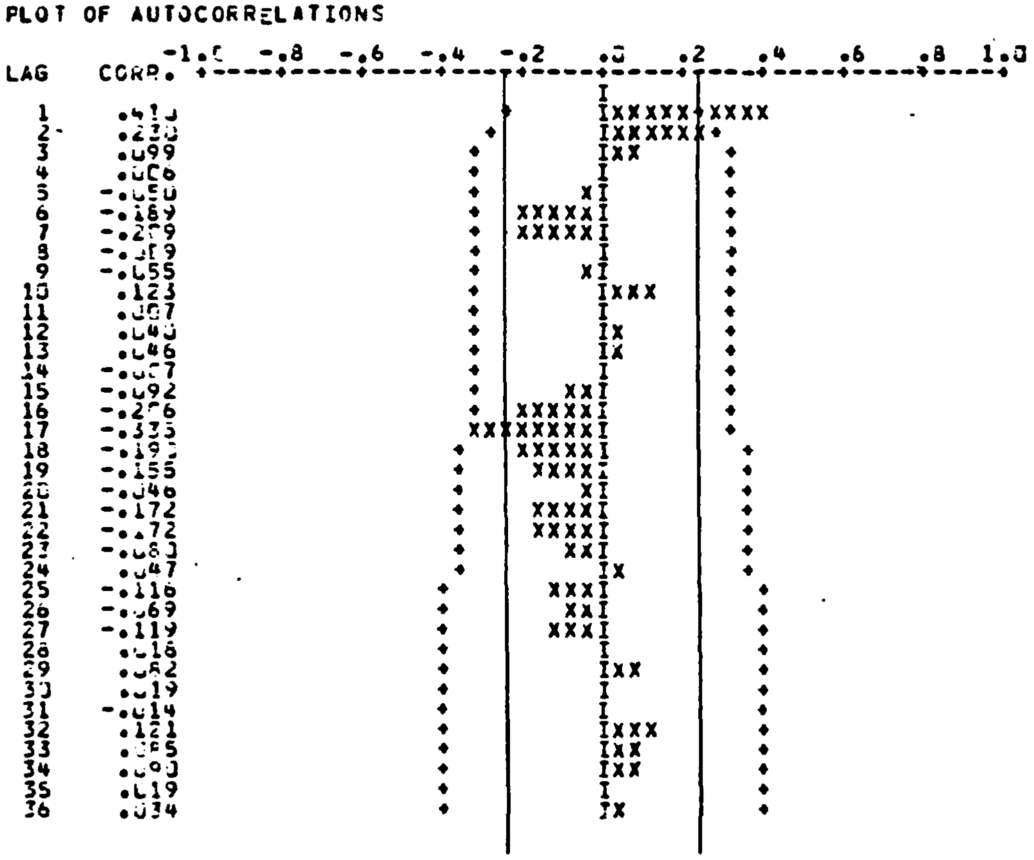
```
AUTOCORRELATIONS

  1- 12       -.03   0.0   .07  -.11  -.01  -.07  -.11   0.0  -.04   .17   0.0   .05
 ST.E.         .13   .13   .13   .13   .13   .13   .13   .13   .13   .13   .14   .14

 13- 24        .16   .05   0.0  -.05  -.21   0.0  -.04   .10   .03  -.18  -.02   .14
 ST.E.         .14   .14   .14   .14   .14   .15   .15   .15   .15   .15   .15   .15

 25- 36       -.12   .04  -.18  -.01   .06  -.10  -.07  -.01  -.06   .01   0.0  -.02
 ST.E.         .15   .16   .16   .16   .16   .16   .16   .16   .16   .16   .16   .16

PLOT OF AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1   -.029                    +    XI     +
  2   -.000                    +     I     +
  3    .065                    +     IXX   +
  4   -.113                    +  XXXI     +
  5   -.008                    +     I     +
  6   -.069                    +   XXI     +
  7   -.105                   +   XXXI      +
  8   -.002                   +      I      +
  9   -.038                   +     XI      +
 10    .172                   +      IXXXX  +
 11    .004                   +      I      +
 12    .046                   +      IX     +
 13    .163                   +      IXXXX  +
 14    .046                   +      IX     +
 15    .004                   +      I      +
 16   -.053                   +     XI      +
 17   -.205                   + XXXXXI      +
 18   -.005                   +      I      +
 19   -.043                   +     XI      +
 20    .098                   +      IXX    +
 21    .028                   +      IX     +
 22   -.178 .184(59) = 10.87  +  XXXXI      +
 23   -.020                   +     XI      +
 24    .136                   +      IXXX   +
 25   -.122                  +    XXXI       +
 26    .044                  +       IX      +
 27   -.184                  +  XXXXXI       +
 28   -.015                  +       I       +
 29    .055                  +       IX      +
 30   -.102                  +    XXXI       +
 31   -.072                  +     XXI       +
 32   -.011                  +       I       +
 33   -.056                  +      XI       +
 34    .005                  +       I       +
 35    .004                  +       I       +
 36   -.017                  +       I       +
```

Figure F-47. Estimated Residuals - Coal

```
FORECAST ON VARIABLE TRANS    FROM TIME PERIOD    61

PERIOD      FORECASTS      ST. ERR.      ACTUAL     ERROR
  61        27.37654       15.67752      19.888     -7.489
  62        30.18750       17.43874      64.116     33.928
  63        31.16040       18.10173      41.776     10.616
  64        31.49713       18.51520      19.028    -12.469
  65        31.61368       18.85389      40.916      9.302
  66        31.65401       19.16555      34.161      2.493
  67        31.66798       19.46520      19.197    -12.471
  68        31.67281       19.75793      33.085      1.412
  69        31.67448       20.04558      41.567      9.893
  70        31.67506       20.32888      19.103    -12.572
  71        31.67526       20.60620      19.405    -12.27
  72        31.67533       20.88374      19.712    -11.963
STANDARD ERROR =  15.6775     (BY CONDITIONAL METHOD  )

                 373.53                      375.94    MSE = 192.60
```

Figure F-48. Forecast FY 82 - Coal

```
AUTOCORRELATIONS

  1- 12       .41  .23  .10  .01 -.05 -.19 -.21 -.01 -.06  .12  .01  .04
  ST.E.       .13  .15  .16  .16  .16  .16  .16  .16  .16  .16  .17  .17

 13- 24       .05 -.01 -.09 -.21 -.34 -.19 -.16 -.05 -.17 -.17 -.08  .05
  ST.E.       .17  .17  .17  .17  .17  .18  .19  .19  .19  .19  .19  .19

 25- 36      -.12 -.07 -.12  .02  .08  .02 -.01  .12  .08  .09  .02  .03
  ST.E.       .19  .20  .20  .20  .20  .20  .20  .20  .20  .20  .20  .20
```



```
PLOT OF AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1    .410                    +     IXXXXX+XXXX
  2    .230                   +      IXXXXXX+
  3    .099                  +       IXX     +
  4    .006                  +       I       +
  5   -.050                  +      XI       +
  6   -.189                  +  XXXXXI       +
  7   -.209                  +  XXXXXI       +
  8   -.009                  +       I       +
  9   -.055                  +      XI       +
 10    .123                  +       IXXX    +
 11    .007                  +       I       +
 12    .040                  +       IX      +
 13    .046                  +       IX      +
 14   -.007                  +       I       +
 15   -.092                  +     XXI       +
 16   -.206                  +  XXXXXI       +
 17   -.335                  XXXXXXXXI       +
 18   -.190                 +   XXXXXI        +
 19   -.155                 +    XXXXI        +
 20   -.046                 +       XI        +
 21   -.172                 +    XXXXI        +
 22   -.172                 +    XXXXI        +
 23   -.083                 +      XXI        +
 24    .047                 +        IX       +
 25   -.116                +      XXXI         +
 26   -.069                +       XXI         +
 27   -.119                +      XXXI         +
 28    .018                +         I         +
 29    .082                +         IXX       +
 30    .019                +         I         +
 31   -.014                +         I         +
 32    .121                +         IXXX      +
 33    .085                +         IXX       +
 34    .090                +         IXX       +
 35    .019                +         I         +
 36    .034                +         IX        +
```

Figure F-49. ACF - Raw Data - Coal Adjusted

```
PARTIAL AUTOCORRELATIONS

  1- 12      .41  .07 -.02 -.05 -.05 -.17 -.08  .18 -.07  .18 -.13  .01
  ST.E.      .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 13- 24     -.03 -.01 -.09 -.16 -.19 -.01  .04  .02 -.22 -.19 -.08  .12
  ST.E.      .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 25- 36     -.19  0.0 -.16 -.02  .12 -.06 -.08  .01 -.08 -.12  .10 -.05
  ST.E.      .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

PLOT OF PARTIAL AUTOCORRELATIONS

            -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG     CORR. +----+----+----+----+----+----+----+----+----+----+
                                       I
  1      .410                    +     IXXXXX+XXXX
  2      .075                    +     IXX   +
  3     -.023                    +    XI     +
  4     -.050                    +    XI     +
  5     -.048                    +    XI     +
  6     -.174                    + XXXXI     +
  7     -.083                    +   XXI     +
  8      .184                    +     IXXXXX+
  9     -.074                    +   XXI     +
 10      .180                    +     IXXXX +
 11     -.133                    +  XXXI     +
 12      .014                    +     I     +
 13     -.026                    +    XI     +
 14     -.015                    +     I     +
 15     -.092                    +   XXI     +
 16     -.159                    + XXXXI     +
 17     -.187                    +XXXXXI     +
 18     -.007                    +     I     +
 19      .042                    +     IX    +
 20      .017                    +     I     +
 21     -.223                    XXXXXXI     +
 22     -.188                    +XXXXXI     +
 23     -.082                    +   XXI     +
 24      .115                    +     IXXX  +
 25     -.186                    +XXXXXI     +
 26      .001                    +     I     +
 27     -.158                    + XXXXI     +
 28     -.019                    +     I     +
 29      .118                    +     IXXX  +
 30     -.064                    +   XXI     +
 31     -.080                    +   XXI     +
 32      .008                    +     I     +
 33     -.077                    +   XXI     +
 34     -.118                    +  XXXI     +
 35      .101                    +     IXXX  +
 36     -.051                    +    XI     +
```

Figure F-50. PACF - Raw Data - Coal Adjusted

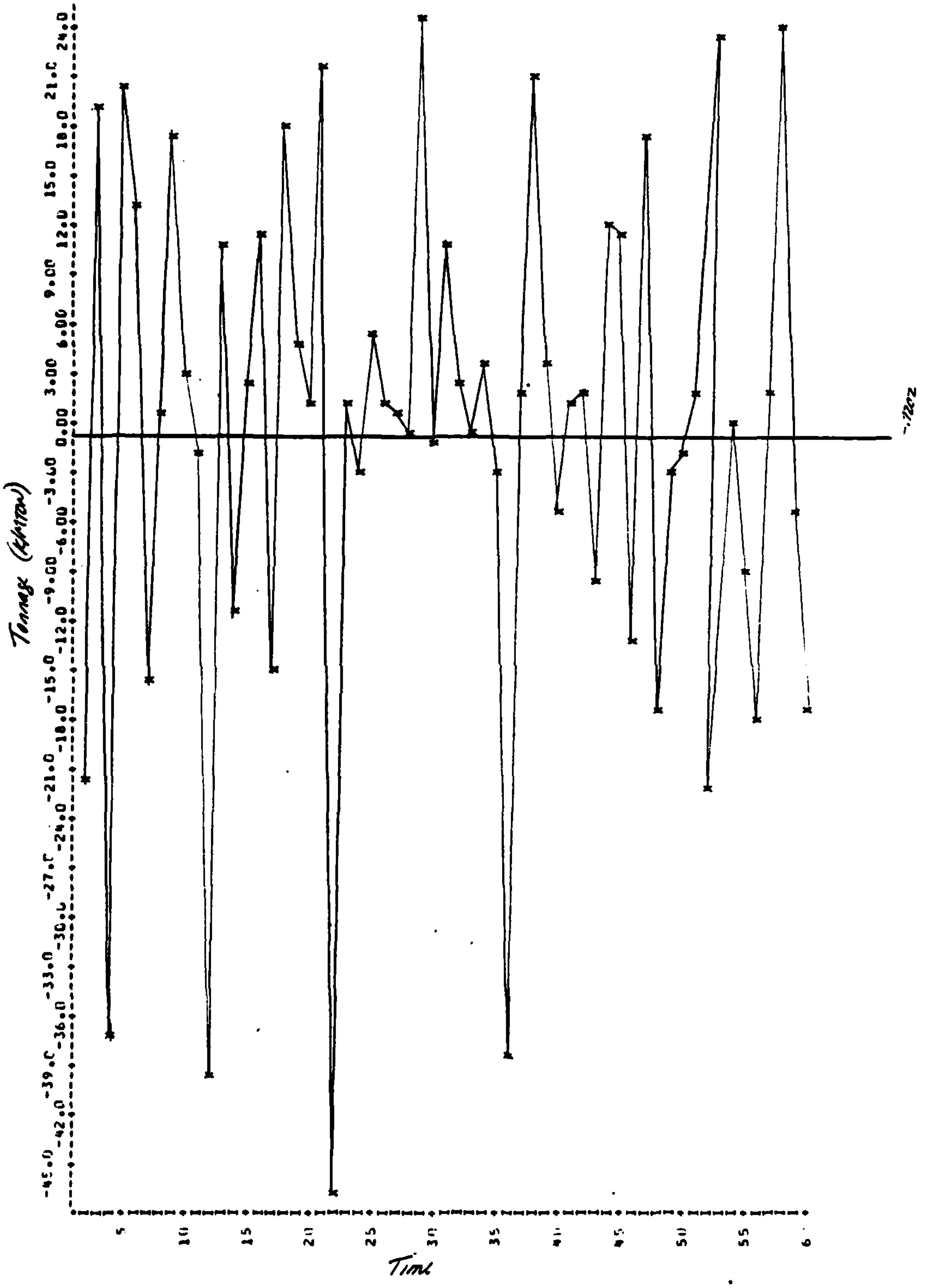


Figure F-51. Differenced Series (1-month lag) Coal Adjusted

```
AUTOCORRELATIONS

 1- 12     -.31  -.07  -.01  -.07   .08  -.07  -.20   .16  -.18   .26  -.07   .01
 ST.E.      .13   .14   .14   .14   .14   .14   .14   .15   .15   .16   .16   .15

13- 24      .10   0.0   .03   .02  -.29   .10  -.07   .17  -.03  -.09  -.06   .25
 ST.E.      .16   .16   .16   .16   .16   .17   .17   .18   .18   .18   .18   .18

25- 36     -.14   .09  -.17   .03   .11  -.06  -.16   .12  -.04   .07  -.02  -.06
 ST.E.      .18   .19   .19   .19   .19   .19   .19   .19   .19   .20   .20   .20

PLOT OF AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1   -.313                  XX+XXXXXI     +
  2   -.067                   +    XXI      +
  3   -.009                   +      I      +
  4   -.068                   +    XXI      +
  5    .076                   +      IXX    +
  6   -.071                   +    XXI      +
  7   -.200                   + XXXXXI      +
  8    .163                   +      IXXXX  +
  9   -.180                   + XXXXXI      +
 10    .265                  +       IXXXXXXX+
 11   -.068                  +     XXI       +
 12    .010                  +       I       +
 13    .096                  +       IXX     +
 14    .002                  +       I       +
 15    .027                  +       IX      +
 16    .023                  +       IX      +
 17   -.292                  +XXXXXXXI       +
 18    .105                  +       IXXX    +
 19   -.072                 +      XXI        +
 20    .174                 +        IXXXX    +
 21   -.032                 +       XI        +
 22   -.089                 +      XXI        +
 23   -.055                 +       XI        +
 24    .250                 +        IXXXXXX  +
 25   -.140                 +    XXXXI        +
 26    .091                 +        IXX      +
 27   -.170                 +    XXXXI        +
 28    .026                 +        IX       +
 29    .114                 +        IXXX     +
 30   -.060                 +       XI        +
 31   -.156                 +    XXXXI        +
 32    .121                 +        IXXX     +
 33   -.045                +        XI         +
 34    .070                +         IXX       +
 35   -.020                +        XI         +
 36   -.061                +       XXI         +
```

std error

$= \frac{1}{\sqrt{59}} (1.96)$

= .255

Figure F-52. ACF - Lagged 1 Month

```
PARTIAL AUTOCORRELATIONS

  1- 12     -.31 -.18 -.10 -.14 -.01 -.08 -.30 -.07 -.29  .08 -.05  .03
 ST.E.       .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 13- 24      .07  .09  .14  .14 -.11 -.07 -.07  .14  .10  .01 -.22  .07
 ST.E.       .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 25- 36     -.13  0.0 -.09 -.13  .08 -.02 -.15 -.05 -.02 -.20  0.0 -.15
 ST.E.       .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

PLOT OF PARTIAL AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1   -.313                  XX+XXXXXI     +
  2   -.183                    +XXXXXI     +
  3   -.105                    +  XXXI     +
  4   -.138                    +  XXXI     +
  5   -.009                    +     I     +
  6   -.084                    +   XXI     +
  7   -.300                   X+XXXXXI     +
  8   -.065                    +   XXI     +
  9   -.286                   X+XXXXXI     +
 10    .077                    +     IXX   +
 11   -.052                    +    XI     +
 12    .028                    +     IX    +
 13    .069                    +     IXX   +
 14    .095                    +     IXX   +
 15    .138                    +     IXXX  +
 16    .139                    +     IXXX  +
 17   -.107                    +  XXXI     +
 18   -.074                    +   XXI     +
 19   -.069                    +   XXI     +
 20    .142                    +     IXXXX +
 21    .097                    +     IXX   +
 22    .012                    +     I     +
 23   -.221                    XXXXXXI     +
 24    .065                    +     IXX   +
 25   -.134                    +  XXXI     +
 26   -.001                    +     I     +
 27   -.092                    +   XXI     +
 28   -.125                    +  XXXI     +
 29    .077                    +     IXX   +
 30   -.020                    +     I     +
 31   -.147                    + XXXXI     +
 32   -.046                    +    XI     +
 33   -.019                    +     I     +
 34   -.198                    +XXXXXI     +
 35   -.003                    +     I     +
 36   -.153                    + XXXXI     +
```

Figure F-53. PACF - Lagged 1 Month

```
ESTIMATION BY BACKCASTING METHOD

RELATIVE CHANGE IN RESIDUAL SUM OF SQUARES LESS THAN  .1000-004


SUMMARY OF THE MODEL

OUTPUT VARIABLE -- TRANS
INPUT VARIABLES -- NOISE

VARIABLE  VAR. TYPE  MEAN      TIME     DIFFERENCES
                                           1
TRANS      RANDOM             1-  60  (1-B  )

PARAMETER VARIABLE   TYPE  FACTOR  ORDER ESTIMATE        ST. ERR.  T-RATIO
      1   TRANS       MA      1      1      .7693          .0794      9.69
      2   TRANS       MA      1     10    -.2705          .0711     -3.80
      3   TRANS       AR      1      1      .2168          .1484      1.46

RESIDUAL SUM OF SQUARES  =      9903.394165 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM       =               55
RESIDUAL MEAN SQUARE     =       180.061710
```

Figure F-54. Model Parameters - Coal Adjusted

```
AUTOCORRELATIONS

  1- 12      .02 -.04 -.01 -.06  .03 -.06 -.14  .10 -.07  .06 -.05  .04
 ST.E.       .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .14  .14

 13- 24      .08  .03  .03 -.05 -.26 -.02 -.05  .15 -.01 -.12 -.05  .17
 ST.E.       .14  .14  .14  .14  .14  .15  .15  .15  .15  .15  .15  .15

 25- 36     -.13  .01 -.15 -.02  .09 -.07 -.14  .09  .01  .03  .01 -.04
 ST.E.       .15  .16  .16  .16  .16  .16  .16  .16  .16  .16  .16  .16

PLOT OF AUTOCORRELATIONS

             -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG      CORR. +----+----+----+----+----+----+----+----+----+----+
                                        I
  1       .020                    +     I     +
  2      -.043                    +    XI     +
  3      -.014                    +     I     +
  4      -.056                    +    XI     +
  5       .027                    +     IX    +
  6      -.065                    +   XXI     +
  7      -.143                    + XXXXI     +
  8       .100                   +      IXX    +
  9      -.072                   +    XXI      +
 10       .062                   +      IXX    +
 11      -.049                   +     XI      +
 12       .035                   +      IX     +
 13       .085                   +      IXX    +
 14       .030                   +      IX     +
 15       .033                   +      IX     +
 16      -.050                   +     XI      +
 17      -.260                   XXXXXXXI      +
 18      -.023                   +     XI      +
 19      -.047                   +     XI      +
 20       .148                   +      IXXXX  +
 21      -.009                   +      I      +
 22      -.124                   +   XXXI      +
 23      -.054                   +     XI      +     .175(60)=10.51
 24       .175                   +      IXXXX  +
 25      -.134                  +    XXXI       +
 26       .005                  +       I       +
 27      -.151                  +   XXXXI       +
 28      -.018                  +       I       +
 29       .093                  +       IXX     +
 30      -.074                  +     XXI       +
 31      -.136                  +    XXXI       +
 32       .094                  +       IXX     +
 33       .008                  +       I       +
 34       .030                  +       IX      +
 35       .013                  +       I       +
 36      -.036                  +      XI       +
```

Figure F-55. Estimated Residuals - Coal Adjusted

```
 FORECAST ON VARIABLE TRANS      FROM TIME PERIOD    61
PERIOD              FORECASTS        ST.  ERR.        ACTUAL        ERROR
  61                25.70256         15.46104         19.888       -5.814
  62                23.11375         16.93817         64.116       41.003
  63                28.94411         17.67957         41.776       12.832
  64                34.56539         18.28460         19.028      -15.537
  65                36.85821         18.84892         40.916        4.058
  66                34.34627         19.39238         38.247        3.901
  67                31.67653         19.92009         19.197      -12.479
  68                36.47410         20.43398         33.085       -3.389
  69                39.01207         20.93522         41.567        2.555
  70                36.44484         21.42472         19.103      -17.341
  71                35.88835         23.13714         19.405      -16.483
  72                35.76772         25.06581         19.712      -16.055
STANDARD ERROR =  15.4610        (BY CONDITIONAL METHOD  )

                    398.80                            376.67       MSE = 262.99
```

Figure F-56. Forecast FY 82 - Coal Adjusted

F-6. AMMUNITION

a. The raw series for ammunition is depicted in Figure F-57. The raw series depicts a recurring pattern with the troughs occurring in the first two quarters of each fiscal year and the peaks in the latter two quarters. This pattern is more identifiable in the 3-month and 6-month moving average diagrams (Figures F-58 and F-59). However, a visual examination of the 12-month moving average (Figure F-60) indicates that the amount of ammunition shipped from year to year has remained relatively constant with a slight trend downwards.

b. Autocorrelation function analysis of the model data confirms the evidence of a trend in the data and suggests the possibility of seasonal data (Figure F-61). The seasonality in the data was eliminated by differencing the series at a lag of 12 months. The autocorrelation function of the resulting series is depicted in Figure F-62. Stationarity in the data has not been achieved as evidenced by an increasing trend in the autocorrelation function for lags 1-4. Attempts to achieve stationarity through differencing or other transformations of the seasonally adjusted series were futile. Therefore, the original series was differenced at a lag of one month and the plot is depicted in Figure F-63.

c. The autocorrelation and partial autocorrelation of the differenced series are illustrated in Figures F-64 and F-65. Analysis of the autocorrelation function indicates that an ARIMA (2,1,0) model is appropriate to model the data. This model was tested and the resulting fit of the model was not good due to significant autocorrelation coefficients at lags 4 through 7. To improve the fit of the model, MA parameters were added. The resulting model was an ARIMA (2,1,4) model of the form:

$$(1-\phi_1 B - \phi_2 B^2)(1 - B) X_t = (1 - \theta_4 B^4 - \theta_5 B^5 - \theta_6 B^6 - \theta_7 B^7)\epsilon_t$$

d. The results of the model (Figure F-66) are as follows:

$$(1+\underset{(-7.33)}{.8418B} + \underset{(-4.59)}{.5399 B^2})(1-B) X_t = (1+\underset{(-3.11)}{.3454B^4}-\underset{(3.86)}{.3689B^5}-\underset{(4.57)}{.3875B^6}-\underset{(2.43)}{.2561^7})\epsilon_t$$

$$x^2 (6,20) = 17.61$$

All of the estimated parameters are significant at the 5 percent significance level. The Q statistic for the model (Figure F-67) indicates that the null hypothesis, estimated residuals are uncorrelated, should not be rejected at the 40 percent significance level.

e. The model forecasted that ammunition shipments during FY 82 would be 189.62 K/MTON (Figure F-68). The actual lift of ammunition during FY 82 was 179.31. The MSE of the ammunition forecast was 119.91 and the annual forecast error was 5.7 percent. It should be noted that this model, used in conjunction with a slightly modified model, resulted in an annual forecast error of .3 percent.

f. Problems with attaining stationarity in the data are in part attributed to outliers in the data series. The amounts of tonnage shipped during February 1980, November 1980, and January 1981 are far below the average amount of ammunition shipped during a given month. Like coal, the ammunition data series should be monitered and adjusted with extreme care. An attempt was made to modify the data series, however, additional work in this area is required before adequate modeling can proceed.

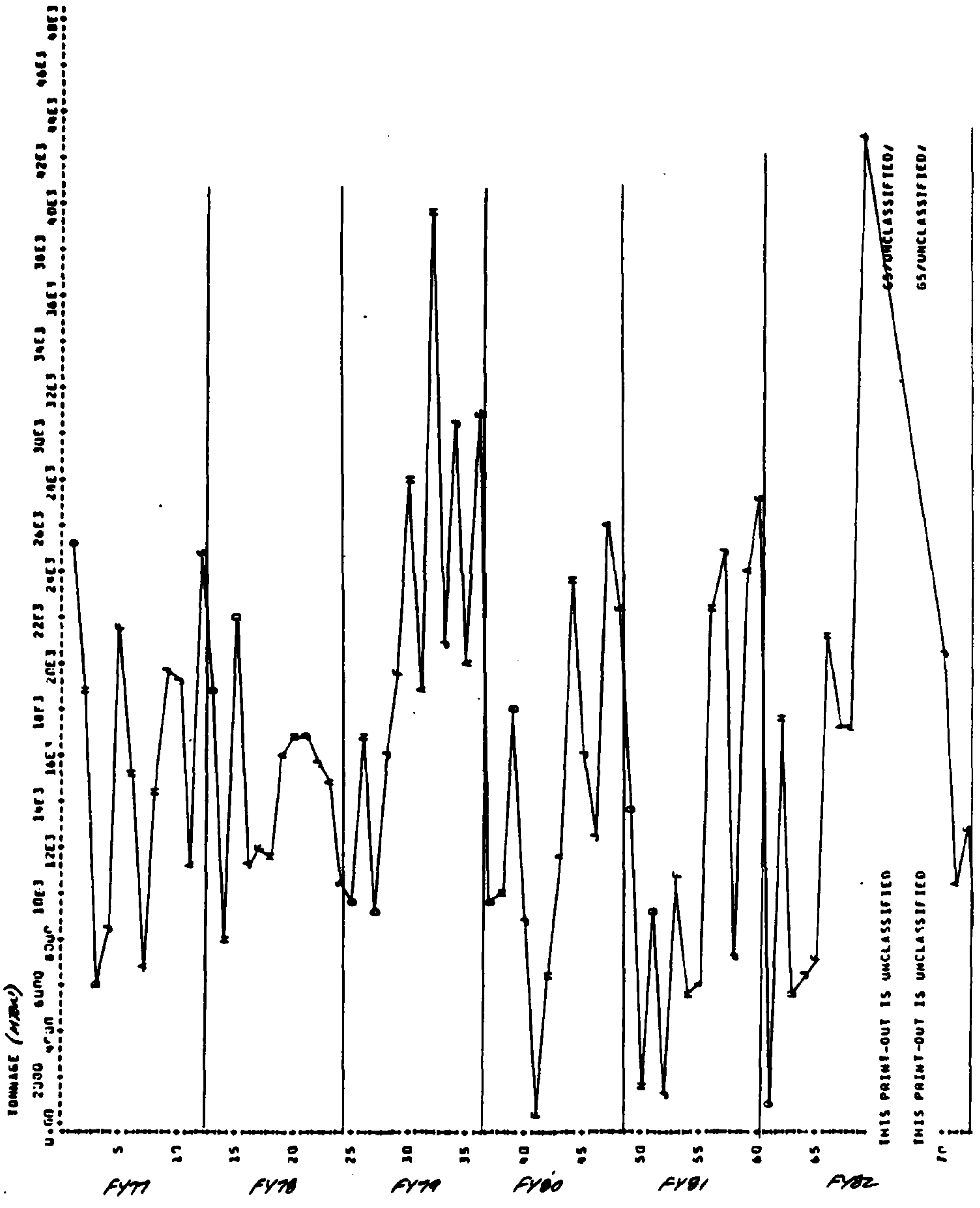
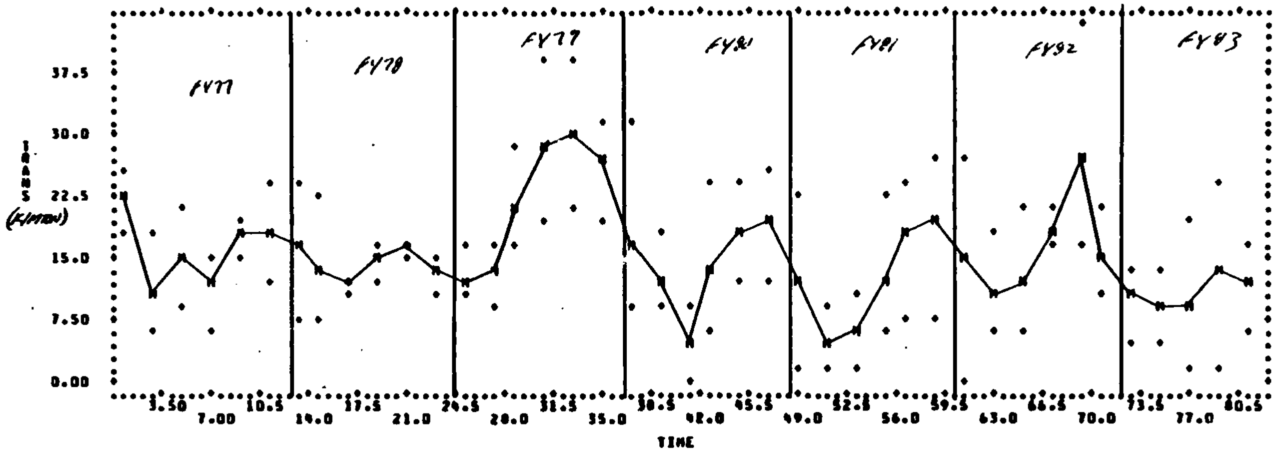
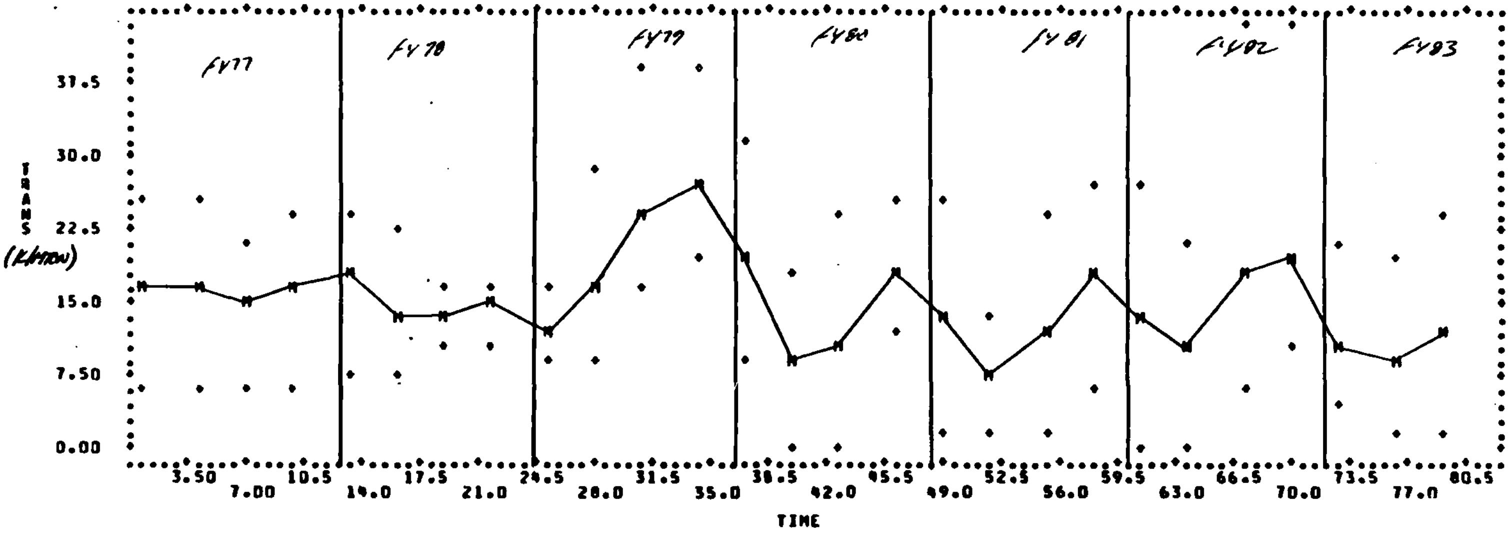


Figure F-57. Ammunition Cargo FY 77 - FY 82



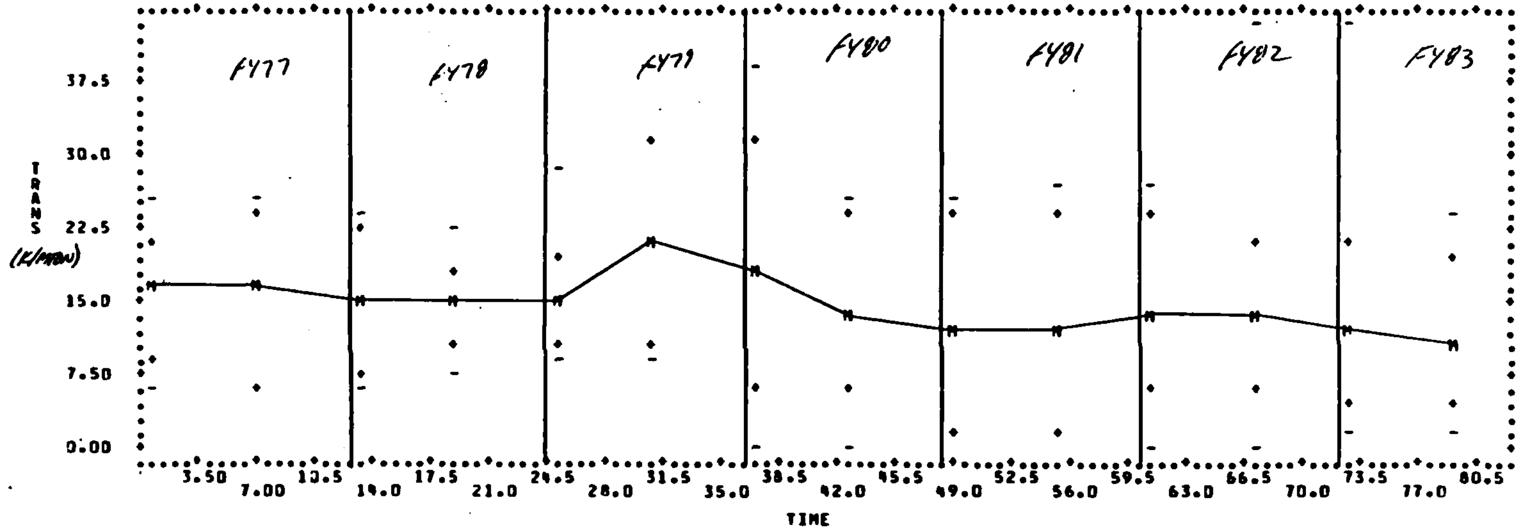
TIME VALUE	NO. OF CASES	MINIMUM VALUE	MEAN	MAXIMUM VALUE
1.000	2	18.6054	21.9412	25.2773
3.000	3	5.8570	10.9641	18.6054
5.000	3	8.4300	15.1283	21.6070
7.000	3	6.6960	12.1830	15.3400
9.000	3	14.5050	17.7237	19.5950
11.000	3	11.3190	18.3663	24.7093
13.000	3	7.9900	17.1107	24.7093
15.000	3	7.9900	13.6729	21.9550
17.000	3	11.0738	11.5955	12.1964
19.000	3	11.5163	14.7511	16.7197
21.000	3	15.4436	16.3718	16.9514
23.000	3	10.4451	13.5629	15.4436
25.000	3	9.7973	12.3711	16.8709
27.000	3	9.0937	13.9552	16.8709
29.000	3	15.9010	21.1055	27.9130
31.000	3	18.9489	28.7573	39.4099
33.300	3	20.6076	30.1368	39.4099
35.000	3	19.8860	27.0322	30.8177
37.000	3	9.6241	16.7715	30.8177
39.000	3	8.6192	12.1439	17.9396
41.000	3	.5154	5.2056	8.6192
43.000	3	6.4821	13.8747	23.4551
45.000	3	12.3595	17.2782	23.4551
47.000	3	12.3595	20.2429	25.8786
49.300	3	1.6279	12.5351	22.4995
51.000	3	1.2351	3.9907	9.1090
53.000	3	1.2351	5.8947	10.9083
55.000	3	5.5409	11.3291	22.2604
57.000	3	7.0733	17.9823	24.6131
59.000	3	7.0733	19.4165	27.3331
61.003	3	.6620	15.1090	27.3331
63.000	3	5.4822	9.8318	17.5570
65.000	3	6.4562	11.6254	21.0274
67.000	3	17.2187	18.4919	21.0274
69.000	3	17.2187	26.8211	42.9027
71.000	3	10.3941	14.4617	20.3419
73.000	3	4.0552	10.3689	13.6024
75.000	3	5.0458	8.2054	13.6024
77.000	3	1.5781	9.2399	19.9335
79.000	3	1.5781	14.0386	23.4994
81.000	2	5.8467	11.4425	17.0384

Figure F-58. Three-month Moving Average - Ammunition



```
TIME      NO. OF    MINIMUM               MAXIMUM

VALUE     CASES       VALUE      MEAN      VALUE
   1.000       3     5.8570   16.5798   25.2770
   4.000       6     5.8570   15.8541   25.2770
   7.000       6     6.6960   14.3635   21.6070
  10.000       6     6.6960   15.9825   24.7090
  13.000       6     7.9900   17.2795   24.7090
  16.000       6     7.9900   13.8941   21.9550
  19.000       6    11.0738   14.0792   16.9514
  22.000       6    10.4451   15.0629   16.9514
  25.000       6     9.0937   12.7418   16.8709
  28.000       6     9.0937   16.5131   27.9130
  31.000       6    15.9010   23.7139   39.4099
  34.000       6    18.9489   26.6772   39.4099
  37.000       6     9.6241   19.7555   30.8177
  40.000       6      .5154    8.8422   17.9396
  43.000       6      .5154   11.1298   23.4551
  46.000       6    11.6867   18.6484   25.8786
  49.000       6     1.6279   14.1587   25.8785
  52.000       6     1.2351    6.9846   13.4869
  55.000       6     1.2351   11.7906   24.6131
  58.000       6     6.1860   18.5515   27.3331
  61.000       6      .6620   13.6585   27.3331
  64.000       6      .6620    9.7629   21.0274
  67.000       6     6.4562   19.7043   42.9027
  70.000       6    10.3941   20.1224   42.9027
  73.000       6     4.8552   11.1481   20.3419
  76.000       6     1.5781    8.5372   19.9335
  79.000       6     1.5781   12.3507   23.4994
```

Figure F-59. Six-month Moving Average - Ammunition



```
TIME      NO. OF    MINIMUM   TRIMMED   TRIMMED   TRIMMED    MAXIMUM
VALUE     CASES      VALUE    MINIMUM    MEAN     MAXIMUM     VALUE
  1.000      6      5.8570    8.4300   15.9976   21.6073    25.2770
  7.000     12      5.8570    6.6960   15.9885   24.7090    25.2770
 13.000     12      6.6960    7.9900   14.7855   21.9550    24.7090
 19.000     12      7.9900   10.4451   14.3797   18.6330    21.9550
 25.000     12      9.0937    9.7973   15.2449   19.5024    27.9130
 31.000     12      9.0937    9.7973   21.0638   33.8177    39.4099
 37.000     12       .5154    6.4821   17.3191   33.8177    39.4099
 43.000     12       .5154    6.4821   13.8553   23.4551    25.8786
 49.000     12      1.2351    1.6279   12.6685   23.4551    25.8786
 55.000     12      1.2351    1.6279   12.4649   24.6131    27.3331
 61.000     12       .6620    5.4822   14.1891   24.6131    27.3331
 67.000     12       .6620    5.4822   13.5747   21.0274    42.9027
 73.000     12      1.5781    4.8552   12.7477   20.3419    42.9027
 79.000      9      1.5781    4.8552   10.3614   19.9335    23.4994
```

Figure F-60. Twelve-month Moving Average - Ammunition

```
AUTOCORRELATIONS
  1- 12      .27   .16   .18   .17  -.26  -.29  -.29  -.16  -.12  -.07   .03   .13
  ST.E.      .13   .14   .14   .15   .15   .16   .16   .17   .18   .18   .18   .18

 13- 24      .17   .04   .03  -.11   0.0  -.23  -.22  -.17  -.03  -.16  -.03   .12
  ST.E.      .18   .18   .18   .18   .18   .18   .19   .19   .19   .19   .20   .20

 25- 36      .05   0.0   .15   .03  -.04   .02   .05  -.04  -.01   .11   .08   .01
  ST.E.      .20   .20   .20   .20   .20   .20   .20   .20   .20   .20   .20   .20

PLOT OF AUTOCORRELATIONS
            -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG     CORR. +----+----+----+----+----+----+----+----+----+----+
                                       I
   1     .272                    +     IXXXXX+X
   2     .165                   +      IXXXX  +
   3     .185                   +      IXXXXX +
   4     .167                   +      IXXXX  +
   5    -.255                   +XXXXXXI      +
   6    -.290                  +XXXXXXXI       +
   7    -.289                  +XXXXXXXI       +
   8    -.157                  +   XXXXI       +
   9    -.124                 +     XXXI        +
  10    -.066                 +      XXI        +
  11     .029                 +        IX       +
  12     .126                 +        IXXX     +
  13     .159                 +        IXXXX    +
  14     .038                 +        IX       +
  15     .030                 +        IX       +
  16    -.109                 +     XXXI        +
  17     .004                 +        I        +
  18    -.229                 +  XXXXXXI        +
  19    -.218                 +   XXXXXI        +
  20    -.155                 +    XXXXI        +
  21    -.028                 +       XI        +
  22    -.165                +     XXXXI         +
  23    -.033                +        XI         +
  24     .116                +         IXXX      +
  25     .048                +         IX        +
  26     .002                +         I         +
  27     .147                +         IXXXX     +
  28     .027                +         IX        +
  29    -.041                +        XI         +
  30     .024                +         IX        +
  31     .047                +         IX        +
  32    -.039                +        XI         +
  33    -.009                +         I         +
  34     .112                +         IXXX      +
  35     .079                +         IXX       +
  36     .010                +         I         +
```

std error

$= \frac{1}{\sqrt{60}} (1.96)$

$= .253$

Figure F-61. ACF - Raw Data - Ammunition

```
AUTOCORRELATIONS

  1- 12      .19  .28  .22  .39 -.12 -.01 -.08 -.15 -.26 -.15 -.13 -.45
  ST.E.      .14  .15  .16  .17  .18  .19  .19  .19  .19  .20  .20  .20

 13- 24      .01 -.13 -.09 -.18  .19 -.10 -.01 -.04  .14 -.15 -.03  .12
  ST.E.      .22  .22  .22  .22  .23  .23  .23  .23  .23  .23  .23  .23

 25- 36     -.01 -.08  .04  .09 -.04  .02  .01  .01 -.04  .09 -.04 -.07
  ST.E.      .24  .24  .24  .24  .24  .24  .24  .24  .24  .24  .24  .24

PLOT OF AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1    .190                   +      IXXXXX +
  2    .275                   +      IXXXXXXX
  3    .224                  +       IXXXXXX +
  4    .394                  +       IXXXXXXX+XX
  5   -.121                 +     XXXI        +
  6   -.010                 +        I        +
  7   -.084                 +      XXI        +
  8   -.154                 +    XXXXI        +
  9   -.263                 + XXXXXXXI        +
 10   -.149                +     XXXXI         +
 11   -.129                +      XXXI         +
 12   -.451               X+XXXXXXXXXI         +
 13    .005               +          I          +
 14   -.125               +       XXXI          +
 15   -.087               +        XXI          +
 16   -.183               +     XXXXXI          +
 17    .189               +          IXXXXX     +
 18   -.097               +        XXI          +
 19   -.014               +          I          +
 20   -.038               +         XI          +
 21    .141               +          IXXXX      +
 22   -.154               +      XXXXI          +
 23   -.034               +         XI          +
 24    .119              +           IXXX        +
 25   -.005              +           I           +
 26   -.081              +         XXI           +
 27    .038              +           IX          +
 28    .088              +           IXX         +
 29   -.037              +          XI           +
 30    .024              +           IX          +
 31    .008              +           I           +
 32    .011              +           I           +
 33   -.036              +          XI           +
 34    .094              +           IXX         +
 35   -.045              +          XI           +
 36   -.069              +         XXI           +
```

std error

$= \frac{1}{\sqrt{48}} (1.96)$

$= .283$

Figure F-62. ACF - Lagged 12 Months

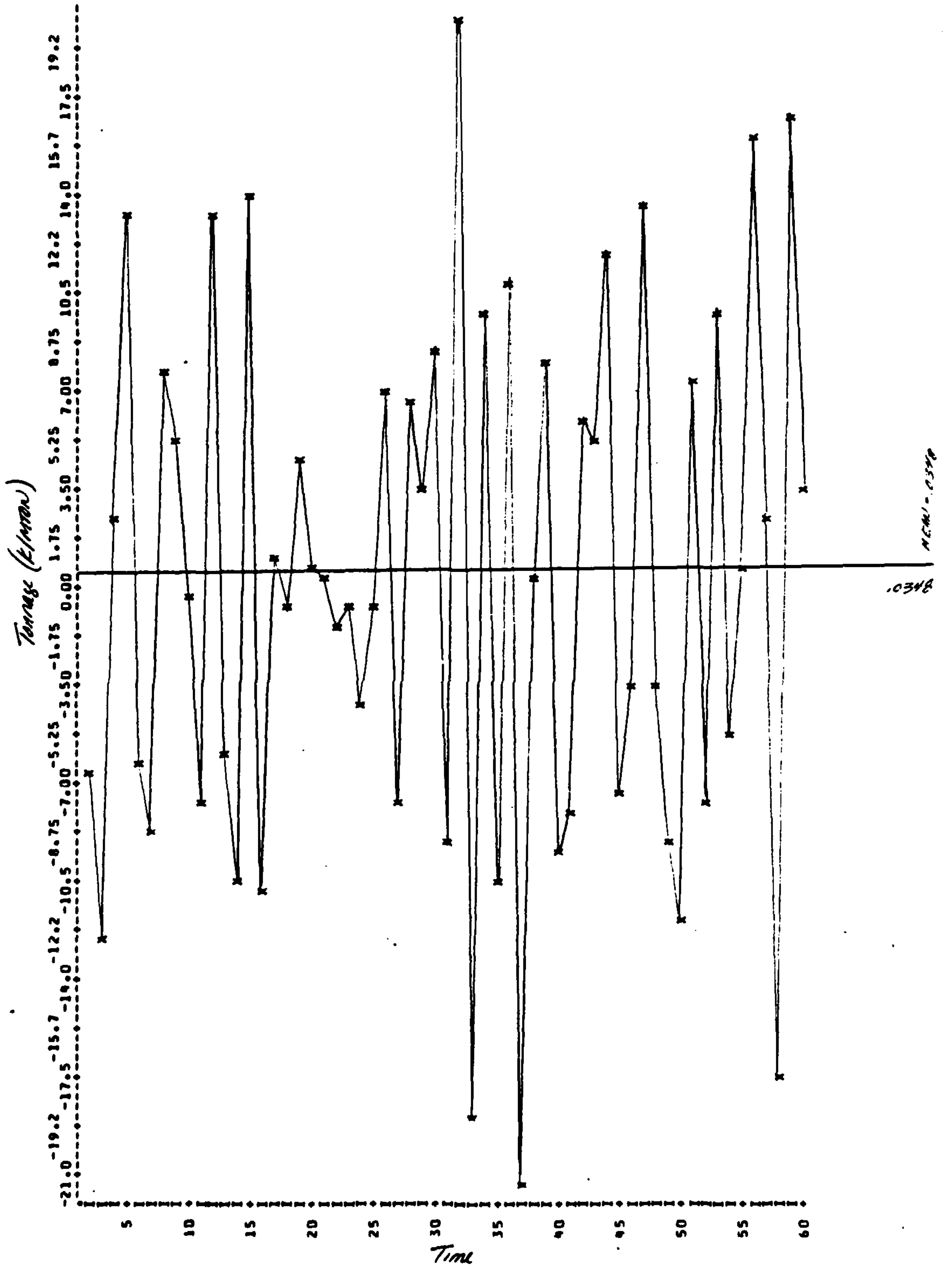


Figure F-63. Differenced Series (1-month lag) - Ammunition

```
AUTOCORRELATIONS

  1- 12      -.43 -.03 -.02  .27 -.23 -.01 -.12  .08 -.03  0.0 -.05  .03
  ST.E.       .13  .15  .15  .15  .16  .17  .17  .17  .17  .17  .17  .17

 13- 24       .14 -.08  .11 -.20  .28 -.17 -.02 -.08  .18 -.17  0.0  .11
  ST.E.       .17  .17  .17  .17  .18  .18  .19  .19  .19  .19  .19  .19

 25- 36       0.0 -.15  .20 -.09 -.07  .03  .06 -.04 -.07  .11  .02  0.0
  ST.E.       .19  .19  .19  .20  .20  .20  .20  .20  .20  .20  .20  .20

PLOT OF AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1   -.425               XXXXX+XXXXXI     +
  2   -.030                   +     XI      +
  3   -.017                   +      I      +
  4    .271                   +      IXXXXXXX
  5   -.230                  + XXXXXXI       +
  6   -.008                  +       I       +
  7   -.121                  +    XXXI       +
  8    .084                  +       IXX     +
  9   -.035                  +      XI       +
 10    .005                  +       I       +
 11   -.052                  +      XI       +
 12    .029                  +       IX      +
 13    .137                  +       IXXX    +
 14   -.083                  +     XXI       +
 15    .105                  +       IXXX    +
 16   -.199                  +  XXXXXI       +
 17    .275                 +        IXXXXXXX +
 18   -.171                 +    XXXXI        +
 19   -.018                 +        I        +
 20   -.079                 +      XXI        +
 21    .179                 +        IXXXX    +
 22   -.173                 +    XXXXI        +
 23   -.003                 +        I        +
 24    .108                 +        IXXX     +
 25   -.004                 +        I        +
 26   -.147                 +    XXXXI        +
 27    .199                +         IXXXXX    +
 28   -.086                +       XXI         +
 29   -.065                +       XXI         +
 30    .027                +         IX        +
 31    .059                +         IX        +
 32   -.040                +        XI         +
 33   -.069                +       XXI         +
 34    .112                +         IXXX      +
 35    .022                +         IX        +
 36   -.002                +         I         +
```

std error

$= \frac{1}{\sqrt{59}}(1.96)$

$= .255$

Figure F-64. ACF - Lagged 1 Month

```
PARTIAL AUTOCORRELATIONS

  1- 12    -.43 -.26 -.19  .23  .01 -.07 -.28 -.26 -.11  .02  .05 -.07
 ST.E.      .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 13- 24     .05 -.04  .15 -.17  .10 -.02 -.08 -.04  .01  0.0 -.12  .13
 ST.E.      .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 25- 36    -.01 -.16  .04 -.11 -.10 -.14  .03 -.01 -.01  .03  .07  .10
 ST.E.      .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

PLOT OF PARTIAL AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1   -.425               XXXXX+XXXXXI     +
  2   -.258                    XXXXXXI     +
  3   -.196                    +XXXXXI     +
  4    .232                    +     IXXXXXX
  5    .012                    +     I     +
  6   -.068                    +   XXI     +
  7   -.283                   X+XXXXXI     +
  8   -.262                   X+XXXXXI     +
  9   -.108                    +  XXXI     +
 10    .016                    +     I     +
 11    .047                    +     IX    +
 12   -.065                    +   XXI     +
 13    .052                    +     IXX   +
 14   -.044                    +    XI     +
 15    .154                    +     IXXXX +
 16   -.157                    + XXXXI     +
 17    .098                    +     IXX   +
 18   -.021                    +    XI     +
 19   -.082                    +   XXI     +
 20   -.044                    +    XI     +
 21    .012                    +     I     +
 22   -.000                    +     I     +
 23   -.122                    +  XXXI     +
 24    .134                    +     IXXX  +
 25   -.013                    +     I     +
 26   -.153                    + XXXXI     +
 27    .039                    +     IX    +
 28   -.109                    +  XXXI     +
 29   -.095                    +   XXI     +
 30   -.141                    + XXXXI     +
 31    .034                    +     IX    +
 32   -.007                    +     I     +
 33   -.007                    +     I     +
 34    .034                    +     IX    +
 35    .074                    +     IXX   +
 36    .101                    +     IXXX  +
```

Figure F-65. PACF - Lagged 1 Month

```
ESTIMATION BY BACKCASTING METHOD

* * * WARNING.  MAXIMUM NO. OF ITERATIONS ( 10) USED.


SUMMARY OF THE MODEL

OUTPUT VARIABLE -- TRANS
INPUT VARIABLES -- NOISE

VARIABLE  VAR. TYPE  MEAN       TIME      DIFFERENCES
                                                1
TRANS       RANDOM              1-  60  (1-B   )

PARAMETER VARIABLE    TYPE  FACTOR  ORDER ESTIMATE         ST. ERR.  T-RATIO
        1  TRANS       MA      1       4     -.3454           .1111    -3.11
        2  TRANS       MA      1       5      .3689           .0955     3.86
        3  TRANS       MA      1       6      .3875           .0848     4.57
        4  TRANS       MA      1       7      .2561           .1053     2.43
        5  TRANS       AR      1       1     -.8418           .1148    -7.33
        6  TRANS       AR      1       2     -.5399           .1176    -4.59

RESIDUAL SUM OF SQUARES  =      2111.992340 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM       =               51
RESIDUAL MEAN SQUARE     =        41.411614
```

Figure F-66. Model Parameters - Ammunition

```
AUTOCORRELATIONS

  1- 12      -.06  .05  .01  .04 -.14 -.21 -.19 -.06 -.05  .04  0.0  .15
 ST.E.        .13  .13  .13  .13  .13  .13  .14  .14  .14  .14  .14  .14

 13- 24       .11 -.09  .07 -.09  .17 -.19 -.10 -.14  .02 -.09 -.05  .14
 ST.E.        .15  .15  .15  .15  .15  .15  .16  .16  .16  .16  .16  .16

 25- 36       0.0 -.02  .19 -.01  0.0 -.03 -.01 -.03 -.02  .14  .02  .01
 ST.E.        .16  .16  .16  .17  .17  .17  .17  .17  .17  .17  .17  .17

FLOT OF AUTOCORRELATIONS

            -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG    CORR.  +----+----+----+----+----+----+----+----+----+----+
                                        I
   1     -.059                   +    XI     +
   2      .051                   +     IX    +
   3      .014                   +     I     +
   4      .043                   +     IX    +
   5     -.138                   +  XXXI     +
   6     -.209                   +XXXXXI     +
   7     -.193                  + XXXXXI      +
   8     -.057                  +     XI      +
   9     -.048                  +     XI      +
  10      .040                  +      IX     +
  11      .001                  +      I      +
  12      .147                  +      IXXXX  +
  13      .106                  +      IXXX   +
  14     -.086                  +    XXI      +
  15      .068                  +      IXX    +
  16     -.092                  +    XXI      +
  17      .170                  +      IXXXX  +
  18     -.187                  + XXXXXI      +
  19     -.102                 +    XXXI       +
  20     -.138                 +    XXXI       +
  21      .018                 +       I       +
  22     -.093                 +     XXI       +
  23     -.046                 +      XI       +
  24      .142                 +       IXXXX   +
  25     -.002                 +       I       +
  26     -.020 .295(60)=17.61  +      XI       +
  27      .186                 +       IXXXXX  +
  28     -.005                 +       I       +
  29      .005                 +       I       +
  30     -.027                 +      XI       +
  31     -.005                 +       I       +
  32     -.032                 +      XI       +
  33     -.015                 +       I       +
  34      .143                 +       IXXXX   +
  35      .017                 +       I       +
  36      .009                 +       I       +
```

Figure F-67. Estimated Residuals - Ammunition

```
 FORECAST ON VARIABLE TRANS    FROM TIME PERIOD    61

PERIOD          FORECASTS        ST. ERR.        ACTUAL        ERROR
  61            14.82388         6.88577           .662       -14.162
  62            13.27270         6.97144         17.557         4.284
  63            19.90887         7.32575          5.482       -14.426
  64            17.02037         8.54706          6.456       -10.564
  65            15.51233         9.58698          7.393       - 8.119
  66            15.87883         9.61184         21.027         5.148
  67            15.31700         9.67796         17.228         1.911
  68            15.59204         9.72631         17.219         1.627
  69            15.66387         9.76489         42.903        27.239
  70            15.45490         9.82005         20.342         4.877
  71            15.59202         9.86582         10.394       - 5.198
  72            15.58943         9.90975         12.649       - 2.94
STANDARD ERROR =  6.68577      (BY CONDITIONAL METHOD  )

                 189.62                          179.31     MSE = 119.91
```

Figure F-68. Forecast FY 82 - Ammunition

F-7. SPECIAL

a. The raw series for the special cargo commodity is illustrated in Figure F-69. The raw series does not depict a discernible pattern or trend in the data. Also, examination of the 3-month and 6-month moving averages does not identify a visible pattern (Figures F-70 and F-71). The 12-month moving average (Figure F-72) suggests that a general trend may exist in the data which could be interpreted as the program funding of the defense budget. In fact, the trend shows a gradual decline during the period under study.

b. Autocorrelation function analysis of the data (Figures F-73 and F-74) suggests the possibility of seasonal data. Therefore, the series was differenced at a lag of 12 months in an effort to achieve stationarity. The variance of the seasonally differenced series exhibited heteroscedasticity (change in variance over time). Thus, the original series was transformed using natural logarithms and then differenced at a lag of 12 months. The differenced logarithmetic series is found in Figure F-75. The autocorrelation and partial autocorrelation functions of the data (Figures F-76 and F-77) indicates that a random stationary series has been generated.

c. Analysis of the autocorrelation and partial autocorrelation functions indicates that the data could be modeled as a possible ARIMA (2,0,0) nonseasonal process and an ARIMA (0,1,1) seasonal model. Thus, the appropriate model is:

$$(1 - \phi_1 B - \phi_2 B^2)(1 - B^{12}) \ln x_t = (1 - \theta_{12} B^{12}) \epsilon_t$$

d. The results of this model (Figure F-78) are as follows:

$$\underset{(1.21)}{(1 - .1496B} - \underset{(3.16)}{.3875B^2)}(1 - B^{12}) \ln X_t = (1 - \underset{(10.61)}{.801B^{12}} - \underset{(1.65)}{.1503B^{14}})\epsilon_t$$

$$x^2\ (4,20) = 13.15$$

All of the estimated parameters except ϕ_1 and θ_{14} are significant at the 5 percent significance level. The additional MA parameter (θ_{14}) was added to the model since the autocorrelation coefficient at lag 14 of the original hypothesized seasonal model was highly significant. The model was verified using the Box-Pierce test and a visual check of the estimated residuals. The Q statistic for this model with 20 degrees of freedom is 13.15 (Figure F-79). This diagnostic indicates that the residuals are not significant and that the null hypothesis should not be rejected at the 15 percent significance level. All of the residuals are within the 95 percent confidence interval.

e. This model forecasted that 559.42 K/MTON of special cargo would be shipped during FY 82 (Figure F-80) versus an actual amount of 489.83 K/MTON The annual forecast error was 12.4 percent and the forecast MSE was 159.23. Although this discrepancy would cause one to doubt the usefulness of this model, it should be noted that the amount of special cargo tonnage shipped during FY 82 is much lower than any of the preceding years. In fact, the average tonnage of special cargo shipped over the past 5 years was 669.17 K/MTON. In all cases, forecasting methodologies are employed based upon the assumption that the behavior of future observations will not differ greatly from the behavior of past observations. When the future is radically different than the past, as in the case of special cargo tonnage for FY 82, forecasts cannot predict the future with any degree of accuracy.

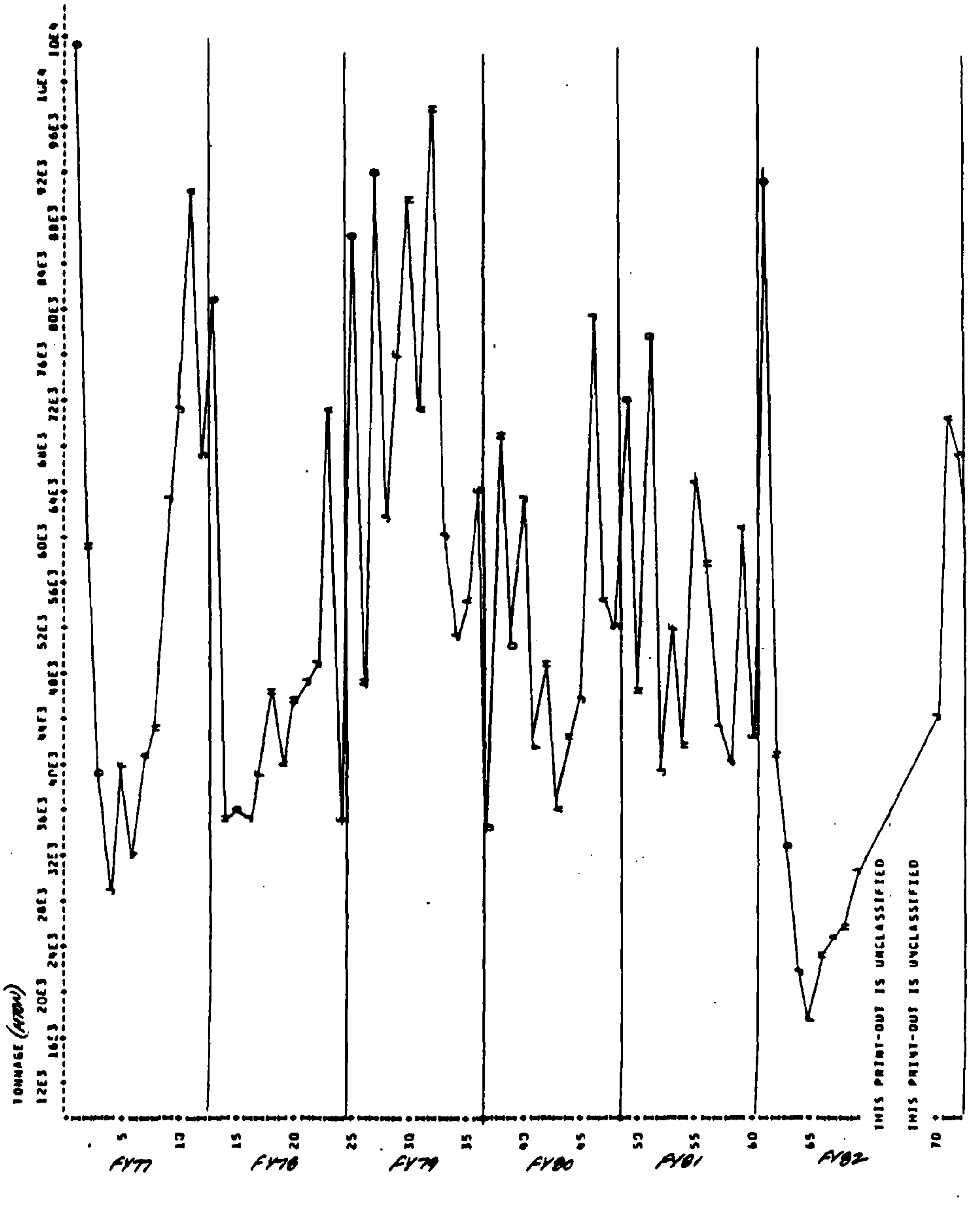
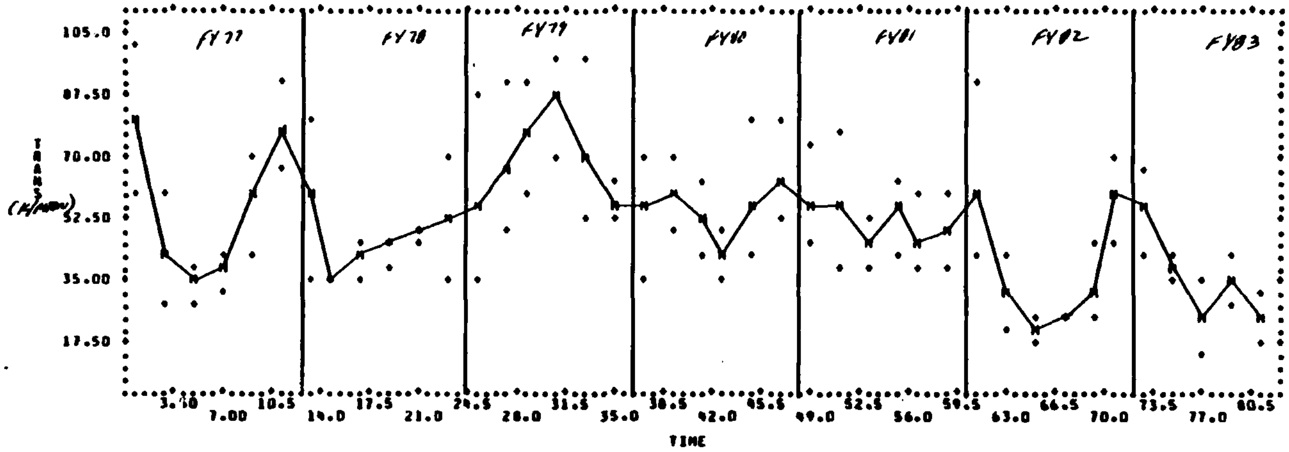
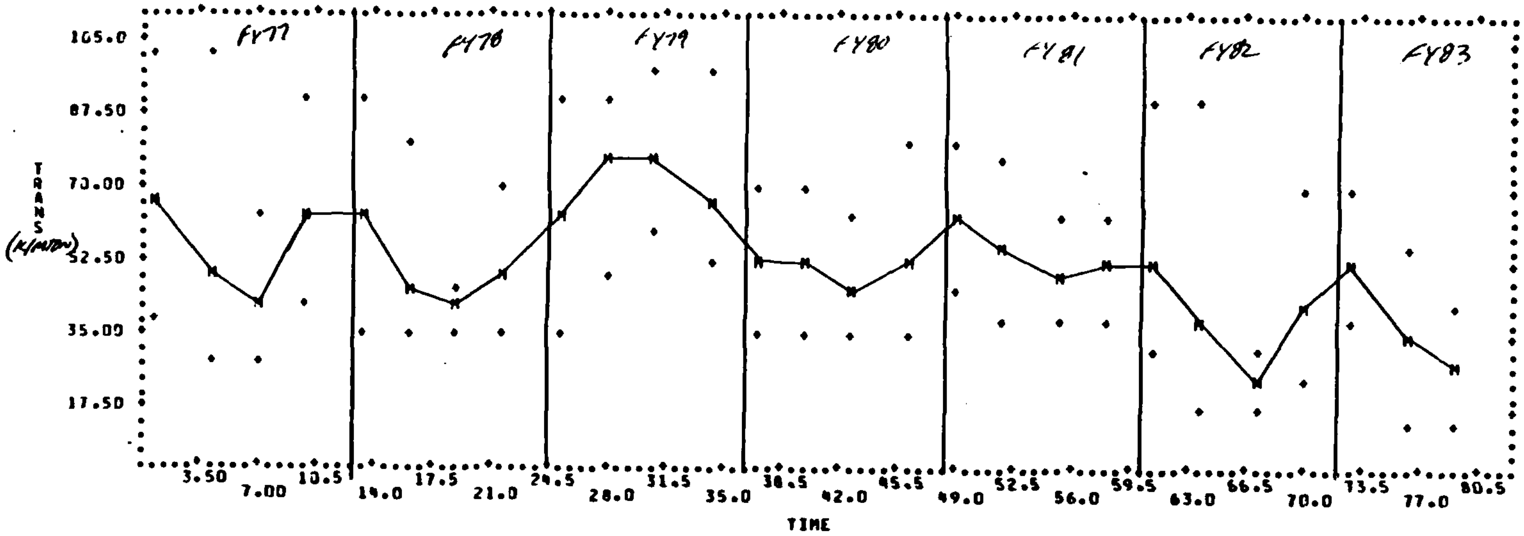


Figure F-69. Special Cargo FY 77 - FY 82



TIME VALUE	NO. OF CASES	MINIMUM VALUE	MEAN	MAXIMUM VALUE
1.000	2	58.8710	81.0140	103.1570
3.000	3	24.4770	42.2693	58.8710
5.000	3	28.4770	33.3747	39.8540
7.000	3	31.7930	38.7012	43.1397
9.000	3	43.1397	59.3142	71.2807
11.000	3	67.3351	76.2557	90.1931
13.000	3	35.1168	61.2073	81.1703
15.000	3	35.1168	35.4409	35.6833
17.000	3	35.5454	40.2537	46.1395
19.000	3	39.6838	43.8654	46.1395
21.000	3	45.7729	47.2721	48.9943
23.000	3	34.8689	51.7749	71.4612
25.000	3	34.8689	56.1375	86.1509
27.000	3	47.3928	66.9249	92.1618
29.000	3	61.2186	75.5618	89.7008
31.000	3	71.4103	86.3621	97.9752
33.000	3	51.0957	69.7997	97.9752
35.000	3	51.0957	56.6973	64.1873
37.000	3	34.1999	55.7720	68.9292
39.000	3	59.7155	60.4269	68.9292
41.000	3	41.7536	51.1527	62.0359
43.000	3	35.9816	42.5301	48.8685
45.000	3	42.7402	55.7154	79.0213
47.000	3	51.7484	61.6455	79.0213
49.000	3	46.7733	56.9497	72.3276
51.000	3	39.0462	54.3733	77.3005
53.000	3	39.0462	44.3007	52.0462
55.000	3	41.8096	54.7250	64.5550
57.000	3	40.2291	47.1263	57.8104
59.000	3	40.2291	47.6559	63.6740
61.000	3	41.0209	58.1562	91.3829
63.000	3	21.8588	31.8693	41.0209
65.000	3	17.8238	21.0695	23.5263
67.000	3	23.5260	24.6399	25.3995
69.000	3	25.3995	33.2373	44.2224
71.000	3	44.2224	60.3509	70.0033
73.000	3	41.9286	55.2381	66.8269
75.000	3	33.9871	37.8759	41.9286
77.000	3	13.1577	25.1859	33.9871
79.000	3	28.4127	33.6022	40.2973
81.000	2	17.6220	24.6594	32.0967

Figure F-70. Three-month Moving Average - Special

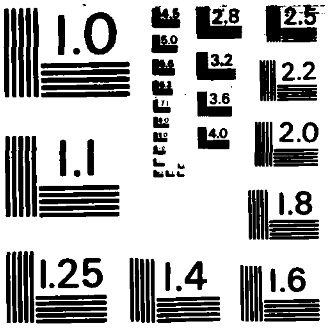


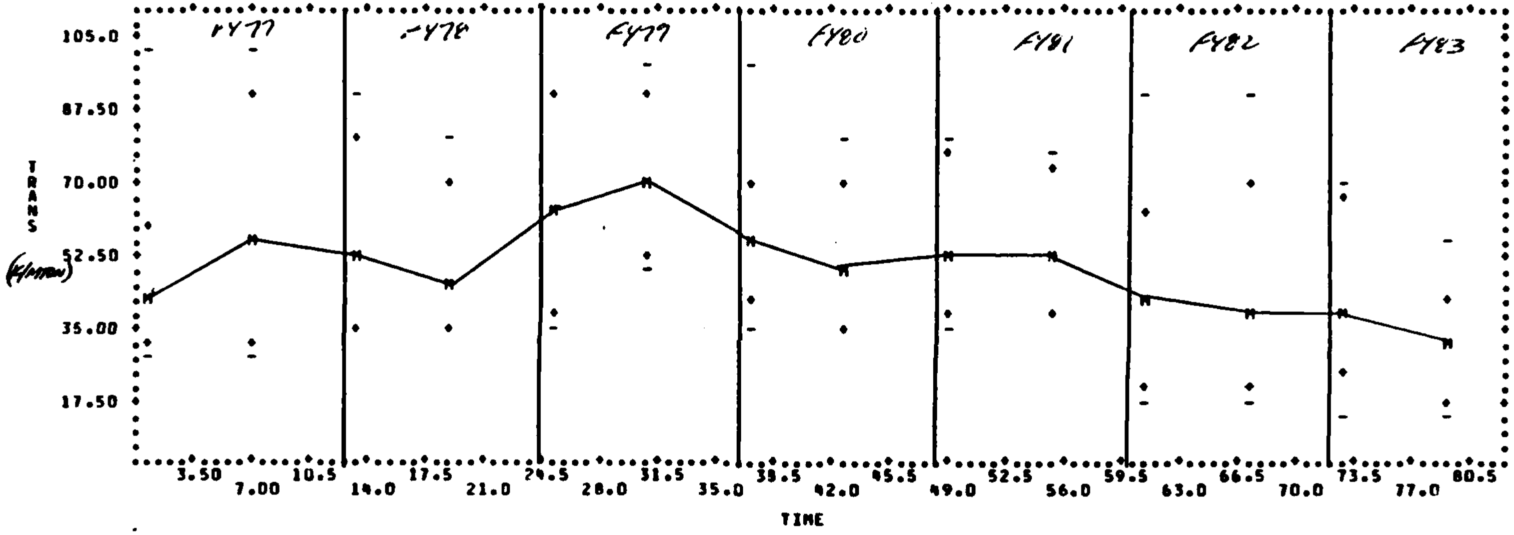
```
TIME        NO. OF     MINIMUM               MAXIMUM

VALUE       CASES       VALUE       MEAN      VALUE
   1.000       3       39.4600    67.1627  103.1570
   4.000       6       28.4770    50.2687  103.1570
   7.000       6       28.4770    41.3248   63.5142
  10.000       6       41.1710    62.7653   90.1431
  13.000       6       35.1168    63.4561   90.1431
  16.000       6       35.1168    45.4551   81.1770
  19.000       6       35.5454    42.2112   47.0492
  22.000       6       34.8689    47.9717   71.4612
  25.000       6       34.8689    63.5050   92.1618
  28.000       6       47.3928    75.3985   92.1619
  31.000       6       60.3283    76.0665   97.9752
  34.000       6       51.0957    66.6093   97.9752
  37.000       6       34.1999    53.9644   68.9292
  40.000       6       34.1999    51.2171   68.9292
  43.000       6       35.9816    46.2617   62.8359
  46.000       6       35.9816    51.5074   79.0213
  49.000       6       46.7733    63.5563   79.0213
  52.000       6       39.0462    54.8939   77.3005
  55.000       6       39.0462    49.7678   64.5550
  58.000       6       40.2291    51.4454   64.5550
  61.000       6       32.7281    51.3499   91.3829
  64.000       6       17.8238    39.0568   91.3829
  67.000       6       17.8238    23.9487   30.0899
  70.000       6       24.9941    43.5894   70.0033
  73.000       6       37.7103    52.9417   70.0033
  76.000       6       13.1577    35.3592   56.9587
  79.000       6       13.1577    27.5956   40.2970
```

Figure F-71. Six-month Moving Average - Special

AD-A139 872 TRANSPORTATION WORKLOAD FORECASTING (TWF) STUDY(U) ARMY 3/4
CONCEPTS ANALYSIS AGENCY BETHESDA MD J N KEENAN ET AL.
JAN 84 CAA-SR-84-2

UNCLASSIFIED F/G 15/5 NL


1.0
4.5
5.0
5.6
6.3
7.1
8.0
9.0
10
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6



```
  TIME      NO. OF     MINIMUM    TRIMMED    TRIMMED    TRIMMED     MAXIMUM
  VALUE     CASES       VALUE     MINIMUM     MEAN      MAXIMUM      VALUE
    1.000      6       28.4770    31.7930    42.4945    58.8710   103.1570
    7.000     12       28.4770    31.7930    54.6570    93.1431   103.1570
   13.000     12       35.1168    35.5454    52.4063    81.1700    90.1431
   19.000     12       34.8689    35.1169    44.4522    71.4612    81.1700
   25.000     12       34.8689    39.6839    61.3191    89.7008    92.1618
   31.000     12       47.3928    51.0957    70.6679    92.1618    97.9752
   37.000     12       34.1999    41.7536    57.4783    71.4103    97.9752
   43.000     12       34.1999    35.9816    50.3126    68.9292    79.0213
   49.000     12       35.9816    39.0462    52.3345    77.3005    79.0213
   55.000     12       39.0462    40.2291    52.1629    72.3276    77.3005
   61.000     12       17.8238    21.8589    42.7807    64.5550    91.3829
   67.000     12       17.8238    21.8588    38.0670    73.0033    91.3829
   73.000     12       13.1577    24.9941    39.0530    66.8269    70.0033
   79.000      9       13.1577    17.6220    33.1507    41.9286    56.9587
```

Figure F-72. Twelve-month Moving Average - Special

```
AUTOCORRELATIONS

 1- 12      .21  .39 -.03  0.0 -.14 -.19 -.16 -.12 -.06  .01 -.05 -.09
  ST.E.     .13  .13  .15  .15  .15  .15  .16  .16  .16  .16  .16  .16

13- 24     -.07 -.12 -.03 -.04  .08 -.03  .17  .01  .07 -.04 -.09 -.02
  ST.E.     .16  .16  .17  .17  .17  .17  .17  .17  .17  .17  .17  .17

25- 36     -.18 -.01 -.12 -.02  .02 -.04  .01 -.10 -.04  0.0  .02  .05
  ST.E.     .17  .17  .17  .18  .18  .18  .18  .18  .18  .18  .18  .18

PLOT OF AUTOCORRELATIONS

            -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR.   +----+----+----+----+----+----+----+----+----+----+
                                       I
  1     .206                   +     IXXXXX+
  2     .393                  +      IXXXXXX+XXX
  3    -.025                  +     XI      +
  4     .001                  +      I      +
  5    -.140                  +  XXXXI      +
  6    -.191                 +  XXXXXI       +
  7    -.162                 +   XXXXI       +
  8    -.125                 +    XXXI       +
  9    -.055                 +      XI       +
 10     .014                 +       I       +
 11    -.045                 +      XI       +
 12    -.093                 +     XXI       +
 13    -.071                 +     XXI       +
 14    -.119                 +    XXXI       +
 15    -.031                 +      XI       +
 16    -.036                 +      XI       +
 17     .084                 +       IXX     +
 18    -.033                 +      XI       +
 19     .172                 +       IXXXX   +
 20     .011                 +       I       +
 21     .074                 +       IXX     +
 22    -.044                 +      XI       +
 23    -.088                 +     XXI       +
 24    -.024                 +      XI       +
 25    -.180                 +  XXXXXI       +
 26    -.008                +        I        +
 27    -.119                +     XXXI        +
 28    -.017                +        I        +
 29     .017                +        I        +
 30    -.036                +       XI        +
 31     .008                +        I        +
 32    -.100                +      XXI        +
 33    -.038                +       XI        +
 34    -.004                +        I        +
 35     .020                +        IX       +
 36     .053                +        IX       +
```

stderror

$= \frac{1}{\sqrt{60}}(1.96)$

$= .253$

Figure F-73. ACF - Raw Data - Special

```
PARTIAL AUTOCORRELATIONS

  1- 12       .21  .37 -.18 -.14 -.05 -.14 -.05  .03  0.0  .03 -.11 -.19
  ST.E.       .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 13- 24      -.02 -.05  .01  .04  .06 -.15  .10 -.02 -.08  0.0 -.11  .04
  ST.E.       .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 25- 36      -.14 -.01 -.03 -.05  .03 -.11 -.04 -.13 -.05  .06  .02 -.07
  ST.E.       .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

PLOT OF PARTIAL AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1    .206                    +     IXXXXX+
  2    .366                    +     IXXXXX+XXX
  3   -.183                    +XXXXXI     +
  4   -.137                    +  XXXI     +
  5   -.051                    +    XI     +
  6   -.142                    + XXXXI     +
  7   -.045                    +    XI     +
  8    .026                    +     IX    +
  9    .003                    +     I     +
 10    .031                    +     IX    +
 11   -.105                    +  XXXI     +
 12   -.189                    +XXXXXI     +
 13   -.019                    +     I     +
 14   -.046                    +    XI     +
 15    .009                    +     I     +
 16    .038                    +     IX    +
 17    .061                    +     IXX   +
 18   -.152                    + XXXXI     +
 19    .097                    +     IXX   +
 20   -.024                    +    XI     +
 21   -.079                    +   XXI     +
 22   -.001                    +     I     +
 23   -.105                    +  XXXI     +
 24    .038                    +     IX    +
 25   -.137                    +  XXXI     +
 26   -.014                    +     I     +
 27   -.028                    +    XI     +
 28   -.055                    +    XI     +
 29    .034                    +     IX    +
 30   -.107                    +  XXXI     +
 31   -.045                    +    XI     +
 32   -.131                    +  XXXI     +
 33   -.047                    +    XI     +
 34    .057                    +     IX    +
 35    .016                    +     I     +
 36   -.067                    +   XXI     +
```

Figure F-74. PACF - Raw Data - Special

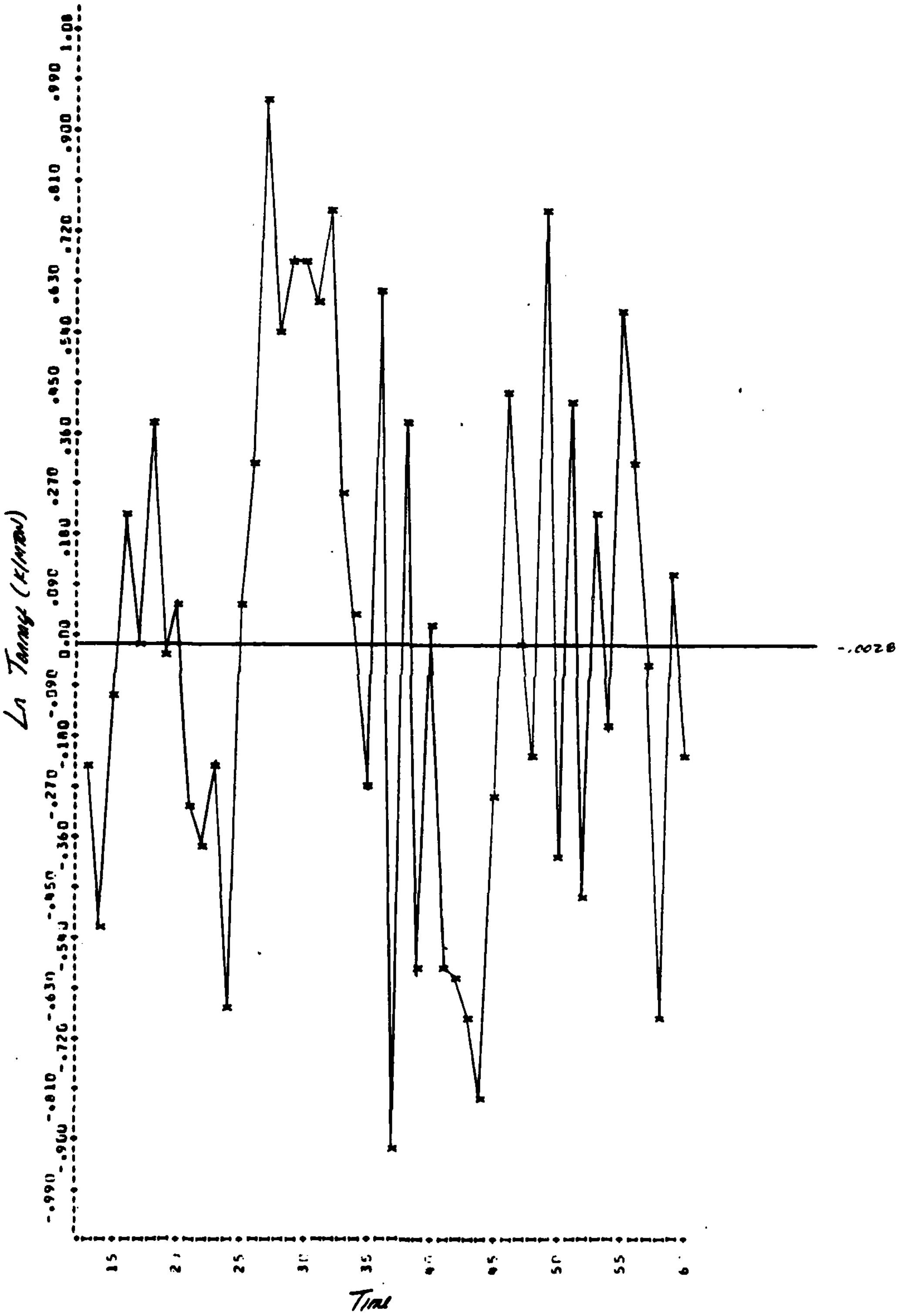


Figure F-75. Log Differenced Series (12-month lag) - Special

```
AUTOCORRELATIONS

 1- 12      .21  .49  .03  .15 -.10 -.04 -.14 -.14 -.12 -.16 -.11 -.46
  ST.E.     .14  .15  .18  .18  .18  .18  .18  .19  .19  .19  .19  .19

13- 24     -.05 -.32 -.02 -.17  .02 -.03  .12  .12  .12  .02  .09  .04
  ST.E.     .22  .22  .23  .23  .23  .23  .23  .23  .23  .23  .23  .23

25- 36     -.06  0.0 -.03  .07  .04  .03 -.04 -.09 -.01 -.01 -.01  .02
  ST.E.     .23  .23  .23  .23  .23  .23  .23  .23  .24  .24  .24  .24

PLOT OF AUTOCORRELATIONS

          -1.0   -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG    CORR. +----+----+----+----+----+----+----+----+----+----+
                                      I
  1     .213                   +      IXXXXX +
  2     .406                   +      IXXXXXX+XXXXX
  3     .030                 +        IX       +
  4     .150                 +        IXXXX    +
  5    -.103                 +     XXXI        +
  6    -.039                 +       XI        +
  7    -.142                 +    XXXXI        +
  8    -.135                 +     XXXI        +
  9    -.123                 +     XXXI        +
 10    -.160                 +    XXXXI        +
 11    -.113                 +     XXXI        +
 12    -.460              XX+XXXXXXXXXI         +
 13    -.047                +         XI          +
 14    -.315                +  XXXXXXXXI          +
 15    -.024                +         XI          +
 16    -.168                +      XXXXI          +
 17     .021                +          IX         +
 18    -.029                +         XI          +
 19     .121                +          IXXX       +
 20     .121                +          IXXX       +
 21     .116                +          IXXX       +
 22     .020                +          IX         +
 23     .090                +          IXX        +
 24     .079                +          IX         +
 25    -.059                +         XI          +
 26     .003                +          I          +
 27    -.027                +         XI          +
 28     .071                +          IXX        +
 29     .040                +          IX         +
 30     .033                +          IX         +
 31    -.036                +         XI          +
 32    -.091                +        XXI          +
 33    -.012               +           I           +
 34    -.014               +           I           +
 35    -.007               +           I           +
 36     .017               +           I           +
```

std error

$= \frac{1}{\sqrt{48}}(1.96)$

$= .283$

Figure F-76. ACF - Lagged 12 Months

```
PARTIAL AUTOCORRELATIONS

  1- 12      .21  .46 -.17 -.07 -.08 -.07 -.03 -.09 -.01 -.07 -.05 -.49
   ST.E.     .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14

 13- 24      .20  .07 -.18 -.02 -.06  .03  .05  .03 -.09 -.13  .05 -.24
   ST.E.     .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14

 25- 36     -.03 -.01  .04  .09 -.09 -.13 -.04  .01  .02  0.0  .08 -.14
   ST.E.     .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14

PLOT OF PARTIAL AUTOCORRELATIONS

           -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG    CORR. +----+----+----+----+----+----+----+----+----+----+
                                      I
  1     .213                  +      IXXXXX +
  2     .461                  +      IXXXXXX+XXXXX
  3    -.165                  +  XXXXI      +
  4    -.074                  +    XXI      +
  5    -.078                  +    XXI      +
  6    -.066                  +    XXI      +
  7    -.026                  +     XI      +
  8    -.088                  +    XXI      +
  9    -.006                  +      I      +
 10    -.073                  +    XXI      +
 11    -.052                  +     XI      +
 12    -.491             XXXXX+XXXXXXI      +
 13     .197                  +      IXXXXX +
 14     .071                  +      IXX    +
 15    -.177                  +  XXXXI      +
 16    -.019                  +      I      +
 17    -.065                  +    XXI      +
 18     .028                  +      IX     +
 19     .054                  +      IX     +
 20     .029                  +      IX     +
 21    -.087                  +    XXI      +
 22    -.135                  +   XXXI      +
 23     .054                  +      IX     +
 24    -.242                  +XXXXXXI      +
 25    -.025                  +     XI      +
 26    -.011                  +      I      +
 27     .037                  +      IX     +
 28     .082                  +      IXX    +
 29    -.091                  +    XXI      +
 30    -.133                  +   XXXI      +
 31    -.039                  +     XI      +
 32     .008                  +      I      +
 33     .020                  +      IX     +
 34     .002                  +      I      +
 35     .078                  +      IXX    +
 36    -.141                  +  XXXXI      +
```

Figure F-77. PACF - Lagged 12 Months

```
ESTIMATION BY BACKCASTING METHOD

RELATIVE CHANGE IN RESIDUAL SUM OF SQUARES LESS THAN  .1000-034


SUMMARY OF THE MODEL

OUTPUT VARIABLE -- TRANS
INPUT VARIABLES -- NOISE

VARIABLE  VAR. TYPE  MEAN      TIME     DIFFERENCES
                                                 12
TRANS       RANDOM             1-  60  (1-B   )

PARAMETER VARIABLE   TYPE  FACTOR  ORDER ESTIMATE        ST. ERR.  T-RATIO
      1    TRANS      MA      1     12     .8014           .0756     10.61
      2    TRANS      MA      1     14     .1503           .0912      1.65
      3    TRANS      AR      1      1     .1496           .1232      1.21
      4    TRANS      AR      1      2     .3875           .1224      3.16

RESIDUAL SUM OF SQUARES  =          3.427251 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM       =                42
RESIDUAL MEAN SQUARE     =           .081601
```

Figure F-78. Model Parameters - Special

```
AUTOCORRELATIONS

 1- 12       .10  .07 -.13 -.04 -.16 -.09 -.11 -.03  0.0  .16  .05 -.19
 ST.E.       .13  .13  .13  .13  .13  .14  .14  .14  .14  .14  .14  .14

13- 24      -.01 -.13 -.03  0.0  .04  .01  .10  .17  .07 -.05  .07 -.06
 ST.E.       .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15

25- 36      -.17 -.12 -.11  .02  .07  .05 -.01 -.12  0.0  .08 -.06 -.02
 ST.E.       .15  .16  .16  .16  .16  .16  .16  .16  .16  .16  .16  .16

PLOT OF AUTOCORRELATIONS

                  -1.0 -.8  -.6  -.4  -.2  .0   .2   .4   .6   .8  1.0
LAG       CORR.   +----+----+----+----+----+----+----+----+----+----+
                                           I
   1      .096                       +     IXX   +
   2      .067                       +     IXX   +
   3     -.134                       +  XXXI     +
   4     -.035                      +     XI      +
   5     -.161                      +  XXXXI      +
   6     -.091                      +    XXI      +
   7     -.112                      +   XXXI      +
   8     -.03[illegible]                      +     XI      +
   9     -.005                      +      I      +
  10      .159                      +      IXXXX  +
  11      .045                      +      IX     +
  12     -.188                      + XXXXXI      +
  13     -.010                      +      I      +
  14     -.131                      +   XXXI      +
  15     -.034                      +     XI      +
  16     -.003                      +      I      +
  17      .041                      +      IX     +
  18      .011                      +      I      +
  19      .103                      +      IXXX   +
  20      .169                      +      IXXXX  +
  21      .071                     +       IXX     +
  22     -.050                     +      XI       +
  23      .070                     +       IXX     +
  24     -.062 (.219)60 = 13.15    +     XXI       +
  25     -.168                     +   XXXXI       +
  26     -.123                     +    XXXI       +
  27     -.114                     +    XXXI       +
  28      .018                     +       I       +
  29      .072                     +       IXX     +
  30      .053                     +       IX      +
  31     -.015                     +       I       +
  32     -.116                     +    XXXI       +
  33     -.001                     +       I       +
  34      .076                     +       IXX     +
  35     -.060                     +     XXI       +
  36     -.016                     +       I       +
```

Figure F-79. Estimated Residuals - Special

```
FORECAST ON VARIABLE TRANS     FROM TIME PERIOD    61

PERIOD             FORECASTS              ST.  ERR.          ACTUAL
  61               11.15029  69.503       .39957            91.303     21.8
  62               10.61142  40.588       .40402            41.021       .433
  63               10.81754  49.808       .43595            32.728    -17.08
  64               10.30615  29.916       .43855            21.859     -8.057
  65               10.45361  34.050       .44419            17.824    -16.226
  66               10.33114  30.673       .44514            23.526     -7.147
  67               10.56622  38.801       .44627            24.994    -13.807
  68               10.56392  38.712       .44655            25.4      -13.312
  69               10.73868  46.105       .44690            30.09     -16.015
  70               10.80981  49.504       .44697            44.222     -5.282
  71               11.21739  74.413       .44693            70.03      -4.383
  72               10.95415  57.190       .44695            66.827      9.637
STANDARD ERROR =  .399574      (BY CONDITIONAL METHOD  )

                         559.42                     489.83       MSE = 159.23
```

Figure F-80. Forecast FY 82 - Special

F-8. CARGO TRAILER/CONEX

a. The raw series for cargo trailer shipments is depicted in Figure F-81. The raw data do exhibit a seasonal pattern that trends upwards over time. The increasing trend over time is more clearly evident after reviewing the 3-month and 6-month moving average diagrams (Figures F-82 and F-83). According to the 12-month moving average diagram (Figure F-84), the increasing trend appears to be an increasing linear function over time. However, it should be noted that over the past 2 years (FY 81-FY 83), the trend has remained flat.

b. Autocorrelation function analysis (Figures F-85 and F-86) of the data confirms the existence of the seasonality in the data as indicated by the damping peaks at 12, 24, and 36 lags. To eliminate the seasonality, the series was differenced at a lag of 12 months. Figure F-87 depicts the seasonally adjusted series. The autocorrelation and partial autocorrelation functions of the seasonally adjusted series are illustrated in Figures F-88 and F-89. The autocorrelation function indicates that the series is stationary and that a mean exists in the series (t-value of mean is significant at the 5 percent significance level).

c. Analysis of the autocorrelation and partial autocorrelation functions suggests that the data could be modeled with an ARIMA (0,0,1) nonseasonal model and an ARIMA (0,1,1) seasonal model. Thus, the suggested model takes the form:

$$(1 - B^{12})\, X_t = \mu + (1 - \theta_1 B)\,(1 - \theta_{12} B^{12})\epsilon_t$$

d. The results of the model (Figure F-90) are as follows:

$$(1 - B^{12})\, X_t = \underset{(4.09)}{.4057} + (1 + \underset{(-2.32)}{.2912B})\,(1 - \underset{(14.97)}{.8264B^{12}})\epsilon_t$$

$$\chi^2\ (2,20) = 12.74$$

The results indicate that all of the estimated parameters are significant at the 5 percent significance level. The Q statistic for the estimated model residuals at 20 degrees of freedom is 12.74 which is significant at the 13 percent significance level (Figure F-91). Therefore, the null hypothesis, uncorrelated residuals, should not be rejected at the 13 percent significance level.

e. The model forecasted CONEX/cargo trailer shipments for FY 82 to be 76.43 K/MTON (Figure F-92) versus an actual lift for FY 82 of 74.47 K/MTON. The MSE of the forecast was .81 and the annual forecast error was 2.6 percent.

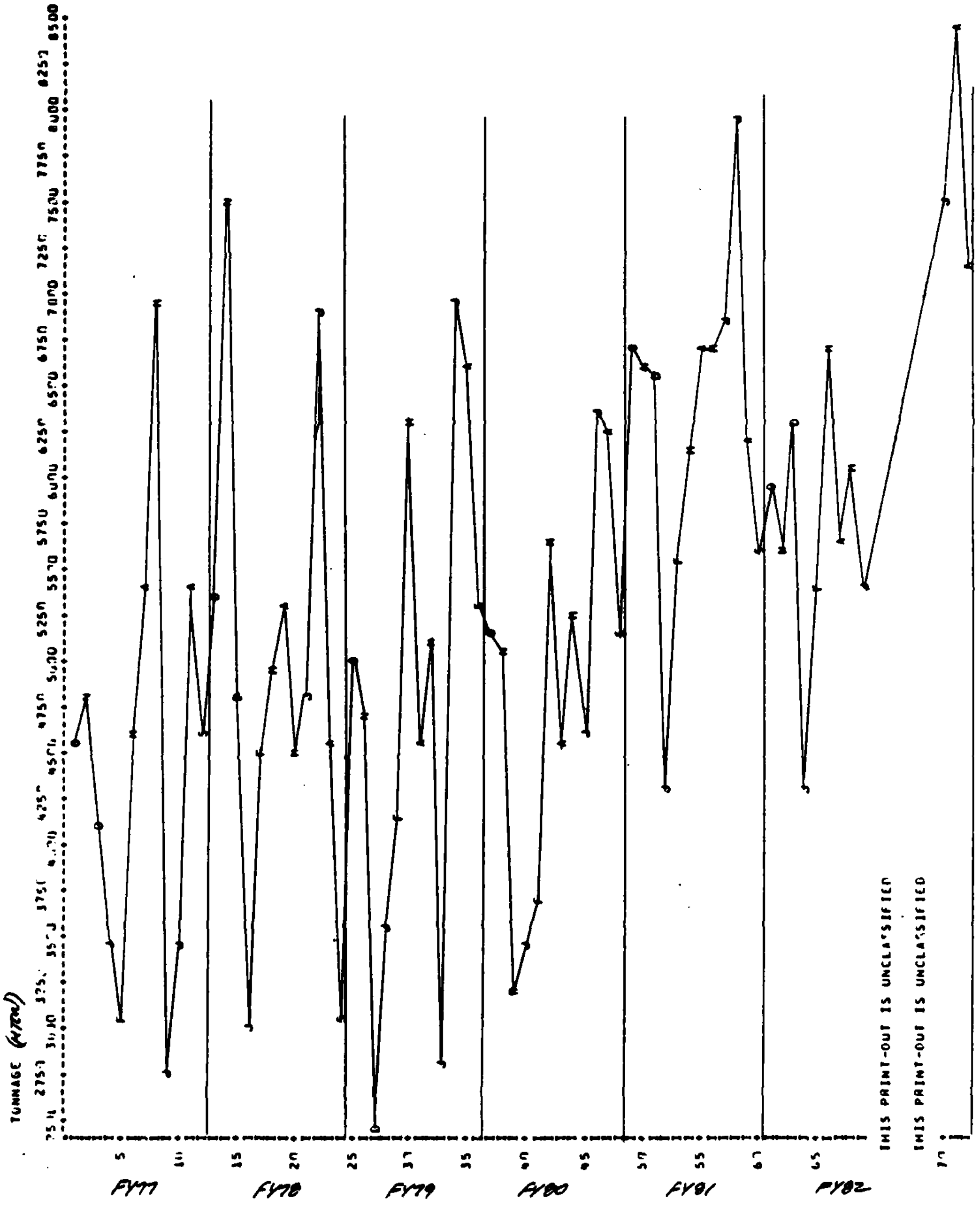
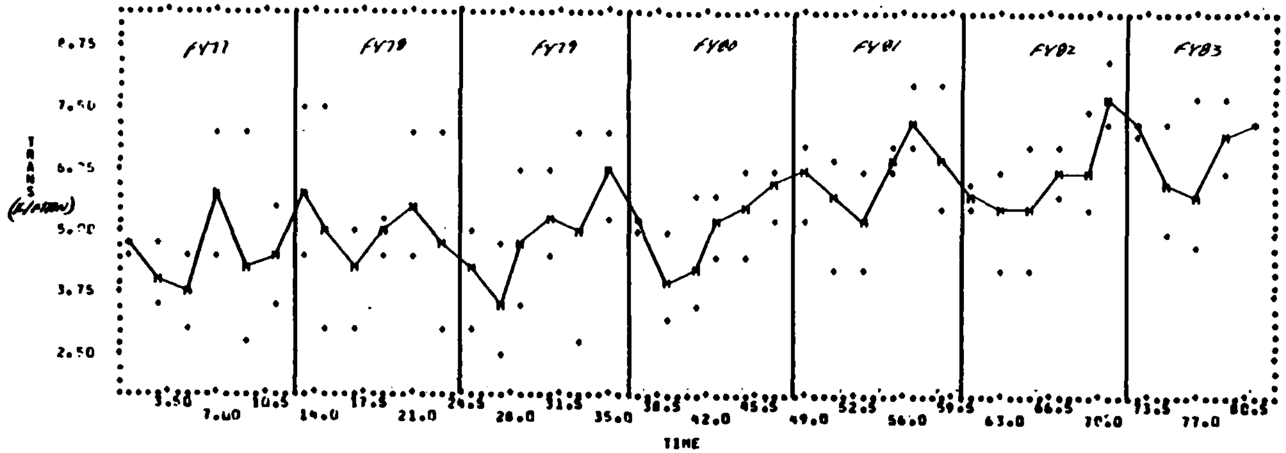
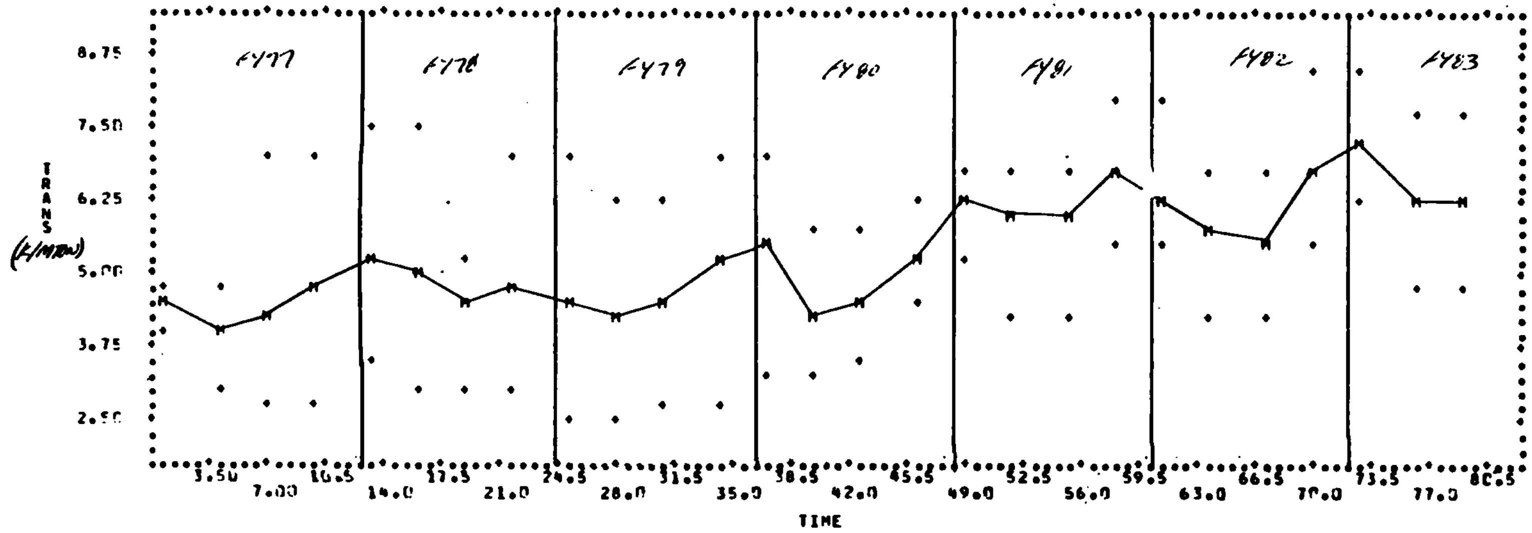


Figure F-81. CONEX Cargo FY 77 - FY 82



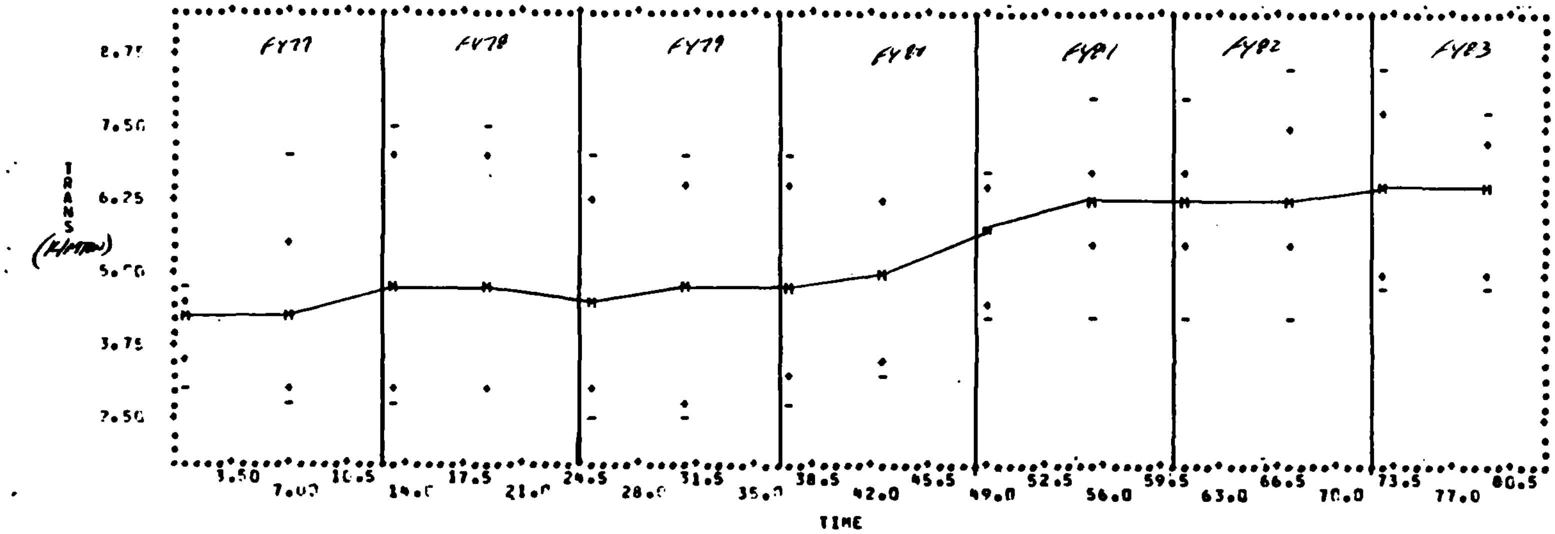
```
TIME      NO. OF   MINIMUM               MAXIMUM

VALUE     CASES     VALUE      MEAN       VALUE
   1.000    2      4.5660     4.6815     4.7970
   3.000    3      3.4350     4.1057     4.7970
   5.000    3      3.0350     3.6963     4.6190
   7.000    3      4.6190     5.6490     6.9250
   9.000    3      2.7400     4.3670     6.9250
  11.000    3      3.4360     4.4813     5.4230
  13.000    3      4.5850     5.8357     7.5030
  15.000    3      3.0784     5.1058     7.5030
  17.000    3      3.0084     4.1492     4.9552
  19.000    3      4.5176     4.9284     5.3122
  21.000    3      4.5178     5.3948     6.8903
  23.000    3      3.0430     4.8203     6.8903
  25.000    3      3.0478     4.2472     4.9921
  27.000    3      2.4597     3.5679     4.7088
  29.000    3      3.5361     4.6595     6.3034
  31.000    3      4.5670     5.3157     6.3034
  33.000    3      2.8797     4.9493     6.9616
  35.000    3      5.3198     6.2965     6.9616
  37.000    3      5.0691     5.1822     5.3198
  39.000    3      3.1546     3.9096     5.0691
  41.000    3      3.4648     4.2686     5.6343
  43.000    3      4.5471     5.1497     5.6343
  45.000    3      4.6012     5.4091     6.3585
  47.000    3      5.1696     5.9232     6.3585
  49.000    3      5.1696     6.1646     6.6991
  51.000    3      4.3275     5.4387     6.6250
  53.000    3      4.3275     5.3502     6.1658
  55.000    3      6.1658     6.5266     6.7184
  57.000    3      6.7184     7.1738     7.9621
  59.000    3      5.5836     6.5787     7.9671
  61.000    3      5.5836     5.7238     5.9678
  63.000    3      4.2890     5.4148     6.3056
  65.000    3      4.2890     5.4738     6.7176
  67.000    3      5.6281     6.1295     6.7176
  69.000    3      5.3789     6.3171     7.4995
  71.000    3      7.1727     7.7119     8.4327
  73.000    3      7.0979     7.1705     7.2477
  75.000    3      4.9122     6.1002     7.4877
  77.000    3      4.7567     5.7764     7.6672
  79.000    3      6.1662     6.9922     7.6672
  81.000    2      7.1513     7.2449     7.3395
```

Figure F-82. Three-month Moving Average - CONEX



```
TIME      NO. OF    MINIMUM              MAXIMUM

VALUE     CASES      VALUE      MEAN      VALUE
   1.000      3     4.0850     4.4827    4.7970
   4.000      6     3.0350     4.0895    4.7970
   7.000      6     2.7410     4.3595    6.9250
  10.000      6     2.7400     4.7523    6.9250
  13.000      6     3.4360     5.1808    7.5000
  16.000      6     3.0094     5.0348    7.5000
  19.000      6     3.0084     4.5789    5.3122
  22.000      6     3.0438     4.8445    6.8903
  25.000      6     2.4587     4.4368    6.8903
  28.000      6     2.4537     4.3564    6.7434
  31.000      6     2.8097     4.4753    6.7434
  34.000      6     2.6097     5.2238    6.9616
  37.000      6     3.1948     5.3842    6.9616
  40.000      6     3.1948     4.3703    5.6343
  43.000      6     3.4646     4.5371    5.6343
  46.000      6     4.5471     5.3643    6.3585
  49.000      6     5.0696     6.2774    6.6991
  52.000      6     4.3205     5.9969    6.6991
  55.000      6     4.3205     6.0509    6.9407
  58.000      6     5.5836     6.6648    7.9621
  61.000      6     5.5636     6.2712    7.9621
  64.000      6     4.2890     5.7191    6.7176
  67.000      6     4.2890     5.5705    6.7176
  70.000      6     5.3789     6.6924    8.4320
  73.000      6     6.1747     7.2696    8.4320
  76.000      6     4.7567     6.3771    7.6602
  79.000      6     4.7567     6.3319    7.6602
```

Figure F-83. Six-month Moving Average - CONEX



TIME VALUE	NO. OF CASES	MINIMUM VALUE	TRIMMED MINIMUM	TRIMMED MEAN	TRIMMED MAXIMUM	MAXIMUM VALUE
1.000	6	3.0350	3.4350	4.1762	4.6190	4.7970
7.000	12	2.7400	3.0350	4.3384	5.4230	6.9250
13.000	12	2.7400	3.0084	4.8361	6.9750	7.5000
19.000	12	3.0084	3.2018	4.8647	6.8903	7.5000
25.000	12	2.4587	3.0408	4.5856	6.3734	6.8903
31.000	12	2.4587	2.8397	4.8061	6.6782	6.9616
37.000	12	2.9397	3.1948	4.7793	6.6782	6.9616
43.000	12	4.1946	3.4648	4.8854	6.2414	6.3585
49.000	12	4.3215	4.5471	5.7131	6.6250	6.6991
55.000	12	4.3215	5.5643	6.3651	6.8407	7.9621
61.000	12	4.2890	5.4147	6.2052	6.8407	7.9621
67.000	12	4.2890	5.3789	6.1746	7.4995	8.4320
73.000	12	4.7567	4.9122	6.4808	7.6602	8.4320
79.000	9	4.7567	4.9122	6.5631	7.3395	7.6602

Figure F-84. Twelve-month Moving Average - CONEX

```
AUTOCORRELATIONS

  1- 12      .35  .08  .11  .20  .04  .07  .12  .16  0.0 -.10  .09  .24
 ST.E.       .13  .14  .14  .15  .15  .15  .15  .15  .16  .16  .16  .16

 13- 24      .01  .02  .06  .03 -.06 -.16 -.12  .02  .05  .02  .12  .15
 ST.E.       .16  .16  .16  .16  .16  .16  .17  .17  .17  .17  .17  .17

 25- 36     -.15 -.14 -.06  .04 -.07 -.15 -.19 -.08 -.10 -.05  .05  .14
 ST.E.       .17  .17  .18  .18  .18  .18  .18  .18  .18  .18  .18  .18

PLOT OF AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1    .353                    +     IXXXXX+XXX
  2    .079                   +      IXX    +
  3    .110                   +      IXXX   +
  4    .197                   +      IXXXXX +
  5    .039                   +      IX     +
  6    .075                   +      IXX    +
  7    .115                   +      IXXX   +
  8    .165                   +      IXXXX  +
  9    .001                  +       I       +
 10   -.101                  +    XXXI       +
 11    .085                  +       IXX     +
 12    .243                  +       IXXXXXX +
 13    .014                  +       I       +
 14    .019                  +       I       +
 15    .061                  +       IXX     +
 16    .027                  +       IX      +
 17   -.060                  +     XXI       +
 18   -.159                  +   XXXXI       +
 19   -.119                  +    XXXI       +
 20    .019                  +       I       +
 21    .046                  +       IX      +
 22    .023                  +       IX      +
 23    .119                  +       IXXX    +
 24    .146                  +       IXXXX   +
 25   -.150                  +   XXXXI       +
 26   -.140                 +     XXXI        +
 27   -.062                 +      XXI        +
 28    .035                 +        IX       +
 29   -.074                 +      XXI        +
 30   -.152                 +    XXYXI        +
 31   -.189                 +   XXXXXI        +
 32   -.081                 +      XXI        +
 33   -.095                 +      XXI        +
 34   -.045                 +       XI        +
 35    .052                 +        IX       +
 36    .138                 +        IXXX     +
```

std error

$= \frac{1}{\sqrt{60}}(1.96)$

$= .253$

Figure F-85. ACF - Raw Data - CONEX

```
PARTIAL AUTOCORRELATIONS

  1- 12       .35  -.05   .11   .14  -.09   .10   .04   .10  -.10  -.12   .16   .16
 ST.E.        .13   .13   .13   .13   .13   .13   .13   .13   .13   .13   .13   .13

 13- 24      -.13   .08  -.05  -.03   0.0  -.22  -.05   .06   .11   .09   .05   .08
 ST.E.        .13   .13   .13   .13   .13   .13   .13   .13   .13   .13   .13   .13

 25- 36      -.26  -.04  -.07   0.0  -.04  -.06  -.08   .04   .04   .04  -.03   .09
 ST.E.        .13   .13   .13   .13   .13   .13   .13   .13   .13   .13   .13   .13

PLOT OF PARTIAL AUTOCORRELATIONS

           -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR.  +----+----+----+----+----+----+----+----+----+----+
                                      I
  1    .353                     +     IXXXXX+XXX
  2   -.052                     +    XI     +
  3    .113                     +     IXXX  +
  4    .143                     +     IXXXX +
  5   -.093                     +   XXI     +
  6    .105                     +     IXXX  +
  7    .041                     +     IX    +
  8    .100                     +     IXX   +
  9   -.097                     +   XXI     +
 10   -.118                     +  XXXI     +
 11    .164                     +     IXXXX +
 12    .155                     +     IXXXX +
 13   -.126                     +  XXXI     +
 14    .076                     +     IXX   +
 15   -.045                     +    XI     +
 16   -.035                     +    XI     +
 17   -.005                     +     I     +
 18   -.216                     +XXXXXI     +
 19   -.051                     +    XI     +
 20    .061                     +     IXX   +
 21    .115                     +     IXXX  +
 22    .094                     +     IXX   +
 23    .055                     +     IX    +
 24    .082                     +     IXX   +
 25   -.258                     XXXXXXI     +
 26   -.043                     +    XI     +
 27   -.068                     +   XXI     +
 28    .001                     +     I     +
 29   -.039                     +    XI     +
 30   -.058                     +    XI     +
 31   -.083                     +   XXI     +
 32    .040                     +     IX    +
 33    .036                     +     IX    +
 34    .037                     +     IX    +
 35   -.033                     +    XI     +
 36    .090                     +     IXX   +
```

Figure F-86. PACF - Raw Data - CONEX

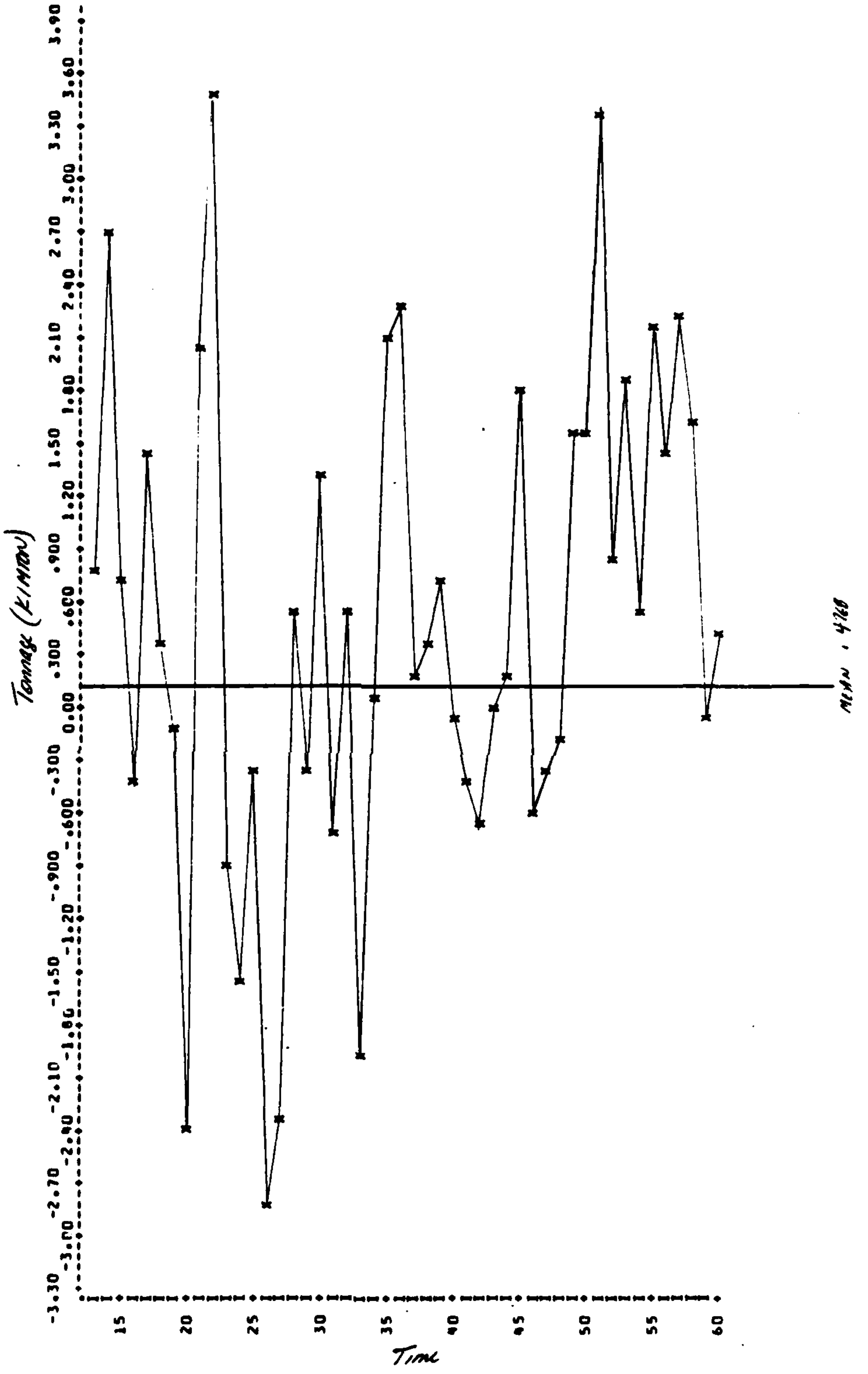


Figure F-87. Differenced Series (12-month lag) - CONEX

```
AUTOCORRELATIONS

  1- 12     .28   .03   .01   .12  -.03   .12   .21   .10  -.13  -.15  -.15  -.27
  ST.E.     .14   .16   .16   .16   .16   .16   .16   .16   .17   .17   .17   .17

 13- 24     .08   .12   .10  -.03   .05  -.05  -.06  -.04   .12   .04   .01  -.21
  ST.E.     .18   .18   .18   .19   .19   .19   .19   .19   .19   .19   .19   .19

 25- 36    -.24  -.15  -.10  -.05  -.09  -.10  -.16  -.10  -.06   .01   .02   .08
  ST.E.     .19   .20   .20   .20   .20   .20   .20   .21   .21   .21   .21   .21

PLOT OF AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1    .277                   +      IXXXXXXX
  2    .035                  +       IX      +
  3    .013                  +       I       +
  4    .118                  +       IXXX    +
  5   -.034                  +      XI       +
  6    .116                  +       IXXX    +
  7    .212                  +       IXXXXX  +
  8    .104                  +       IXXX    +
  9   -.131                  +    XXXI       +
 10   -.151                  +   XXXXI       +
 11   -.152                  +   XXXXI       +
 12   -.267                 + XXXXXXXI        +
 13    .077                 +        IXX      +
 14    .122                 +        IXXX     +
 15    .103                 +        IXXX     +
 16   -.034                 +       XI        +
 17    .049                 +        IX       +
 18   -.052                 +       XI        +
 19   -.061                 +      XXI        +
 20   -.039                 +       XI        +
 21    .124                 +        IXXX     +
 22    .042                 +        IX       +
 23    .008                 +        I        +
 24   -.205                 +   XXXXXI        +
 25   -.237                 +  XXXXXXI        +
 26   -.147                +     XXXXI         +
 27   -.105                +      XXXI         +
 28   -.049                +        XI         +
 29   -.093                +       XXI         +
 30   -.099                +       XXI         +
 31   -.156                +     XXXXI         +
 32   -.096                +       XXI         +
 33   -.060                +       XXI         +
 34    .010                +         I         +
 35    .016                +         I         +
 36    .080                +         IXX       +
```

std error

$= \frac{1}{\sqrt{48}}(1.96)$

$= .283$

Figure F-88. ACF - Lagged 12 Months

```
PARTIAL AUTOCORRELATIONS

  1- 12      .28 -.05  .02  .12 -.11  .18  .15 -.02 -.15 -.12 -.13 -.24
  ST.E.      .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14

 13- 24      .26  .01  .12  .08  .07  0.0 -.06 -.11 -.07 -.07 -.01 -.28
  ST.E.      .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14

 25- 36     -.03  .02 -.02  .08 -.07 -.06 -.06  .03  .01 -.08  .03 -.12
  ST.E.      .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14

PLOT OF PARTIAL AUTOCORRELATIONS

            -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR.  +----+----+----+----+----+----+----+----+----+----+
                                      I
  1    .277                    +      IXXXXXXX
  2   -.046                    +     XI      +
  3    .017                    +      I      +
  4    .121                    +      IXXX   +
  5   -.110                    +   XXXI      +
  6    .175                    +      IXXXX  +
  7    .149                    +      IXXXX  +
  8   -.020                    +     XI      +
  9   -.146                    +  XXXXI      +
 10   -.122                    +   XXXI      +
 11   -.127                    +   XXXI      +
 12   -.243                    +XXXXXXI      +
 13    .260                    +      IXXXXXXX
 14    .011                    +      I      +
 15    .120                    +      IXXX   +
 16    .076                    +      IXX    +
 17    .067                    +      IXX    +
 18    .001                    +      I      +
 19   -.057                    +     XI      +
 20   -.113                    +   XXXI      +
 21   -.072                    +    XXI      +
 22   -.065                    +    XXI      +
 23   -.014                    +      I      +
 24   -.284                    XXXXXXXI      +
 25   -.028                    +     XI      +
 26    .016                    +      I      +
 27   -.025                    +     XI      +
 28    .080                    +      IXX    +
 29   -.065                    +    XXI      +
 30   -.061                    +    XXI      +
 31   -.059                    +     XI      +
 32    .025                    +      IX     +
 33    .008                    +      I      +
 34   -.077                    +    XXI      +
 35    .031                    +      IX     +
 36   -.120                    +   XXXI      +
```

Figure F-89. PACF - Lagged 12 Months

```
ESTIMATION BY BACKCASTING METHOD

RELATIVE CHANGE IN RESICUAL SUM OF SQUARES LESS THAN  .1000-0C4


SUMMARY OF THE MODEL

CUTPUT VARIABLE -- TRANS
INPUT VARIABLES -- NOISE

VARIABLE  VAR. TYPE  MEAN      TIME      DIFFERENCES
                                               12
TRANS       RANCOM              1-  60  (1-B   )

PARAMETER VARIABLE    TYPE  FACTOR  ORDER ESTIMATE         ST. ERR.  T-RATIO
     1    TRANS        MA      1       1     -.2912          .1254     -2.32
     2    TRANS        MA      2      12      .8264          .0552     14.97
     3    TRANS       TRND     1       0      .4057          .0992      4.09

RESIDUAL SUM OF SQUARES  =        40.249663 (BACKCASTS EXCLUDED)
DEGFEES OF FREEDOM       =               45
FESIDUAL MEAN SQUARE     =          .894437
```

Figure F-90. Model Parameters - CONEX

```
AUTOCORRELATIONS

  1- 12       .01  .03 -.07  .13 -.06  .20  .08  .02 -.11 -.03  .03 -.22
  ST.E.       .13  .13  .13  .13  .13  .13  .14  .14  .14  .14  .14  .14

 13- 24       .02  .05  .05 -.09  .12 -.09 -.11 -.13  .10  0.0  .09 -.19
  ST.E.       .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15

 25- 36      -.25 -.10 -.06  .05 -.06 -.07 -.14  0.0 -.06  .05 -.03  .05
  ST.E.       .16  .16  .17  .17  .17  .17  .17  .17  .17  .17  .17  .17

PLOT OF AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1    .008                    +     I     +
  2    .028                    +     IX    +
  3   -.068                    +   XXI     +
  4    .133                    +     IXXX  +
  5   -.056                    +    XI     +
  6    .205                    +     IXXXXX+
  7    .079                   +      IXX    +
  8    .018                   +      I      +
  9   -.114                   +   XXXI      +
 10   -.035                   +     XI      +
 11    .027                   +      IX     +
 12   -.224                   +XXXXXXI      +
 13    .025                   +      IX     +
 14    .050                   +      IX     +
 15    .052                   +      IX     +
 16   -.087                   +    XXI      +
 17    .118                   +      IXXX   +
 18   -.088                   +    XXI      +
 19   -.108                   +   XXXI      +
 20   -.129                   +   XXXI      +
 21    .095                  +       IXX     +
 22    .001                  +       I       +
 23    .087                  +       IXX     +
 24   -.189                  +  XXXXXI       +
 25   -.247                  + XXXXXXI       +
 26   -.098                  +     XXI       +
 27   -.056                  +      XI       +
 28    .045                  +       IX      +
 29   -.063                  +     XXI       +
 30   -.071                  +     XXI       +
 31   -.137                  +    XXXI       +
 32   -.002                  +       I       +
 33   -.056                  +      XI       +
 34    .052                  +       IX      +
 35   -.029                  +      XI       +
 36    .051                  +       IX      +
```

.212(60)=12.74

Figure F-91. Estimated Residuals - CONEX

```
 FORECAST ON VARIABLE TRANS    FROM TIME PERIOD    61
PERIOD            FORECASTS        ST.  ERR.      ACTUAL  |   ERROR
  61              6.58911          1.29529        5.968   |   -.621
  62              6.84431          1.34909        5.62    |  -1.224
  63              5.70318          1.34909        6.306   |    .603
  64              4.99943          1.34909        4.289   |   -.710
  65              5.27962          1.34909        5.415   |    .136
  66              6.70210          1.34909        6.718   |    .016
  67              6.83282          1.34909        5.628   |  -1.205
  68              7.63256          1.34909        6.043   |  -1.59
  69              5.36297          1.34909        5.379   |    .016
  70              6.83380          1.34909        7.499   |    .665
  71              7.16252          1.34909        8.432   |   1.269
  72              6.21428          1.34909        7.173   |    .959
STANDARD ERROR =  1.29529        (BY CONDITIONAL METHOD  )|
                 _______                        _______
                  76.43                          74.47     MSE = .81
```

Figure F-92. Forecast FY 82 - CONEX

F-9. FREEZE

a. The raw series for commodity freeze is depicted in Figure F-93. The raw series does not depict any visible pattern; however, the data exhibit an upward trend over time. The 3-month moving average (Figure F-94) indicates that the data may be seasonal with peaks and troughs occurring at the end and beginning of the fiscal year, respectively. The 6-month moving average (Figure F-95) clearly identifies an upward trend in the data, but the seasonal trend is muted. Finally, the 12-month moving average (Figure F-96) indicates a steady increase of tonnage shipped throughout the data period. In fact, the 12-month moving average suggests that the annual data follow a linear trend upwards.

b. Autocorrelation function analysis (Figure F-97) of the data affirms the trend and seasonality of the freeze data. The trend is verified by the high number of positive coefficients during the first 12 lags. The seasonality of the data is suggested by the significant coefficients at lags 11, 23, and 35. Seasonality in the data was eliminated by differencing the series at a lag of 12 months. The plot of the seasonally adjusted series is shown in Figure F-98. The autocorrelation and partial autocorrelation function of the seasonally adjusted series (Figures F-99 and F-100) indicate that stationarity in the data has not been achieved. To achieve stationarity the seasonally adjusted data was differenced at a lag of one month. The resulting autocorrelation and partial autocorrelation functions are depicted in Figures F-101 and F-102.

c. The autocorrelation function of the differenced series suggests the possibility of a mixed nonseasonal model and a MA seasonal model. The initial model hypothesized was an ARIMA (1,1,1) nonseasonal model and an ARIMA (0,1,1) seasonal model. The autocorrelation function of the estimated residuals for the model depicted significant coefficients at lags 2,3,5, and 11. Next a ARIMA (2,1,2) nonseasonal model was tried. The coefficient for lag 2 was statistically insignificant and the autocorrelation coefficient at lag 11 of the estimated residual was still significant. Finally, an ARIMA (2,1,2) model incorporating the parameter 11 as the second MA parameter was attempted. The form of this model was:

$$(1-\phi_1 B - \phi_2 B^2)(1-B^{12})(1-B)X_t = (1-\theta_1 B - \theta_{11} B^{11})(1-\theta_{12}B^{12})\epsilon_t$$

d. The results of the model (Figure F-103) are as follows:

$$(1+\underset{(-6.76)}{.7740}B+\underset{(-5.96)}{.6789}B^2)\ (1-B^{12})\ (1-B)\ X_t = (1-\underset{(4.32)}{.4729}B+\underset{(-5.76)}{.5038}B^{11})\ (1-\underset{(12.04)}{.7753}B^{12})\epsilon_t$$

$$\chi^2\ (5,20) = 14.66$$

The results indicate that all of the estimated parameters of the model are significant at the 5 percent significance level (Figure F-104). The Q statistic for 20 degrees of freedom is 14.66. Therefore, the null hypothesis, residuals are uncorrelated, should not be rejected at the 22 percent significance level.

e. The freeze seasonal model forecasted that 31.9 K/MTON would be transported during FY 82 versus an actual shipment of 36.4 K/MTON (Figure F-105). The MSE of the forecast was .49, and the annual forecast error was -12.5 percent.

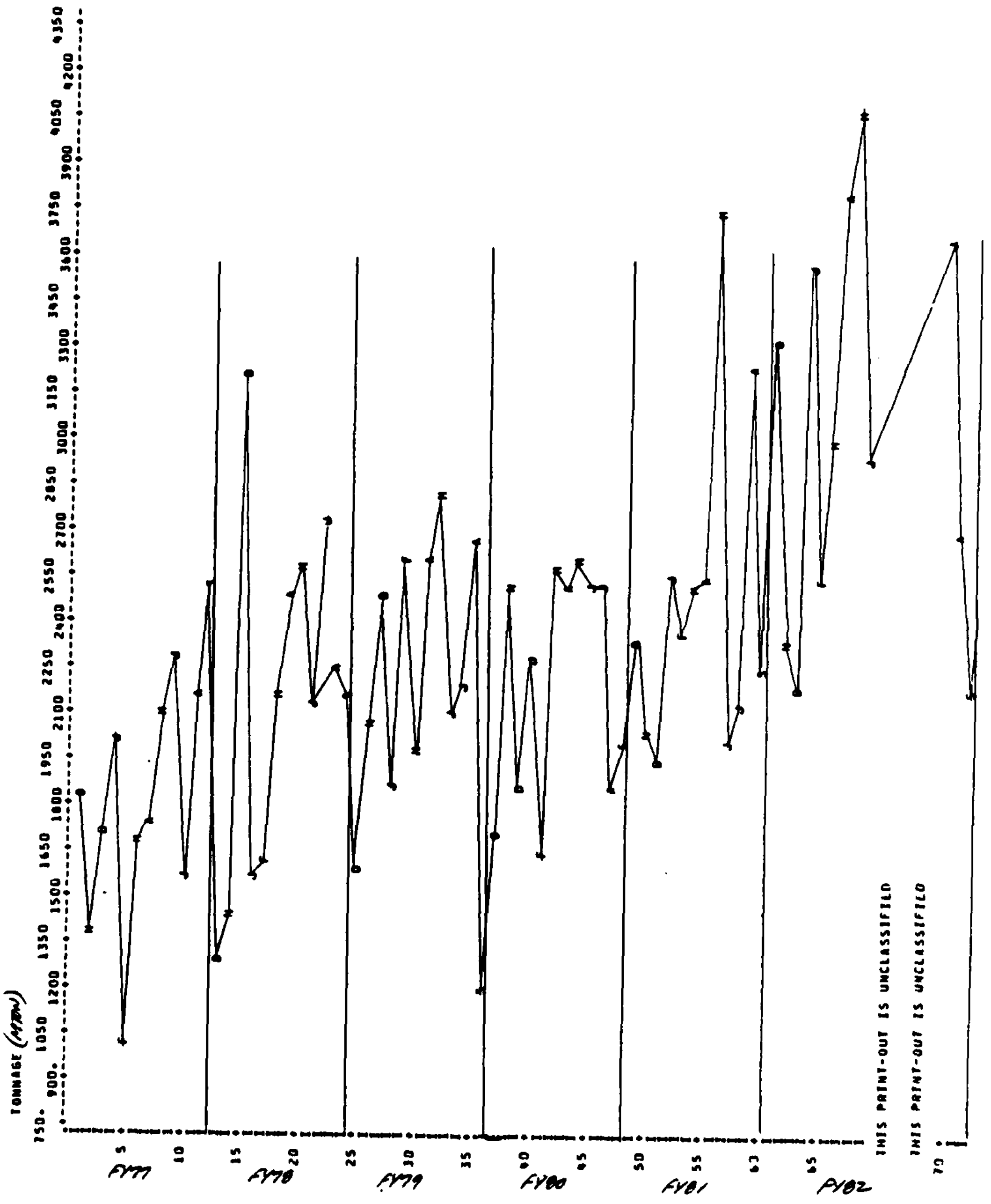
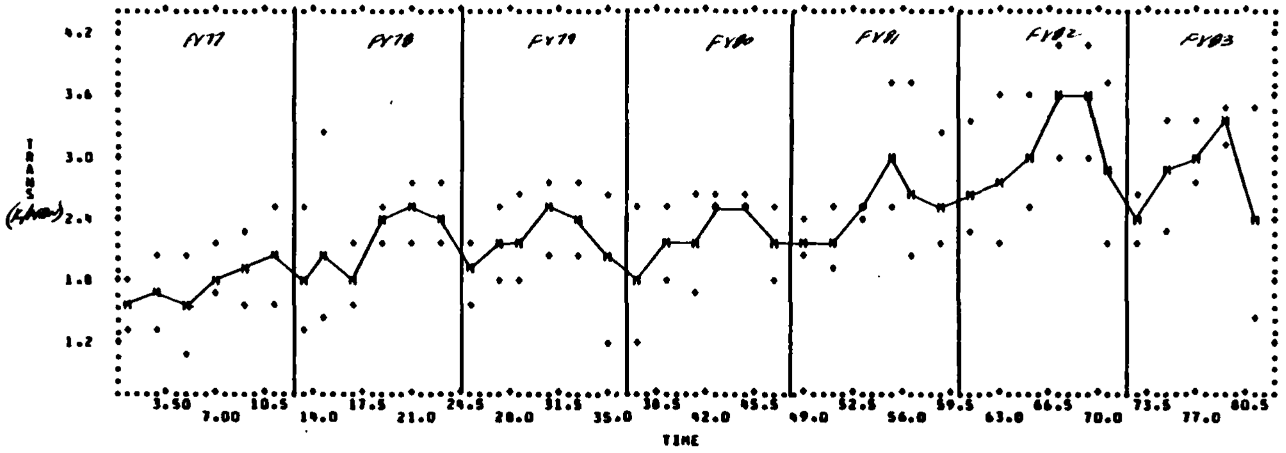
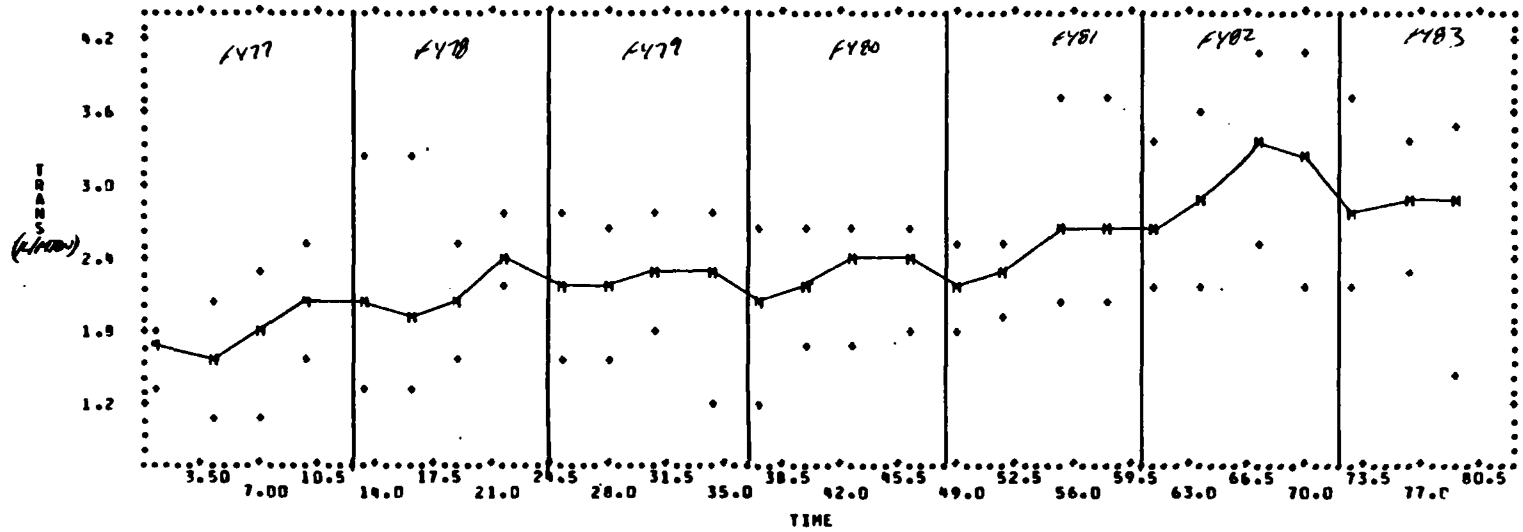


Figure F-93. Freeze Cargo FY 77 - FY 82



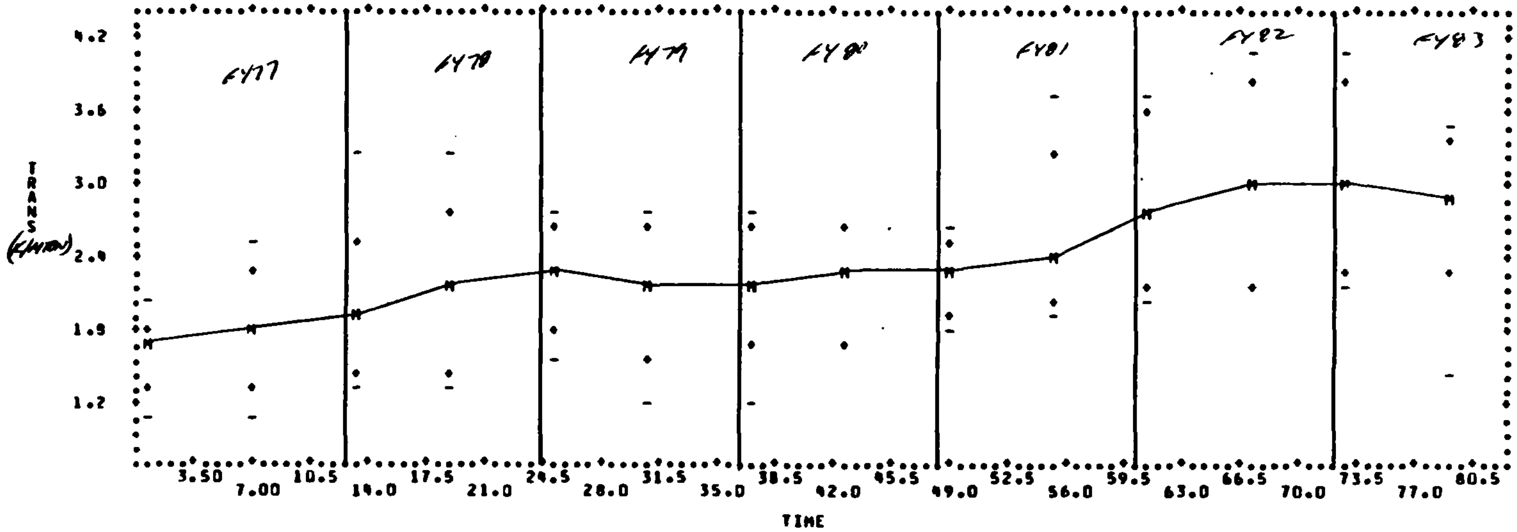
TIME VALUE	NO. OF CASES	MINIMUM VALUE	MEAN	MAXIMUM VALUE
1.000	2	1.3770	1.6010	1.8250
3.000	3	1.3770	1.6961	1.9970
5.000	3	1.0200	1.5697	1.9970
7.000	3	1.6920	1.8980	2.1050
9.000	3	1.5515	1.9780	2.2800
11.000	3	1.5515	2.0800	2.5206
13.000	3	1.2915	1.7502	2.5206
15.000	3	1.4326	2.0724	3.2220
17.000	3	1.5627	1.7852	2.1730
19.000	3	2.1730	2.4103	2.5750
21.000	3	2.1262	2.4790	2.7356
23.000	3	2.1556	2.3799	2.7356
25.000	3	1.6032	1.9913	2.1556
27.000	3	1.8542	2.1318	2.4759
29.000	3	1.8542	2.1565	2.6209
31.000	3	1.9942	2.4676	2.8079
33.000	3	2.0960	2.3667	2.8079
35.000	3	1.2047	2.0263	2.6781
37.000	3	1.2047	1.8065	2.5097
39.000	3	1.8493	2.2175	2.5097
41.000	3	1.6581	2.1808	2.5910
43.000	3	2.5100	2.5745	2.6224
45.000	3	2.5102	2.5580	2.6224
47.000	3	1.8560	2.1283	2.5182
49.000	3	2.0108	2.1354	2.3420
51.000	3	1.9486	2.1818	2.5935
53.000	3	2.3660	2.4782	2.5935
55.000	3	2.5252	2.9439	3.7478
57.000	3	2.0029	2.6299	3.7478
59.000	3	2.1439	2.5443	3.2403
61.000	3	2.2490	2.6393	3.3203
63.000	3	2.2046	2.7080	3.5709
65.000	3	2.5641	3.0497	3.5709
67.000	3	3.0119	3.6317	4.0762
69.000	3	2.9528	3.5640	4.0762
71.000	3	2.1891	2.8536	3.6679
73.000	3	2.1891	2.3988	2.6793
75.000	3	2.3331	2.8464	3.3674
77.000	3	2.7393	3.0538	3.3674
79.000	3	3.0846	3.3077	3.4093
81.000	2	1.4088	2.4490	3.4093

Figure F-94. Three-month Moving Average - Freeze



```
TIME       NO. OF   MINIMUM             MAXIMUM

VALUE      CASES     VALUE      MEAN     VALUE
   1.000       3    1.3770    1.6398    1.8253
   4.000       6    1.0200    1.6042    1.9973
   7.000       6    1.0200    1.8068    2.2800
  10.000       6    1.5515    2.0620    2.5206
  13.000       6    1.2975    2.0327    3.2273
  16.000       6    1.2975    1.8846    3.2220
  19.000       6    1.5627    2.0930    2.5753
  22.000       6    2.1262    2.3873    2.7356
  25.000       6    1.6032    2.2147    2.7356
  28.000       6    1.6032    2.1023    2.6209
  31.000       6    1.8542    2.3297    2.8079
  34.000       6    1.2047    2.2639    2.8079
  37.000       6    1.2047    2.0239    2.6781
  40.000       6    1.6581    2.1011    2.5913
  43.000       6    1.6581    2.3687    2.6224
  45.000       6    1.8560    2.3418    2.6224
  49.000       6    1.8560    2.1215    2.5182
  52.000       6    1.9486    2.2964    2.5435
  55.000       6    2.0029    2.6247    3.7428
  58.000       6    2.0029    2.6571    3.7428
  61.000       6    2.1439    2.5944    3.3203
  54.000       6    2.2046    2.3357    3.5709
  67.000       6    2.5641    3.3335    4.0762
  70.000       6    2.1841    3.2328    4.0762
  73.000       6    2.1841    2.7353    3.6629
  76.000       6    2.3331    2.8354    3.3674
  79.000       6    1.4098    2.9714    3.4893
```

Figure F-95. Six-month Moving Average - Freeze



```
TIME      NO. OF     MINIMUM   TRIMMED   TRIMMED   TRIMMED    MAXIMUM
VALUE     CASES       VALUE    MINIMUM   MEAN      MAXIMUM     VALUE
   1.000     6        1.0200    1.3770    1.6521    1.8253     1.9970
   7.000    12        1.0200    1.3770    1.8457    2.2803     2.5206
  13.000    12        1.2975    1.4326    1.9160    2.5206     3.2220
  19.000    12        1.2975    1.4325    2.1112    2.7356     3.2220
  25.000    12        1.6032    1.8542    2.2599    2.6209     2.7356
  31.000    12        1.2047    1.6032    2.2184    2.6781     2.8079
  37.000    12        1.2047    1.6581    2.2178    2.6781     2.8079
  43.000    12        1.6581    1.7052    2.2377    2.5910     2.6224
  49.000    12        1.8560    1.9486    2.3351    2.5435     2.6224
  55.003    12        1.9486    2.0029    2.4033    3.2403     3.7429
  61.003    12        2.0029    2.1439    2.7217    3.5739     3.7429
  67.000    12        2.1841    2.2046    3.0157    3.8071     4.0762
  73.000    12        2.1841    2.3331    3.0149    3.8071     4.0762
  79.000     9        1.4088    2.3331    2.9088    3.3674     3.4893
```

Figure F-96. Twelve-month Moving Average - Freeze

```
AUTOCORRELATIONS

  1- 12     .09  .01  .37  .13 -.05 -.06  .06  .06  0.0 -.01  .30  .17
   ST.E.    .13  .13  .13  .15  .15  .15  .15  .15  .15  .15  .15  .16

 13- 24     0.0  .07 -.05 -.03 -.09 -.13 -.14  .03 -.02 -.03  .17  .07
   ST.E.    .16  .16  .16  .16  .16  .16  .17  .17  .17  .17  .17  .17

 25- 36     .01 -.06  .04 -.06 -.06 -.04  .01  0.0  0.0  .15  .01  .01
   ST.E.    .17  .17  .17  .17  .17  .17  .17  .17  .17  .17  .18  .18

PLOT OF AUTOCORRELATIONS

              -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG     CORR.   +----+----+----+----+----+----+----+----+----+----+
                                         I
  1       .090                     +     IXX   +
  2       .015                     +     I     +
  3       .373                     +     IXXXXX+XXX
  4       .133                    +      IXXX   +
  5      -.045                    +     XI      +
  6      -.055                    +     XI      +
  7       .059                    +      IX     +
  8       .056                    +      IX     +
  9       .005                    +      I      +
 10      -.006                    +      I      +
 11       .303                    +      IXXXXXX+X
 12       .170                   +       IXXXX   +
 13       .001                   +       I       +
 14       .068                   +       IXX     +
 15      -.049                   +      XI       +
 16      -.029                   +      XI       +
 17      -.085                   +     XXI       +
 18      -.135                   +    XXXI       +
 19      -.135                   +    XXXI       +
 20       .034                   +       IX      +
 21      -.024                   +      XI       +
 22      -.034                   +      XI       +
 23       .166                   +       IXXXX   +
 24       .069                   +       IXX     +
 25       .015                   +       I       +
 26      -.056                   +      XI       +
 27       .038                   +       IX      +
 28      -.062                   +     XXI       +
 29      -.055                   +      XI       +
 30      -.036                   +      XI       +
 31       .012                   +       I       +
 32       .004                   +       I       +
 33      -.001                   +       I       +
 34       .153                   +       IXXXX   +
 35       .005                  +        I        +
 36       .013                  +        I        +
```

std error

$= \frac{1}{\sqrt{60}}(1.96)$

$= .253$

Figure F-97. ACF - Raw Data - Freeze

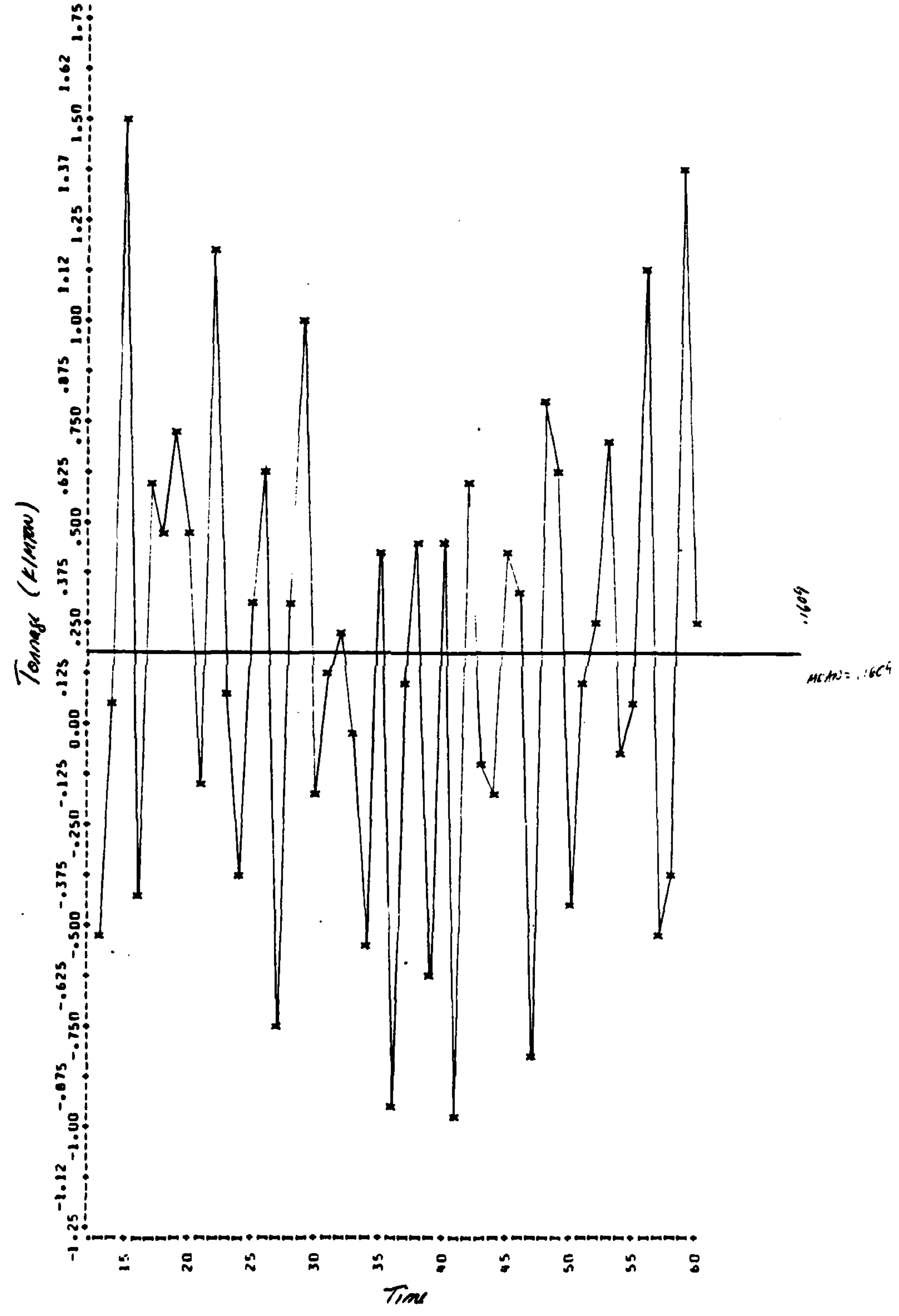


Figure F-98. Differenced Series (12-month lag) - Freeze

```
AUTOCORRELATIONS

  1- 12        -.31 -.18  .38  .02 -.08 -.03  .20 -.02 -.16  .02  .28 -.32
  ST.E.         .14  .16  .16  .18  .18  .18  .18  .19  .19  .19  .19  .20

 13- 24         .01  .16 -.21  .02 -.02 -.09 -.15  .09 -.11 -.13  .12 -.05
  ST.E.         .21  .21  .21  .21  .21  .21  .21  .22  .22  .22  .22  .22

 25- 36        -.09 -.07  .14 -.04 -.16  .15  .13 -.26  .07  .21 -.17 -.03
  ST.E.         .22  .22  .22  .23  .23  .23  .23  .23  .24  .24  .24  .24

PLOT OF AUTOCORRELATIONS

            -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG     CORR. +----+----+----+----+----+----+----+----+----+----+
                                       I
  1     -.313                  X+XXXXXXI      +
  2     -.179                  +   XXXXI       +
  3      .382                  +       IXXXXXXX+XX
  4      .022                 +        IX       +
  5     -.081                 +      XXI        +
  6     -.028                 +       XI        +
  7      .202                 +        IXXXXX   +
  8     -.017                 +        I        +
  9     -.159                 +    XXXXI        +
 10      .022                 +        IX       +
 11      .281                 +        IXXXXXXX +
 12     -.315                + XXXXXXXXI         +
 13      .013                +         I         +
 14      .156                +         IXXXX     +
 15     -.214                +    XXXXXI         +
 16      .016                +         I         +
 17     -.016                +         I         +
 18     -.088                +       XXI         +
 19     -.155               +      XXXXI          +
 20      .093               +          IXX        +
 21     -.108               +       XXXI          +
 22     -.134               +       XXXI          +
 23      .121               +          IXXX       +
 24     -.048               +         XI          +
 25     -.092               +        XXI          +
 26     -.073               +        XXI          +
 27      .142               +          IXXXX      +
 28     -.040               +         XI          +
 29     -.163               +      XXXXI          +
 30      .152               +          IXXXX      +
 31      .133               +          IXXX       +
 32     -.257               +    XXXXXXI          +
 33      .071              +           IXX         +
 34      .206              +           IXXXXX      +
 35     -.171              +       XXXXI           +
 36     -.028              +          XI           +
```

std error

$= \frac{1}{\sqrt{48}}(1.96)$

$= .283$

Figure F-99. ACF - Lagged 12 Months

```
PARTIAL AUTOCORRELATIONS

  1- 12       -.31  -.31   .26   .25   .18  -.13   .05   .05  -.05  -.21   .20  -.13
  ST.E.        .14   .14   .14   .14   .14   .14   .14   .14   .14   .14   .14   .14

 13- 24        .04  -.13  -.14  -.04  -.01  -.18  -.27   .04  -.04  -.14   .13   .05
  ST.E.        .14   .14   .14   .14   .14   .14   .14   .14   .14   .14   .14   .14

 25- 36        .03  -.12  -.05   .05   .01   .06   .08  -.07  -.02  -.13  -.07  -.13
  ST.E.        .14   .14   .14   .14   .14   .14   .14   .14   .14   .14   .14   .14

PLOT OF PARTIAL AUTOCORRELATIONS

            -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR.   +----+----+----+----+----+----+----+----+----+----+
                                       I
  1    -.313                 X+XXXXXXI      +
  2    -.306                 X+XXXXXXI      +
  3     .261                  +      IXXXXXXX
  4     .254                  +      IXXXXXX+
  5     .176                  +      IXXXX  +
  6    -.127                  +   XXXI      +
  7     .052                  +      IX     +
  8     .054                  +      IX     +
  9    -.052                  +     XI      +
 10    -.209                  + XXXXXI      +
 11     .205                  +      IXXXXX +
 12    -.125                  +   XXXI      +
 13     .039                  +      IX     +
 14    -.125                  +   XXXI      +
 15    -.143                  +  XXXXI      +
 16    -.044                  +     XI      +
 17    -.006                  +      I      +
 18    -.180                  + XXXXXI      +
 19    -.269                  XXXXXXXI      +
 20     .039                  +      IX     +
 21    -.037                  +     XI      +
 22    -.135                  +   XXXI      +
 23     .125                  +      IXXX   +
 24     .050                  +      IX     +
 25     .027                  +      IX     +
 26    -.121                  +   XXXI      +
 27    -.053                  +     XI      +
 28     .047                  +      IX     +
 29     .010                  +      I      +
 30     .056                  +      IX     +
 31     .084                  +      IXX    +
 32    -.074                  +    XXI      +
 33    -.019                  +      I      +
 34    -.125                  +   XXXI      +
 35    -.069                  +    XXI      +
 36    -.130                  +   XXXI      +
```

Figure F-100. PACF - Lagged 12 Months

```
AUTOCORRELATIONS

  1- 12      -.56 -.09  .30 -.12  0.0 -.06  .10  .01 -.07 -.11  .35 -.31
   ST.E.      .15  .19  .19  .20  .20  .20  .20  .20  .20  .20  .20  .21

 13- 24       .05  .13 -.15  .39 -.03  .03 -.14  .20 -.10 -.08  .16 -.07
   ST.E.      .22  .22  .23  .23  .23  .23  .23  .23  .23  .23  .24  .24

 25- 36       0.0 -.06  .12 -.03 -.10  .06  .17 -.25  .06  .17 -.16  0.0
   ST.E.      .24  .24  .24  .24  .24  .24  .24  .24  .25  .25  .25  .25

PLOT OF AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1   -.560            XXXXXXX+XXXXXXI      +
  2   -.093                 +      XXI        +
  3    .297                 +        IXXXXXXX +
  4   -.117                +      XXXI         +
  5   -.002                +         I         +
  6   -.061                +       XXI         +
  7    .095                +         IXX       +
  8    .006                +         I         +
  9   -.073                +       XXI         +
 10   -.115                +      XXXI         +
 11    .353                +         IXXXXXXXXX+
 12   -.312               +  XXXXXXXXI          +
 13    .054               +          IX         +
 14    .128               +          IXXX       +
 15   -.147               +      XXXXI          +
 16    .089               +          IXX        +
 17   -.028               +         XI          +
 18    .025               +          IX         +
 19   -.137               +       XXXI          +
 20    .196               +          IXXXXX     +
 21   -.104               +       XXXI          +
 22   -.081              +         XXI           +
 23    .159              +           IXXXX       +
 24   -.068              +         XXI           +
 25   -.004              +           I           +
 26   -.060              +          XI           +
 27    .119              +           IXXX        +
 28   -.031              +          XI           +
 29   -.105              +        XXXI           +
 30    .058              +           IX          +
 31    .167              +           IXXXX       +
 32   -.249              +     XXXXXXI           +
 33    .057              +           IX          +
 34    .171              +           IXXXX       +
 35   -.156              +       XXXXI           +
 36    .004              +           I           +
```

std error

$= \frac{1}{\sqrt{47}}(1.96)$

$= .286$

Figure F-101. ACF - Lagged 12 Months and 1 Month

```
PARTIAL AUTOCORRELATIONS

  1- 12     -.56 -.59 -.27 -.08  .15 -.02 -.03  .02  .08 -.32  .07 -.04
  ST.E.      .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15

 13- 24      .11  .01 -.06 -.07  .06  .08 -.28 -.10  .05 -.16 -.04  0.0
  ST.E.      .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15

 25- 36      .12 -.01 -.07 -.37 -.11 -.03  .13  0.0  .07  .01  .09 -.06
  ST.E.      .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15

PLOT OF PARTIAL AUTOCORRELATIONS

          -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR. +----+----+----+----+----+----+----+----+----+----+
                                     I
  1   -.560            XXXXXXX+XXXXXXI      +
  2   -.594           XXXXXXXX+XXXXXXI      +
  3   -.270                   XXXXXXXI      +
  4   -.083                   +    XXI      +
  5    .147                   +      IXXXX  +
  6   -.017                   +      I      +
  7   -.032                   +     XI      +
  8    .021                   +      IX     +
  9    .082                   +      IXX    +
 10   -.320                  X+XXXXXXI      +
 11    .066                   +      IXX    +
 12   -.044                   +     XI      +
 13    .107                   +      IXXX   +
 14    .013                   +      I      +
 15   -.062                   +    XXI      +
 16   -.072                   +    XXI      +
 17    .064                   +      IXX    +
 18    .079                   +      IXX    +
 19   -.277                   XXXXXXXI      +
 20   -.105                   +   XXXI      +
 21    .048                   +      IX     +
 22   -.162                   +  XXXXI      +
 23   -.037                   +     XI      +
 24   -.004                   +      I      +
 25    .117                   +      IXXX   +
 26   -.010                   +      I      +
 27   -.068                   +    XXI      +
 28   -.070                   +    XXI      +
 29   -.106                   +   XXXI      +
 30   -.033                   +     XI      +
 31    .126                   +      IXXX   +
 32   -.001                   +      I      +
 33    .068                   +      IXX    +
 34    .007                   +      I      +
 35    .086                   +      IXX    +
 36   -.063                   +    XXI      +
```

Figure F-102. PACF - Lagged 12 Months and 1 Month

```
ESTIMATION BY BACKCASTING METHOD

RELATIVE CHANGE IN RESIDUAL SUM OF SQUARES LESS THAN  .1000-004


SUMMARY OF THE MODEL

OUTPUT VARIABLE -- TRANS
INPUT VARIABLES -- NOISE

VARIABLE   VAR. TYPE   MEAN       TIME      DIFFERENCES
                                                  12      1
TRANS        RANDOM               1-  60  (1-B   ) (1-B   )

PARAMETER VARIABLE    TYPE  FACTOR   ORDER ESTIMATE          ST. ERR.  T-RATIO
        1   TRANS      MA      1        1      .4729            .1095      4.32
        2   TRANS      MA      1       11    -.5038            .0875     -5.76
        3   TRANS      MA      2       12     .7753            .0644     12.04
        4   TRANS      AR      1        1    -.7740            .1145     -6.76
        5   TRANS      AR      1        2    -.6789            .1139     -5.96

RESIDUAL SUM OF SQUARES  =           4.795347 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM       =                 40
RESIDUAL MEAN SQUARE     =            .119884
```

Figure F-103. Model Parameters - Freeze

```
AUTOCORRELATIONS

   1- 12     -.15  .01 -.09  .01 -.18 -.03  .14  0.0 -.03  .15  .10 -.11
  ST.E.       .13  .13  .13  .13  .13  .14  .14  .14  .14  .14  .14  .14

  13- 24     -.14  .09 -.10  .03 -.09  .08 -.12  .02  .02 -.12  .10 -.15
  ST.E.       .14  .15  .15  .15  .15  .15  .15  .15  .15  .15  .15  .16

  25- 36      .03 -.05  .10 -.10 -.08  .04  .03 -.09  .10  .09 -.02 -.07
  ST.E.       .15  .16  .16  .16  .16  .16  .16  .16  .16  .16  .16  .16

PLOT OF AUTOCORRELATIONS

             -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG    CORR.   +----+----+----+----+----+----+----+----+----+----+

  1    -.149                     +  XXXXI      +
  2     .011                     +      I      +
  3    -.091                     +    XXI      +
  4     .007                    +       I       +
  5    -.183                    +  XXXXXI       +
  6    -.026                    +      XI       +
  7     .140                    +       IXXX    +
  8     .001                    +       I       +
  9    -.027                    +      XI       +
 10     .146                    +       IXXXX   +
 11     .096                    +       IXX     +
 12    -.113                    +    XXXI       +
 13    -.136                    +    XXXI       +
 14     .075                    +       IXX     +
 15    -.105                    +    XXXI       +
 16     .034                    +       IX      +
 17    -.089                    +     XXI       +
 18     .076                    +       IXX     +
 19    -.124                    +    XXXI       +
 20     .020                    +       I       +
 21     .023                    +       IX      +
 22    -.119                    +    XXXI       +
 23     .079                   +        IXX      +
 24    -.148                   +    XXXXI        +
 25     .072                   +        IX       +
 26    -.049                   +       XI        +
 27     .079                   +        IXX      +
 28    -.077                   +      XXI        +
 29    -.071                   +      XXI        +
 30     .045                   +        IX       +
 31     .032                   +        IX       +
 32    -.056                   +      XXI        +
 33     .101                   +        IXXX     +
 34     .091                   +        IXX      +
 35    -.016                   +        I        +
 36    -.070                   +      XXI        +
```

.244(60) = 14.66

Figure F-104. Estimated Residuals - Freeze

```
 FORECAST ON VARIABLE TRANS     FROM TIME PERIOD    61

PERIOD              FORECASTS        ST.  ERR.         ACTUAL
  61                 2.00663          .47265            3.32   |   1.32
  62                 2.34216          .48683            2.348  |   .006
  63                 2.86668          .48719            2.205  |  -.662
  64                 2.62217          .57961            3.571  |   .949
  65                 2.44941          .57964            2.564  |   .115
  66                 2.77187          .58139            3.012  |   .24
  67                 3.05363          .62199            3.807  |   .754
  68                 3.02205          .62397            4.076  |  1.054
  69                 2.55615          .62686            2.953  |   .397
  70                 2.75182          .64922            3.663  |   .911
  71                 2.87791          .65384            2.714  |  -.164
  72                 2.54864          .72470            2.164  |  -.365
STANDARD ERROR =  .472645      (BY CONDITIONAL METHOD   )

                   _______                          _______
                    31.86                            36.42      MSE=.498
                   _______                          _______
```

Figure F-105. Forecast FY 82 - Freeze

F-10. CHILL

a. The raw series for chill is shown in Figure F-106. The raw series indicates the evidence of a recurring pattern and the possibility of seasonality in the data. Visual examination of the plots of the 3-month and 6-month (Figures F-107 and F-108) moving averages indicates that the data do follow a seasonal trend. However, the 12-month moving average indicates that the overall mean of the series during the last 6 1/2 years has been constant (Figure F-109).

b. Autocorrelation function analysis of the modeled data confirms the fact that seasonality does exist in the data (Figures F-110 and F-111). Therefore, to eliminate seasonality, the series was differenced at a lag of 12 months. This process did not produce stationary data since the resulting data plot exhibited heteroscedasticity (change in variance over time). The original series was then transformed using natural logarithms and the logarithmic series was then differenced as a lag of 12 months. The plot of the logarithmic differenced series is depicted in Figure F-112. The autocorrelation and partial autocorrelation functions of the seasonally adjusted series are shown in Figures F-113 and F-114. The autocorrelation function suggests that the data is stationary.

c. Analysis of the autocorrelation and partial autocorrelation function suggests the possibility of an ARIMA (0,0,2) nonseasonal model and an ARIMA (1,1,0) seasonal model. An AR seasonal process was used since the results from the AR model were better than the MA seasonal model. The suggested model is of the form:

$$(1 - \phi_{12}B^{12})(1 - B^{12}) \ln X_t = (1 - \theta_1 B - \theta_2 B^2)\epsilon_t$$

d. The results of the model (Figure F-115) are as follows:

$$(1 + \underset{(-5.61)}{.6371}B^{12})(1 - B^{12}) \ln X_t = (1 - \underset{(2.0)}{.3012}B + \underset{(-1.83)}{.2716}B^2)\epsilon_t$$

$$x^2\ (3.20) = 15.63$$

All of the estimated parameters except θ_2 are significant at the 5 percent significance level (Figure F-116). The Q statistic for 20 degrees of freedom is 15.63, which indicates that the residuals are not significant and that the null hypothesis should not be rejected at the 26 percent significance level. Also, all of the estimated residuals fall within the 95 percent confidence interval and apprear to be distributed randomly. The FY 82 forecast for chill using this model was 15.32 K/MTON of cargo shipped versus an actual lift of 14.13 K/MTON. The MSE of the chill forecast was .21, and the annual forecast error was 8.4 percent.

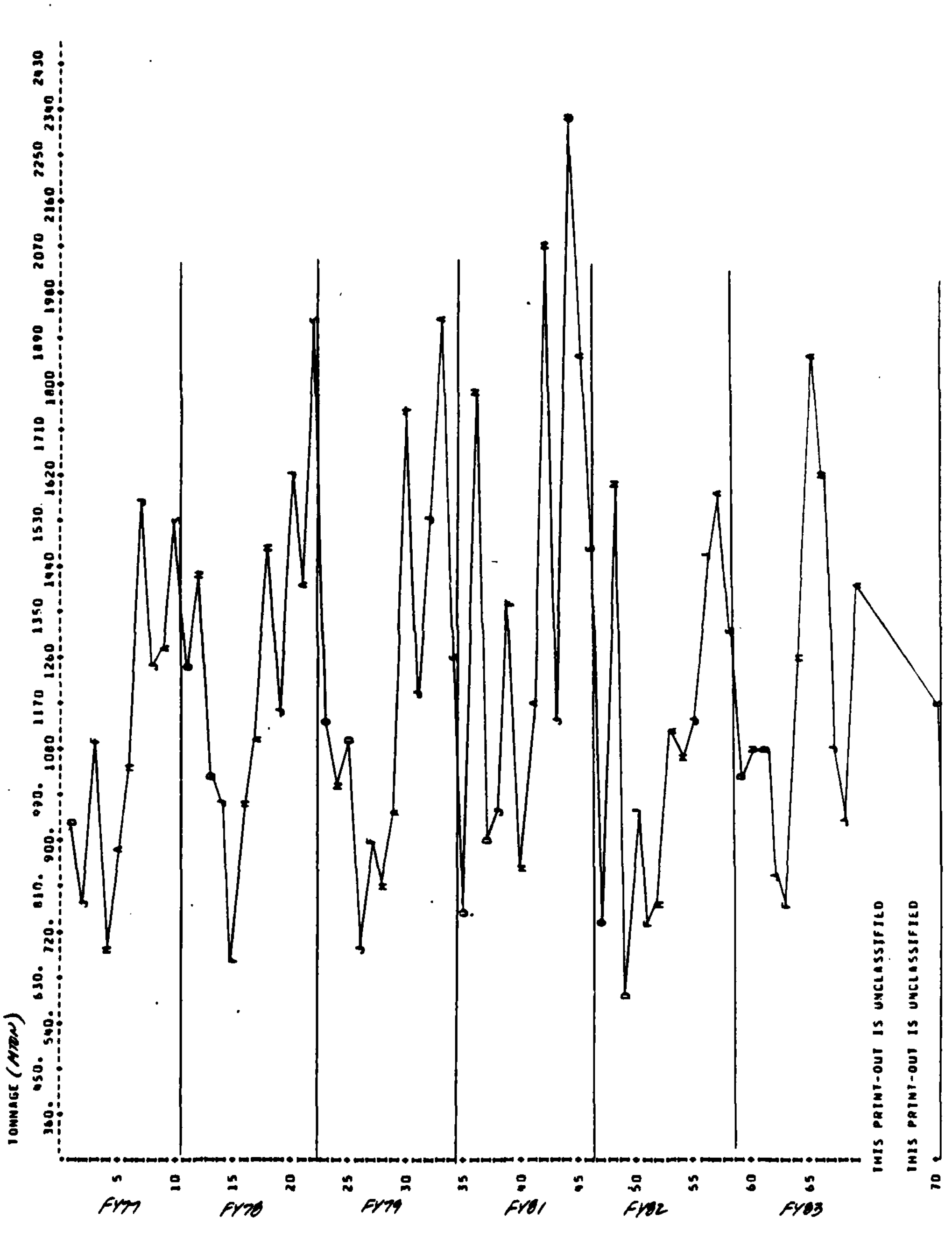
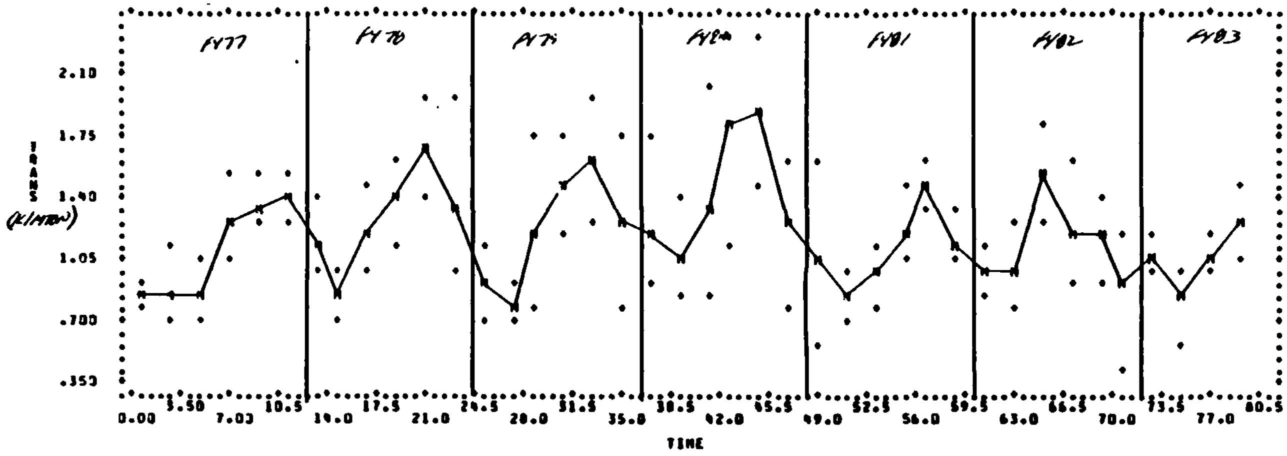
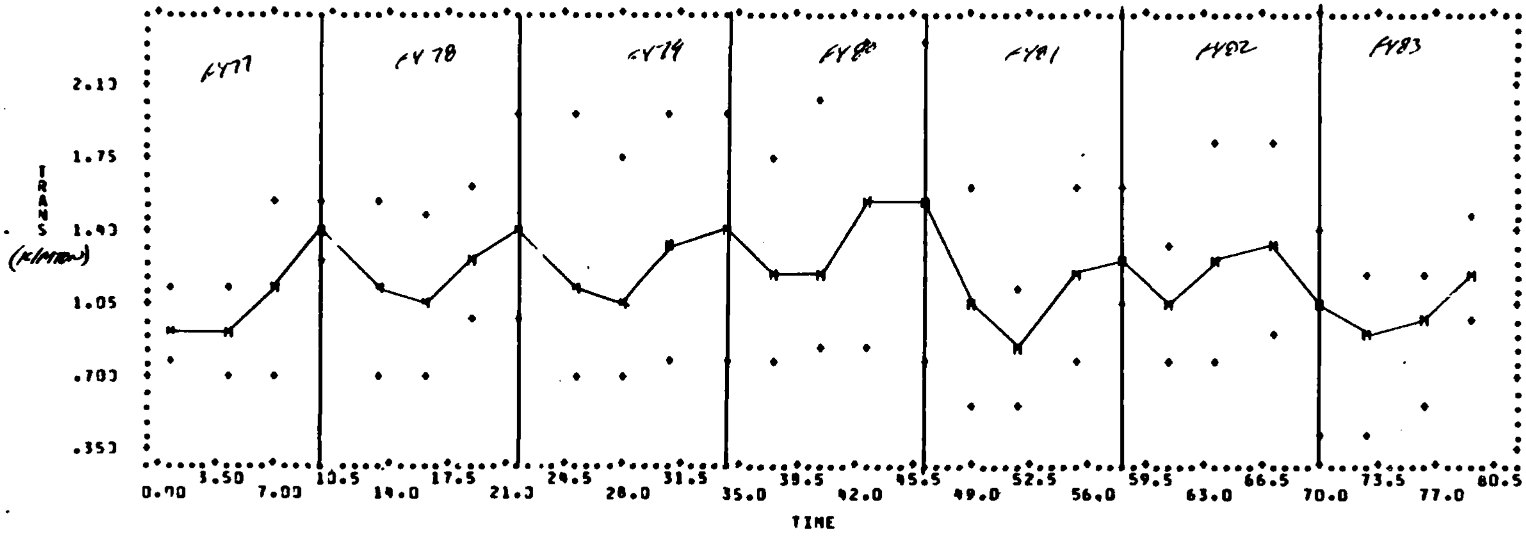


Figure F-106. Chill Cargo FY 77 - FY 82



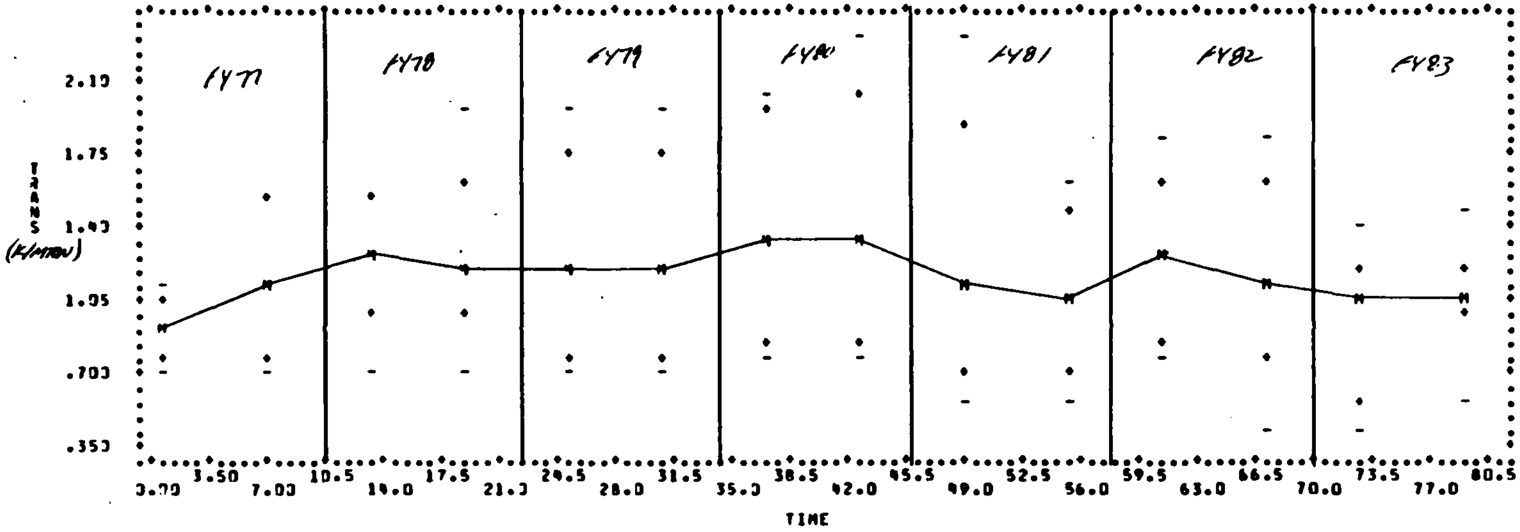
TIME VALUE	NO. OF CASES	MINIMUM VALUE	MEAN	MAXIMUM VALUE
1.000	2	.7730	.8510	.9293
3.000	3	.6860	.8507	1.0920
5.000	3	.6860	.8745	1.0490
7.000	3	1.0490	1.2073	1.5693
9.000	3	1.2440	1.3534	1.5363
11.000	3	1.2417	1.3996	1.5363
13.000	3	.9660	1.1932	1.4207
15.000	3	.6650	.8689	.9732
17.000	3	.9730	1.1798	1.4682
19.000	3	1.1476	1.4133	1.6241
21.000	3	1.3983	1.6515	1.9321
23.000	3	1.0370	1.3570	1.9321
25.000	3	.5795	.9291	1.1307
27.000	3	.6795	.7939	.8984
29.000	3	.9037	1.1679	1.7446
31.000	3	1.1804	1.4973	1.7446
33.000	3	1.2690	1.5775	1.9267
35.000	3	.7538	1.2681	1.7819
37.000	3	.9371	1.2172	1.7819
39.000	3	.8417	1.0582	1.3703
41.000	3	.8417	1.3632	2.0697
43.000	3	1.1319	1.8405	2.3253
45.000	3	1.4759	1.8875	2.3253
47.000	3	.7365	1.2714	1.6017
49.000	3	.5869	1.0404	1.6017
51.000	3	.7332	.8235	.9565
53.000	3	.7809	.9857	1.1112
55.000	3	1.0650	1.2179	1.4623
57.000	3	1.3054	1.4492	1.5003
59.000	3	1.0293	1.1910	1.3054
61.000	3	.8367	1.0003	1.0849
63.000	3	.7766	.9572	1.2503
65.000	3	1.2503	1.5743	1.8522
67.000	3	.9418	1.2125	1.6123
69.000	3	.9418	1.1721	1.4342
71.000	3	.9058	.9252	1.1996
73.000	3	1.0025	1.0689	1.1996
75.000	3	.5537	.8506	1.0348
77.000	3	.9933	1.0779	1.1639
79.000	2	1.0791	1.2919	1.5047

Figure F-107. Three-month Moving Average - Chill



TIME VALUE	NO. OF CASES	MINIMUM VALUE	MEAN	MAXIMUM VALUE
1.000	3	.7730	.9313	1.0920
4.000	6	.6860	.9029	1.0920
7.000	6	.5869	1.1194	1.5690
10.000	6	1.2417	1.3819	1.5690
13.000	6	.5650	1.1439	1.5363
16.000	6	.5650	1.0349	1.4682
19.000	6	.9730	1.2949	1.6241
22.000	6	1.0070	1.3739	1.9321
25.000	6	.6795	1.1253	1.9321
28.000	6	.6795	1.0301	1.7446
31.000	6	.8037	1.3577	1.9267
34.000	6	.7539	1.4080	1.9267
37.000	6	.7538	1.174[illegible]	1.7914
40.000	6	.8417	1.2201	2.0647
43.000	6	.8417	1.5664	2.3253
46.000	6	.7365	1.5220	2.3253
49.000	6	.5869	1.0151	1.6017
52.000	6	.5869	.8723	1.1112
55.000	6	.7839	1.1976	1.5870
58.000	6	1.0293	1.2653	1.5870
61.000	6	.7766	1.0197	1.3054
64.000	6	.7766	1.2353	1.8522
67.000	6	.9418	1.3587	1.8522
70.000	6	.4358	1.0342	1.4342
73.000	6	.4358	.8979	1.1795
76.000	6	.5537	.9657	1.1679
79.000	4	.9933	1.1845	1.5047

Figure F-108. Six-month Moving Average - Chill



TIME VALUE	NO. OF CASES	MINIMUM VALUE	TRIMMED MINIMUM	TRIMMED MEAN	TRIMMED MAXIMUM	MAXIMUM VALUE
1.000	6	.6860	.7730	.9399	1.0490	1.0920
7.000	12	.6860	.7730	1.1454	1.5363	1.5690
13.000	12	.6650	.9660	1.2262	1.5363	1.5690
19.000	12	.5650	.9660	1.1850	1.5241	1.9321
25.000	12	.5795	.8037	1.1812	1.7446	1.9321
31.000	12	.5795	.7539	1.2323	1.7814	1.9267
37.000	12	.7530	.8417	1.2950	1.9267	2.0647
43.000	12	.7365	.8417	1.3391	2.0647	2.3253
49.000	12	.5869	.7332	1.1454	1.8612	2.3253
55.000	12	.5869	.7332	1.0658	1.4623	1.5800
61.000	12	.7766	.8367	1.2375	1.5123	1.8522
67.000	12	.4058	.7766	1.1359	1.6123	1.8522
73.000	12	.4058	.5537	1.0189	1.1996	1.4042
79.000	7	.5537	.9933	1.0481	1.1609	1.5047

Figure F-109. Twelve-month Moving Average - Chill

```
AUTOCORRELATIONS

  1- 12      .21  .25  .14 -.19 -.42 -.20 -.48 -.14  .06  .06  .29  .48
   ST.E.     .13  .13  .14  .14  .15  .17  .17  .19  .19  .19  .19  .20

 13- 24      .12  .17 -.03 -.26 -.32 -.29 -.25 -.02  .01  .19  .27  .30
   ST.E.     .22  .22  .22  .22  .23  .24  .24  .25  .25  .25  .25  .25

 25- 36      .12  .15 -.08 -.16 -.26 -.17 -.17 -.01  .03  .11  .14  .14
   ST.E.     .26  .26  .26  .26  .26  .27  .27  .27  .27  .27  .27  .27

PLOT OF AUTOCORRELATIONS

            -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG    CORR.  +----+----+----+----+----+----+----+----+----+----+
                                       I
  1     .207                     +     IXXXXX+
  2     .247                    +      IXXXXXX+
  3     .136                    +      IXXX   +
  4    -.193                    + XXXXXI      +
  5    -.419                 XXX+XXXXXXI      +
  6    -.202                   +  XXXXXI       +
  7    -.485               XXXX+XXXXXXXI       +
  8    -.140                  +    XXXXI        +
  9     .063                 +         IXX       +
 10     .059                 +         IX        +
 11     .286                 +         IXXXXXXX  +
 12     .484                 +         IXXXXXXXXX+XX
 13     .118                +          IXXX       +
 14     .165                +          IXXXX      +
 15    -.026                +         XI          +
 16    -.256                +    XXXXXXI          +
 17    -.317                +  XXXXXXXXI          +
 18    -.291               +    XXXXXXXI           +
 19    -.247               +     XXXXXXI           +
 20    -.024               +          XI           +
 21     .014               +           I           +
 22     .189               +           IXXXXX      +
 23     .267               +           IXXXXXXX    +
 24     .300               +           IXXXXXXXX   +
 25     .118              +            IXXX         +
 26     .147              +            IXXXX        +
 27    -.081              +          XXI            +
 28    -.158              +        XXXXI            +
 29    -.258              +      XXXXXXI            +
 30    -.172              +        XXXXI            +
 31    -.170              +        XXXXI            +
 32    -.012              +            I            +
 33     .026              +            IX           +
 34     .112              +            IXXX         +
 35     .142              +            IXXXX        +
 36     .143              +            IXXXX        +
```

std error

$= \frac{1}{\sqrt{60}} (1.96)$

$= .253$

Figure F-110. ACF - Raw Data - Chill

```
PARTIAL AUTOCORRELATIONS

  1- 12      .21  .21  .06 -.30 -.47 -.01 -.25  .09  .18 -.02  .08  .20
 ST.E.       .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 13- 24     -.09 -.14 -.16 -.03 -.06 -.07  .20  .08 -.14 -.02 -.08  .05
 ST.E.       .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

 25- 36     -.05  .13  .08 -.05 -.02  .05 -.07 -.06 -.01 -.09 -.07  0.0
 ST.E.       .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13  .13

PLOT OF PARTIAL AUTOCORRELATIONS

           -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR.  +----+----+----+----+----+----+----+----+----+----+
                                      I
  1     .207                   +     IXXXXX+
  2     .213                   +     IXXXXX+
  3     .056                   +     IX    +
  4    -.302                 XX+XXXXXI     +
  5    -.465             XXXXXX+XXXXXI     +
  6    -.015                   +     I     +
  7    -.245                   XXXXXXI     +
  8     .090                   +     IXX   +
  9     .185                   +     IXXXXX+
 10    -.017                   +     I     +
 11     .082                   +     IXX   +
 12     .201                   +     IXXXXX+
 13    -.094                   +   XXI     +
 14    -.137                   +  XXXI     +
 15    -.158                   + XXXXI     +
 16    -.032                   +    XI     +
 17    -.063                   +   XXI     +
 18    -.066                   +   XXI     +
 19     .199                   +     IXXXXX+
 20     .081                   +     IXX   +
 21    -.139                   +  XXXI     +
 22    -.021                   +    XI     +
 23    -.078                   +   XXI     +
 24     .053                   +     IX    +
 25    -.053                   +    XI     +
 26     .128                   +     IXXX  +
 27     .084                   +     IXX   +
 28    -.050                   +    XI     +
 29    -.022                   +    XI     +
 30     .052                   +     IX    +
 31    -.071                   +   XXI     +
 32    -.055                   +    XI     +
 33    -.009                   +     I     +
 34    -.091                   +   XXI     +
 35    -.066                   +   XXI     +
 36    -.004                   +     I     +
```

Figure F-111. PACF - Raw Data - Chill

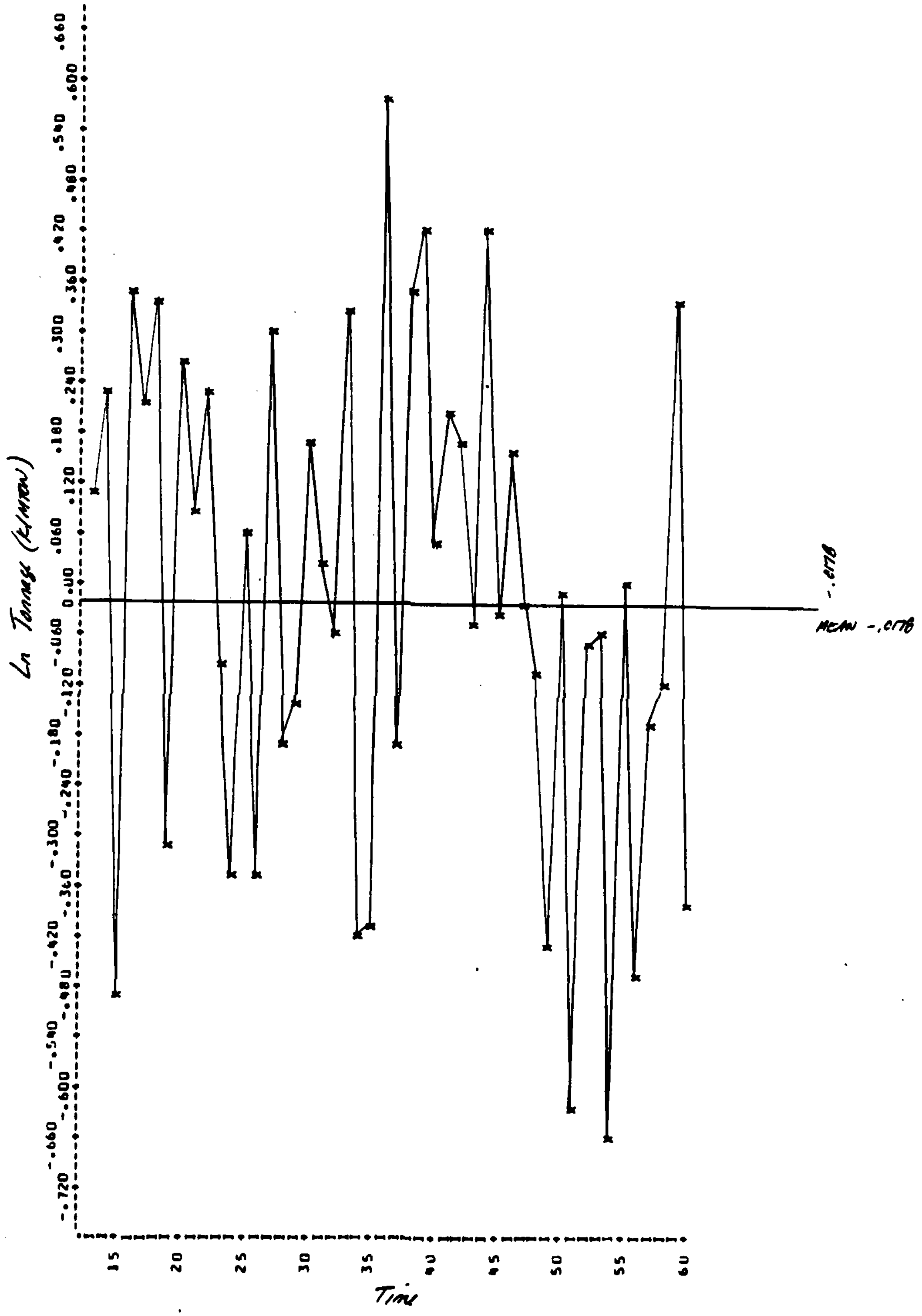


Figure F-112. Log Differenced Series (12-month lag) - Chill

```
AUTOCORRELATIONS

  1- 12      -.15  .22  .22  .03  .08  .18 -.14 -.04  .12 -.33  .14 -.27
   ST.E.      .14  .15  .15  .16  .16  .16  .17  .17  .17  .17  .18  .18

 13- 24      -.14  .02 -.17 -.07  .04 -.25  .12  .08 -.10  .10  .12 -.12
   ST.E.      .19  .19  .19  .20  .20  .20  .20  .21  .21  .21  .21  .21

 25- 36       .12  .12 -.05  .15 -.12  .10 -.09  .06 -.13 -.01 -.09 -.02
   ST.E.      .21  .21  .21  .21  .22  .22  .22  .22  .22  .22  .22  .22
```

```
PLOT OF AUTOCORRELATIONS

             -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG   CORR.    +----+----+----+----+----+----+----+----+----+----+
                                        I
  1    -.147                     +  XXXXI      +
  2     .216                     +      IXXXXX +
  3     .219                    +       IXXXXX  +
  4     .031                    +       IX      +
  5     .082                    +       IXX     +
  6     .183                    +       IXXXXX  +
  7    -.141                    +   XXXXI       +
  8    -.036                    +      XI       +
  9     .119                    +       IXXX    +
 10    -.326                    XXXXXXXXI       +
 11     .138                   +        IXXX     +
 12    -.273                   + XXXXXXXI        +
 13    -.135                   +     XXXI        +
 14     .019                  +         I         +
 15    -.165                  +     XXXXI         +
 16    -.065                  +       XXI         +
 17     .038                  +         IX        +
 18    -.250                  +   XXXXXXI         +
 19     .119                  +         IXXX      +
 20     .081                  +         IXX       +
 21    -.102                  +      XXXI         +
 22     .104                  +         IXXX      +
 23     .123                  +         IXXX      +
 24    -.117                  +      XXXI         +
 25     .117                  +         IXXX      +
 26     .116                  +         IXXX      +
 27    -.054                 +         XI          +
 28     .148                 +          IXXXX      +
 29    -.118                 +       XXXI          +
 30     .098                 +          IXX        +
 31    -.093                 +        XXI          +
 32     .062                 +          IXX        +
 33    -.126                 +       XXXI          +
 34    -.015                 +          I          +
 35    -.094                 +        XXI          +
 36    -.023                 +         XI          +
```

std error

$= \frac{1}{\sqrt{48}}(1.96)$

$= .283$

Figure F-113. ACF - Lagged 12 Months

```
PARTIAL AUTOCORRELATIONS

 1- 12      -.15  .20  .29  .07 -.02  .13 -.15 -.21  .07 -.24  .06 -.20
  ST.E.      .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14

13- 24      -.10  .10 -.05  .08  .05 -.21  .16  .03  .06 -.06  .08 -.06
  ST.E.      .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14

25- 36      -.21  .17  .07 -.07 -.10  .02 -.08  .06 -.04 -.05 -.04 -.03
  ST.E.      .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14  .14

PLOT OF PARTIAL AUTOCORRELATIONS

           -1.0  -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG    CORR. +----+----+----+----+----+----+----+----+----+----+
                                      I
  1    -.147                   +  XXXXI      +
  2     .199                   +      IXXXXX +
  3     .291                   +      IXXXXXXXX
  4     .072                   +      IXX    +
  5    -.017                   +      I      +
  6     .126                   +      IXXX   +
  7    -.146                   +  XXXXI      +
  8    -.214                   + XXXXXI      +
  9     .075                   +      IXX    +
 10    -.238                   +XXXXXXI      +
 11     .059                   +      IX     +
 12    -.202                   + XXXXXI      +
 13    -.097                   +    XXI      +
 14     .101                   +      IXXX   +
 15    -.052                   +     XI      +
 16     .082                   +      IXX    +
 17     .051                   +      IX     +
 18    -.210                   + XXXXXI      +
 19     .165                   +      IXXXX  +
 20     .034                   +      IX     +
 21     .062                   +      IXX    +
 22    -.063                   +    XXI      +
 23     .077                   +      IXX    +
 24    -.057                   +     XI      +
 25    -.214                   + XXXXXI      +
 26     .168                   +      IXXXX  +
 27     .067                   +      IXX    +
 28    -.069                   +    XXI      +
 29    -.099                   +    XXI      +
 30     .013                   +      I      +
 31    -.084                   +    XXI      +
 32     .061                   +      IXX    +
 33    -.036                   +     XI      +
 34    -.049                   +     XI      +
 35    -.043                   +     XI      +
 36    -.034                   +     XI      +
```

Figure F-114. PACF - Lagged 12 Months

```
ESTIMATION BY BACKCASTING METHOD

RELATIVE CHANGE IN RESIDUAL SUM OF SQUARES LESS THAN  .1000-004


SUMMARY OF THE MODEL

OUTPUT VARIABLE -- TRANS
INPUT VARIABLES -- NOISE

VARIABLE  VAR. TYPE  MEAN      TIME      DIFFERENCES
                                              12
TRANS       RANDOM             1-  58  (1-B   )

PARAMETER VARIABLE    TYPE  FACTOR  ORDER ESTIMATE        ST. ERR.  T-RATIO
       1  TRANS        MA      1       1      .3012          .1507      2.00
       2  TRANS        MA      1       2     -.2716          .1484     -1.83
       3  TRANS        AR      1      12     -.6371          .1136     -5.61

RESIDUAL SUM OF SQUARES  =          2.189792 (BACKCASTS EXCLUDED)
DEGREES OF FREEDOM       =                31
RESIDUAL MEAN SQUARE     =           .070638
```

Figure F-115. Model Parameters - Chill

```
AUTOCORRELATIONS

  1- 12      .04  -.04   .21  -.07   .06   .11  -.12   0.0   .07  -.21   .08  -.03
  ST.E.      .13   .13   .13   .14   .14   .14   .14   .14   .14   .14   .15   .15

 13- 24     -.20   .04  -.12  -.05  -.09  -.17   .04   .11  -.08   .09   .09  -.17
  ST.E.      .15   .15   .15   .15   .15   .16   .16   .16   .16   .16   .16   .16

 25- 36      .05   .04   .04   .03  -.09   .08   .01   0.0  -.07  -.06  -.06   0.0
  ST.E.      .17   .17   .17   .17   .17   .17   .17   .17   .17   .17   .17   .17

PLOT OF AUTOCORRELATIONS

             -1.0 -.8  -.6  -.4  -.2   .0   .2   .4   .6   .8  1.0
LAG     CORR.  +----+----+----+----+----+----+----+----+----+----+
                                        I
  1      .038                     +     IX    +
  2     -.039                     +    XI     +
  3      .208                     +     IXXXXX+
  4     -.066                    +    XXI      +
  5      .064                    +      IXX    +
  6      .107                    +      IXXX   +
  7     -.120                    +   XXXI      +
  8     -.004                    +      I      +
  9      .071                    +      IXX    +
 10     -.208                    + XXXXXI      +
 11      .083                    +      IXX    +
 12     -.035                    +     XI      +
 13     -.198                    + XXXXXI      +
 14      .042                    +      IX     +
 15     -.124                    +   XXXI      +
 16     -.046                   +      XI       +
 17     -.088                   +     XXI       +
 18     -.166                   +   XXXXI       +
 19      .044                   +       IX      +
 20      .115                   +       IXXX    +
 21     -.084                   +     XXI       +
 22      .090                   +       IXX     +
 23      .092                   +       IXX     +      .269(50)=15.63
 24     -.174                   +   XXXXI       +
 25      .047                   +       IX      +
 26      .044                   +       IX      +
 27      .041                   +       IX      +
 28      .027                   +       IX      +
 29     -.088                   +     XXI       +
 30      .085                   +       IXX     +
 31      .005                   +       I       +
 32     -.005                   +       I       +
 33     -.069                   +     XXI       +
 34     -.064                   +     XXI       +
 35     -.058                   +      XI       +
 36     -.005                   +       I       +
```

Figure F-116. Estimated Residuals - Chill

```
FORECAST ON VARIABLE TRANS     FROM TIME PERIOD     59

PERIOD              FORECASTS          ST. ERR.           ACTUAL      ERROR
  59                 6.58359   .947    .26832              1.029       .082
  60                 7.43510  1.694    .28022              1.088      -.606
  61                 6.65226   .774    .28955              1.076       .302
  62                 6.86727   .960    .28955               .837      -.123
  63                 6.99583  1.092    .28955               .777      -.315
  64                 6.70819   .819    .28955              1.258       .439
  65                 7.04839  1.151    .28955              1.852       .701
  66                 7.39250  1.623    .28955              1.612      -.011
  67                 7.02959  1.129    .28955              1.083      -.046
  68                 7.58327  1.965    .28955               .942     -1.023
  69                 7.46953  1.754    .28955              1.404      -.35
  70                 7.25248  1.412    .28955              1.170      -.242
STANDARD ERROR =   .268319      (BY CONDITIONAL METHOD  )

                              15.32                        14.13     MSE=.21
```

Figure F-117. Forecast FY 82 - Chill

APPENDIX G

WINTERS MODEL INITIALIZATION AND SMOOTHING CONSTANTS

G-1. GENERAL. This section addresses initialization of model parameters and development of smoothing constants.

G-2. INITIALIZATION. Chapter 6 discussed the procedure for updating the parameters (permanent component, trend, and seasonal factor), given that initial values exist. Upon option, initial estimates of the Winters model parameters can be specified by the user. Alternatively, several heuristic algorithms have been devised to initialize parameters based on manipulation of historical data. The initialization procedure described below is due to Montgomery,[5] and is similar to the one proposed by Winters.

a. Trend Component. Assuming that data are available for m seasons, then compute the mean of all observations for the first and last of these seasons. Denote the average observation for the jth season by $\bar{x}_j$, j = 1,2,...,m. Estimate the trend in the same manner that would be used to compute a simple algebraic slope. Since there are m-1 seasons between season 1 and season m, and since there are L periods per season, then the initial estimate of the trend becomes

$$\hat{b}_2(0) = \frac{\bar{x}_m - \bar{x}_1}{(m - 1)\ L} \qquad \text{(G-1)}$$

b. Permanent Component. For initialization purposes, it is assumed that the average observation $\bar{x}_1$ for the first season occurs timewise at the middle of the season. With this in mind, the permanent component can be treated like a simple y-intercept. Writing the equation in slope-intercept form gives

$$\bar{x}_1 = \hat{a}_1(0) + \frac{L}{2}\hat{b}_2(0) \qquad \text{(G-2)}$$

Since all terms are known except for the permanent component, equation (G-2) can be rewritten as

$$\hat{a}_1(0) = \bar{x}_1 - \frac{L}{2}\hat{b}_2(0) \qquad \text{(G-3)}$$

c. Seasonal Factor. Since there are m seasons and L periods per season, seasonal factors are computed initially for each of the mL periods. Each factor is computed as the ratio of the actual observation to the average seasonally adjusted value for that season, further adjusted by the trend. The computation is

$$\hat{c}_t = \frac{x_t}{\bar{x}_i - [(L + 1)/2 - j]\hat{b}_2(0)} \qquad t = 1,2,\ldots,mL \qquad \text{(G-4)}$$

where $\bar{x}_i$ is the average for a season corresponding to the t index, and j is the position of period t within the season. For example, if $1 \leq t \leq L$, then $i = 1$, and if $L + 1 \leq t \leq 2L$, then $i = 2$. Equation (G-4) produces m estimates of the seasonal factor for each period. (In the TWF Study, m was usually five, and there were five estimates for each month of the year.) The m estimates for each period (month) are averaged to produce a single estimate of the seasonal factor for each period within the season.

$$\bar{c}_t = \frac{1}{m} \sum_{k=0}^{m-1} \hat{c}_{t+kL} \qquad t = 1,2,\ldots,L \qquad \text{(G-5)}$$

Finally, the seasonal factors are normalized so that they sum to L (L = 12 in the study).

$$\hat{c}_t(0) = \bar{c}_t \frac{L}{\sum_{t=1}^{L} \bar{c}_t} \qquad t = 1,2,\ldots,L \qquad \text{(G-6)}$$

The above procedure produces estimates $\hat{a}_1(0)$, $\hat{b}_2(0)$, and $\hat{c}_t(0)$ assuming that the origin of time is immediately prior to period 1. The parameters may then be updated by the technique described in paragraph 6-5 of this report.

G-3. SMOOTHING CONSTANTS. Smoothing constants are necessary in order to combine (weight) previous estimates of parameters with their updated values. Numerical estimates of the permanent component, trend component, and seasonal factor receive the weights α , β , and γ for the current interval T. These weighted estimates are combined additively with complementary weighted values (using $1-\alpha$, $1-\beta$, and $1-\gamma$) for the previous time period or season, as appropriate. All weights are varied incrementally so that the parameters of the model ultimately provide the best fit according to some predetermined criterion, i.e., mean square error. Unlike the formal method of least squares, which uses partial derivatives to develop a set of simultaneous linear equations (normal equations) that are solved through matrix inversion, the Winters method is heuristic in nature. As such, the optimum set of smoothing constants is determined by trial and error. The coefficients lie in the interval (0,1). In order to keep computer time requirements modest, a coarse grid is tried first. Values of α , β , and γ are stepped across the unit interval in increments of 0.05 until all possible combinations of smoothing constants have been examined. The set of (α, β, γ) producing the smallest mean square error is used in the program as the basis for a second, fine-grained search. A step of 0.01 is used to search in a narrow interval about the coarse estimates of (α, β, γ) to yield refined values of the smoothing constants.

APPENDIX H

THE WINTERS METHOD COMMODITY ANALYSIS

For the nine commodities evaluated in the study, this appendix contains three exhibits each:

a. The first exhibit for each commodity displays the top 40 sets of smoothing constants obtained during the Winters model optimization process. The sets of (α , β , γ) are rank-ordered according to the residual sums of squares they produce. Since each smoothing constant is stepped across the unit interval (0,1) in increments of 0.01, there are 100^3, or one million, candidate sets of smoothing constants evaluated for each commodity. The model ultimately defined for each commodity is the one yielding the smallest residual sum of squares over the data interval defined up to, but not including, the forecast interval. This set of optimum smoothing constants is then presumed to yield the best fit over the forecast interval. It should be noted that although this selection criterion provides the best fit over the initialization interval, it does not always guarantee the best fit over the forecast interval.

b. The second exhibit for each commodity displays both the raw and fitted time series over the entire model initialization interval, i.e., up to but not including the forecast interval. For most of the nine commodities, 60 months (5 years) worth of data were used in the initialization phase to formulate the optimum model. Because transportation workload forecasting requires a lead time of at least 12 months, the parameters (permanent component, trend, and seasonal factor) from the last 12 months (usually months 49 to 60) of the initialization phase were used to produce the 12 monthly estimates of the forecast phase.

c. The third exhibit for each commodity shows the actual forecast phase. Summary statistics are provided at the end of each printout. Once the Winters model smoothing constants and parameters have been developed internally, calculation of forecasts is straightforward. For example, applying the forecast formula

$$\hat{x}_{T+\tau}(T) = \left[\hat{a}_1(T) + \hat{b}_2(T)\tau\right]\hat{c}_{T+\tau}(T+\tau-L)$$

to obtain an estimate for POVs shipped during month 67 would require use of parameters from month 55 (T=55; τ =12; L=12).

$$\hat{x}_{67}(55) = \left[40.1948 + (0.0376)(12)\right] 0.8949$$
$$= 36.37$$

```
ALPHA              BETA             GAMMA                RESIDUAL SUM OF SQUARES

  .0400             .1500             .0000                           .2156452+004
  .0500             .1400             .0000                           .2161700+004
  .0400             .1400             .0000                           .2162006+004
  .0300             .1500             .0000                           .2163242+004
  .0400             .1500             .0100                           .2164442+004
  .0400             .1400             .0100                           .2169780+004
  .0300             .1400             .0100                           .2170400+004
  .0500             .1500             .0100                           .2172151+004
  .0400             .1500             .0200                           .2172574+004
  .0400             .1400             .0200                           .2177097+004
  .0500             .1400             .0200                           .2179227+004
  .0400             .1500             .0300                           .2180638+004
  .0600             .1500             .0200                           .2181186+004
  .0400             .1400             .0300                           .2185753+004
  .0500             .1400             .0300                           .2188175+004
  .0600             .1400             .0000                           .2188705+004
  .0300             .1500             .0000                           .2189010+004
  .0400             .1500             .0400                           .2189229+004
  .0500             .1500             .0300                           .2190338+004
  .0400             .1400             .0400                           .2193938+004
  .0300             .1500             .0100                           .2195634+004
  .0500             .1400             .0400                           .2197238+004
  .0700             .1400             .0100                           .2198079+004
  .0600             .1500             .0000                           .2198525+004
  .0300             .1400             .0000                           .2199353+004
  .0200             .1500             .0400                           .2199602+004
  .0300             .1500             .0200                           .2202424+004
  .0300             .1400             .0100                           .2205771+004
  .0600             .1400             .0200                           .2207568+004
  .0600             .1500             .0100                           .2208121+004
  .0300             .1500             .0300                           .2209372+004
  .0300             .1400             .0200                           .2212358+004
  .0300             .1500             .0400                           .2216471+004
  .0600             .1400             .0300                           .2217168+004
  .0600             .1500             .0200                           .2217832+004
  .0300             .1400             .0300                           .2219106+004
  .0200             .1400             .0400                           .2226008+004
  .0600             .1400             .0400                           .2226674+004
  .0600             .1500             .0300                           .2227651+004
  .0700             .1400             .0000                           .2236265+004
THE OPTIMUM SMOOTHING CONSTANTS ARE
ALPHA =        .0400       BETA =        .1500       GAMMA =        .0000
```

Figure H-1. Smoothing Constant Optimization Routine - POV

```
PERIOD    OBSERVATION      PERMANENT COMPONENT  TREND       SEASONAL FACTOR    FITTED MODEL    RESIDUAL

   1        41.8210             44.1774          -.0694          .8786            .0000           .0000
   2        35.9660             43.9387          -.0948          .9019            .0000           .0000
   3        36.0050             43.8524          -.0935          .8173            .0000           .0000
   4        27.0640             43.5496          -.1249          .7544            .0000           .0000
   5        25.6070             43.2041          -.1580          .6755            .0000           .0000
   6        34.8120             42.9724          -.1691          .8449            .0000           .0000
   7        34.0600             42.6136          -.1975          .8949            .0000           .0000
   8        53.1710             42.6181          -.1672         1.1202            .0000           .0000
   9        64.7710             42.5069          -.1588         1.4770            .0000           .0000
  10        66.2930             42.6007          -.1209         1.3623            .0000           .0000
  11        49.2690             42.3329          -.1430         1.2696            .0000           .0000
  12        52.1340             42.5806          -.0843         1.0034            .0000           .0000
  13        34.3520             42.3603          -.1047          .8786            .0000         34.3520
  14        42.2300             42.4381          -.0774          .9019          38.6046          3.6254
  15        32.3950             42.2519          -.0937          .8173          34.9222         -2.5272
  16        37.3910             42.4545          -.0493          .7544          31.7223          5.6687
  17        28.3350             42.3870          -.0520          .6755          27.9021           .4329
  18        30.8300             42.1012          -.0871          .8449          34.5928         -3.7628
  19        37.0850             41.9912          -.0905          .8949          36.0131          1.0719
  20        43.4380             41.7757          -.1092         1.1202          45.4937         -2.0557
  21        48.7130             41.3190          -.1614         1.4770          59.9687        -11.2557
  22        57.8420             41.2098          -.1535         1.3623          56.0569          1.7851
  23        54.8990             41.1436          -.1404         1.2696          51.5690          3.3300
  24        37.0340             40.8394          -.1650         1.0034          41.7091         -4.6751
  25        40.0110             40.8689          -.1358          .8786          36.1154          3.8956
  26        34.6780             40.6417          -.1495          .9019          37.4398         -2.7618
  27        34.2080             40.5467          -.1414          .8173          33.6124           .5956
  28        30.1880             40.3898          -.1437          .7544          31.5810         -1.3930
  29        28.5490             40.3269          -.1316          .6755          28.2094           .3396
  30        35.2520             40.2565          -.1224          .8449          34.6881           .5639
  31        36.7740             40.1725          -.1166          .8949          36.6053           .1687
  32        42.2980             39.9639          -.1304         1.1202          45.3295         -3.0315
  33        57.7660             39.8046          -.1348         1.4770          58.1690          -.4030
  34        47.1440             39.4673          -.1651         1.3623          53.6287         -6.4847
  35        51.8800             39.3646          -.1558         1.2696          50.0974          1.7826
  36        37.4080             39.1317          -.1673         1.0034          38.9909         -1.5829
  37        35.8890             39.0396          -.1561          .8786          34.4773          1.4117
  38        36.8110             38.9607          -.1445          .9019          35.0382          1.7728
  39        34.7370             38.9638          -.1224          .8173          31.7514          2.9856
  40        30.0510             38.8812          -.1164          .7544          29.1686           .8824
  41        30.9360             39.0462          -.0742          .6755          26.1729          4.7631
  42        38.7330             39.2469          -.0329          .8449          32.7713          5.9617
  43        37.2930             39.3123          -.0182          .8949          34.6970          2.5960
  44        53.3450             39.6272           .0318         1.1202          43.0152         10.3298
  45        70.8400             39.9910           .0816         1.4770          56.4035         14.4365
  46        54.6410             40.0741           .0818         1.3623          51.0654          3.5756
  47        49.1420             40.0979           .0731         1.2696          47.6050          1.5370
  48        39.1960             40.1267           .0665         1.0034          37.2493          1.9467
  49        31.0530             39.9991           .0374          .8786          32.6567         -1.6037
  50        37.3380             40.0909           .0455          .9019          33.5769          3.7611
  51        32.0780             40.1010           .0402          .8173          30.6441          1.4339
  52        28.9860             40.0725           .0299          .7544          28.2776           .7084
  53        25.8230             40.0275           .0187          .6755          25.7730           .0500
  54        34.3270             40.0695           .0222          .8449          32.8251          1.5019
  55        38.1860             40.1948           .0376          .8949          34.9844          3.2016
  56        38.3020             39.9908           .0014         1.1202          44.8182         -6.5162
  57        60.5390             40.0320           .0074         1.4770          60.5134           .0256
  58        52.7060             39.9854          -.0007         1.3623          55.9290         -3.2230
  59        52.6520             40.0441           .0082         1.2696          52.0233           .6287
  60        38.7010             39.9930          -.0007         1.0034          41.0628         -2.3618
SUM OF RESIDUALS =     67.4840      AVERAGE RESIDUAL =      1.1247      VARIANCE =     32.6351      STANDARD DEVIATION =      5.7127

MEAN ABSOLUTE DEVIATION =      2.9127

NUMBER OF RESIDUALS EXCEEDING TWO STANDARD DEVIATIONS =    2
```

Figure H-2. Output of the Initialization Phase - POV

```
                                   LENGTH OF THE SEASON IS  12 PERIODS     FORECAST LEAD TIME IS  12 PERIODS
PERIOD     OBSERVATION      PERMANENT COMPONENT     TREND     SEASONAL FACTOR     FORECAST     ERROR            TRACKING SIGNALS
                                                                                                          CUM. ERROR  SMOOTHED ERROR
  61         33.6640               39.9251          -.0106           .8786         35.5391    -1.8751       -.6675      -.0668
  62         42.0160               40.1811           .0292           .9019         36.6526     5.3634       1.1303       .1200
  63         35.0200               40.3159           .0451           .8173         33.1677     1.8523       1.8146       .1753
  64         30.7990               40.3796           .0479           .7544         30.5006      .2984       2.1051       .1845
  65         28.0000               40.4665           .0540           .6755         27.1883      .8117       2.5986       .2111
  66         38.2140               40.7108           .0623           .8449         34.0788     4.1352       3.9952       .3339
  67         40.3110               40.9632           .1078           .8949         36.3737     3.9373       5.2159       .4281
  68         47.2010               41.1136           .1142          1.1202         44.8172     2.3838       6.1607       .4778
  69         57.0710               41.1242           .0986          1.4770         59.2584    -2.1874       5.4747       .3575
  70         61.3440               41.3751           .1215          1.3623         54.4588     6.6852       6.9506       .4997
  71         51.1920               41.4496           .1144          1.2696         50.9658      .2262       7.7412       .5039
  72         45.4200               41.7121           .1266          1.0034         40.1198     5.3002       8.8430       .5896
SUM OF FORECAST ERRORS =   27.1312     MEAN FORECAST ERROR =     2.2609     VARIANCE =     8.5216     STANDARD DEVIATION =    2.9192
ROOT MEAN SQUARE ERROR =    3.5949     MEAN OBSERVATION =   42.5210
MEAN ERROR AS FRACTION OF MEAN OBSERVATION =     .0532     RMS ERROR AS FRACTION OF MEAN OBSERVATION =     .0845
```

Figure H-3. Output of Forecasting Phase - POV

```
ALPHA          BETA          GAMMA          RESIDUAL SUM OF SQUARES

 .0200         .0100         .0000                   .2737672+005
 .0200         .0100         .0100                   .2738988+005
 .0300         .0100         .0000                   .2740359+005
 .0200         .0100         .0200                   .2740609+005
 .0200         .0100         .0300                   .2742710+005
 .0200         .0100         .0400                   .2745268+005
 .0300         .0100         .0100                   .2745406+005
 .0300         .0100         .0200                   .2750715+005
 .0300         .0100         .0300                   .2756273+005
 .0300         .0000         .0000                   .2759750+005
 .0300         .0000         .0100                   .2762060+005
 .0300         .0100         .0400                   .2762070+005
 .0300         .0000         .0200                   .2764756+005
 .0300         .0000         .0300                   .2767619+005
 .0400         .0000         .0000                   .2769008+005
 .0300         .0000         .0400                   .2771235+005
 .0400         .0000         .0100                   .2773582+005
 .0400         .0100         .0000                   .2777746+005
 .0400         .0000         .0400                   .2778694+005
 .0400         .0000         .0200                   .2778398+005
 .0200         .0000         .0300                   .2778404+005
 .0200         .0000         .0200                   .2779506+005
 .0200         .0000         .0100                   .2780630+005
 .0200         .0000         .0000                   .2783607+005
 .0400         .0000         .0300                   .2783444+005
 .0400         .0100         .0100                   .2784377+005
 .0400         .0000         .0400                   .2788712+005
 .0400         .0100         .0200                   .2791155+005
 .0100         .0000         .0000                   .2793663+005
 .0100         .0100         .0400                   .2795684+005
 .0400         .0100         .0300                   .2798672+005
 .0100         .0000         .0100                   .2798733+005
 .0100         .0100         .0300                   .2800739+005
 .0500         .0000         .0200                   .2804564+005
 .0400         .0100         .0400                   .2805125+005
 .0100         .0100         .0200                   .2806719+005
 .0500         .0000         .0300                   .2810548+005
 .0100         .0100         .0100                   .2813672+005
 .0100         .0000         .0400                   .2816681+005
 .0100         .0100         .0000                   .2821652+005
THE OPTIMUM SMOOTHING CONSTANTS ARE
ALPHA =      .0200     BETA =      .0100     GAMMA =      .0000
```

Figure H-4. Smoothing Constant Optimization Routine - General Cargo

```
PERIOD   OBSERVATION   PERMANENT COMPONENT   TREND    SEASONAL FACTOR   FITTED MODEL   RESIDUAL

  1      169.6850         149.6588          -.0219        .9503           .0000          .0000
  2      136.5980         149.5693          -.0225        .9340           .0000          .0000
  3      137.1570         149.5147          -.0229        .9271           .0000          .0000
  4      118.3890         149.3778          -.0240        .8234           .0000          .0000
  5      119.1380         149.2094          -.0254        .8382           .0000          .0000
  6      156.7930         149.1635          -.0257       1.0583           .0000          .0000
  7      155.4170         149.0886          -.0261       1.0596           .0000          .0000
  8      149.0790         148.7913          -.0289       1.1002           .0000          .0000
  9      151.3190         148.5652          -.0306       1.0816           .0000          .0000
 10      153.6160         148.4037          -.0321       1.0894           .0000          .0000
 11      164.4400         148.3877          -.0320       1.1023           .0000          .0000
 12      175.5320         148.7782          -.0278       1.0357           .0000          .0000
 13      102.8350         147.9396          -.0359        .9503           .0000       102.8350
 14      152.1220         148.2032          -.0329        .9340        139.4390        12.6830
 15      155.6140         148.5640          -.0289        .9271        138.3590        17.2550
 16      131.8680         148.7676          -.0266        .8234        122.7540         9.1140
 17      127.9600         148.8194          -.0258        .8382        124.8093         3.1507
 18      170.9940         149.0493          -.0233       1.0583        157.5279        13.4661
 19      184.4550         149.5271          -.0183       1.0596        157.6414        26.8136
 20      195.2790         150.0686          -.0127       1.1002        163.3190        31.9600
 21      185.6250         150.4872          -.0083       1.0816        160.3138        25.3112
 22      192.7660         151.0083          -.0030       1.0894        161.2488        31.5172
 23      183.7000         151.3182           .0001       1.1023        163.1439        20.5561
 24      172.3100         151.6192           .0031       1.0357        153.7500        18.5600
 25      159.2710         151.9417           .0063        .9503        140.1822        19.0888
 26      152.8860         152.1830           .0086        .9340        138.0475        14.8385
 27      141.4420         152.1991           .0087        .9271        137.4102         4.0318
 28      136.8760         152.4885           .0115        .8234        122.2259        14.6501
 29      132.2370         152.6053           .0126        .8382        124.4787         7.7583
 30      191.2660         153.1803           .0182       1.0583        157.4374        33.8286
 31      171.9870         153.3808           .0200       1.0596        158.2064        13.7806
 32      183.2010         153.6631           .0226       1.1002        164.9383        18.2627
 33      190.8690         154.1413           .0272       1.0816        162.6603        28.2087
 34      194.2460         154.6513           .0320       1.0894        164.4664        29.7796
 35      191.2590         155.0599           .0358       1.1023        166.7981        24.4609
 36      157.4220         155.0336           .0352       1.0357        157.0759          .3461
 37      146.0310         155.0406           .0349        .9503        144.4662         1.5648
 38      160.8880         155.4193           .0383        .9340        142.2295        18.6585
 39      162.2110         155.8478           .0422        .9271        141.1990        21.0120
 40      141.5720         156.2111           .0454        .8234        125.6662        15.9058
 41      140.5560         156.4853           .0477        .8382        128.0381        12.5179
 42      153.6900         156.3069           .0455       1.0583        162.3355        -8.6455
 43      158.9700         156.2259           .0442       1.0596        162.7763        -3.8063
 44      171.5310         156.2629           .0441       1.1002        169.3589         2.1721
 45      169.7890         156.3204           .0443       1.0816        167.0739         2.7151
 46      167.3760         156.3102           .0437       1.0894        168.8936        -1.5176
 47      171.1330         156.3319           .0435       1.1023        171.3949         -.2619
 48      145.8010         156.0633           .0404       1.0357        161.0110       -15.2100
 49      163.0200         156.4124           .0435        .9503        147.7373        15.2827
 50      130.6710         156.1250           .0402        .9340        145.5848       -14.9138
 51      130.6380         155.8601           .0371        .9271        144.9546       -14.3166
 52      117.4170         155.6314           .0344        .8234        129.0664       -11.6494
 53      136.1090         155.8002           .0358        .8382        131.6438         4.4652
 54      157.6270         155.6983           .0344       1.0583        165.9906        -8.3636
 55      159.7460         155.6332           .0334       1.0596        166.0985        -6.3525
 56      164.3520         155.5410           .0322       1.1002        172.5028        -8.1508
 57      151.8720         155.2700           .0291       1.0816        169.6523       -17.7803
 58      147.9970         154.9102           .0252       1.0894        170.8536       -22.8566
 59      153.9760         154.6304           .0222       1.1023        172.8990       -18.9230
 60      157.7460         154.6056           .0217       1.0357        162.1423        -4.3963
SUM OF RESIDUALS =   459.4065    AVERAGE RESIDUAL =     7.6568    VARIANCE =   347.4981    STANDARD DEVIATION =    18.6413
MEAN ABSOLUTE DEVIATION =    12.8949
NUMBER OF RESIDUALS EXCEEDING TWO STANDARD DEVIATIONS =    1
```

Figure H-5. Output of the Initialization Phase - General Cargo

```
                                       LENGTH OF THE SEASON IS  12 PERIODS     FORECAST LEAD TIME IS  12 PERIODS
PERIOD     OBSERVATION     PERMANENT COMPONENT     TREND     SEASONAL FACTOR     FORECAST     ERROR          TRACKING SIGNALS
                                                                                                     CUM. ERROR  SMOOTHED ERROR
  61        148.4970            154.6558           .0226          .9503          149.1387     -.6417     -.0720       -.0072
  62        148.6620            154.7677           .0229          .9340          146.2644     2.3976      .1446        .0152
  63        152.2910            154.5795           .0246          .9271          144.9389     7.3521      .8549        .0847
  64        141.7340            155.3477           .0282          .8234          128.4804    13.2536     2.0706        .1981
  65        145.6330            155.7427           .0319          .8382          130.9496    14.6834     3.3191        .3041
  66        177.4771            156.1132           .0343         1.0583          165.2361    12.2709     4.3783        .3833
  67        207.6660            156.3463           .0423         1.0596          165.3334    42.3326     6.3818        .5633
  68        184.0580            157.0967           .0443         1.1002          171.5507    12.5073     7.3481        .6019
  69        185.2460            157.4236           .0472         1.0816          168.3197    16.9263     8.3800        .6487
  70        190.5320            157.8193           .0507         1.0894          169.0869    21.4451     9.4087        .6985
  71        171.8230            157.8302           .0503         1.1023          170.7416     1.0814    10.4536        .7039
  72        168.1960            157.9701           .0512         1.0357          160.4306     7.7654    11.5164        .7185
SUM OF FORECAST ERRORS =  151.1759     MEAN FORECAST ERROR =   12.5980     VARIANCE =  132.2041     STANDARD DEVIATION =   11.4980
ROOT MEAN SQUARE ERROR =   16.7301     MEAN OBSERVATION =  168.4631
MEAN ERROR AS FRACTION OF MEAN OBSERVATION =     .0748     RMS ERROR AS FRACTION OF MEAN OBSERVATION =     .0993
```

Figure H-6. Output of Forecasting Phase - General Cargo

```
ALPHA            BETA            GAMMA         RESIDUAL SUM OF SQUARES

 .0000          1.0000           .0000                  .1665667+003
 .0000           .9900           .0000                  .1665672+003
 .0000          1.0000           .0100                  .1672567+003
 .0000           .9900           .0100                  .1672571+003
 .0000          1.0000           .0200                  .1679112+003
 .0000           .9900           .0200                  .1679115+003
 .0000          1.0000           .0300                  .1685900+003
 .0000           .9900           .0300                  .1685904+003
 .0000          1.0000           .0400                  .1692730+003
 .0000           .9900           .0400                  .1692734+003
 .0100           .9900           .0000                  .2251016+003
 .0100          1.0000           .0000                  .2260601+003
 .0100           .9900           .0100                  .2251653+003
 .0100          1.0000           .0100                  .2270660+003
 .0100           .9900           .0200                  .2272475+003
 .0100          1.0000           .0200                  .2281304+003
 .0100           .9900           .0300                  .2283680+003
 .0100          1.0000           .0300                  .2291932+003
 .0100           .9900           .0400                  .2293671+003
 .0100          1.0000           .0400                  .2302543+003
 .0200           .9900           .0000                  .3060605+003
 .0200           .9900           .0100                  .3076241+003
 .0200          1.0000           .0000                  .3081452+003
 .0200           .9900           .0200                  .3091971+003
 .0200          1.0000           .0100                  .3097249+003
 .0200           .9900           .0300                  .3107797+003
 .0200          1.0000           .0200                  .3113149+003
 .0200           .9900           .0400                  .3123713+003
 .0200          1.0000           .0300                  .3129139+003
 .0200          1.0000           .0400                  .3145222+003
 .0300           .9900           .0000                  .4355235+003
 .0300           .9900           .0100                  .4372434+003
 .0300           .9900           .0200                  .4389568+003
 .0300           .9900           .0300                  .4406627+003
 .0300          1.0000           .0000                  .4407079+003
 .0300           .9900           .0400                  .4423613+003
 .0300          1.0000           .0100                  .4424109+003
 .0300          1.0000           .0200                  .4441669+003
 .0300          1.0000           .0300                  .4457942+003
 .0300          1.0000           .0400                  .4474734+003
THE OPTIMUM SMOOTHING CONSTANTS ARE
ALPHA =       .0000      BETA =       1.0000      GAMMA =       .0000
```

Figure H-7. Smoothing Constant Optimization Routine - HHG

```
PERIOD     OBSERVATION      PERMANENT COMPONENT   TREND      SEASONAL FACTOR     FITTED MODEL    RESIDUAL

   1          8.2500              9.4076          -.0725          .9026              .0000          .0000
   2          5.4450              9.3351          -.0725          .6399              .0000          .0000
   3          7.0060              9.2626          -.0725          .7864              .0000          .0000
   4          5.8850              9.1901          -.0725          .9760              .0000          .0000
   5          5.9310              9.1177          -.0725          .6393              .0000          .0000
   6          5.7190              9.0452          -.0725          .7969              .0000          .0000
   7          7.2490              8.9727          -.0725          .6979              .0000          .0000
   8          6.4770              8.9002          -.0725          .8337              .0000          .0000
   9         11.9690              8.8277          -.0725         1.3107              .0000          .0000
  10         13.7880              8.7552          -.0725         1.5483              .0000          .0000
  11         13.8700              8.6627          -.0725         1.8106              .0000          .0000
  12         11.9530              8.6103          -.0725         1.0577              .0000          .0000
  13          7.9610              8.5378          -.0725          .9026              .0000         7.9610
  14          5.6590              8.4653          -.0725          .6399             5.4170          .2420
  15          7.8850              8.3928          -.0725          .7864             6.6004         1.2846
  16          5.7300              8.3203          -.0725          .9760             8.1209        -2.3909
  17          5.6180              8.2478          -.0725          .6393             5.2728          .3452
  18          8.1030              8.1754          -.0725          .7969             6.5148         1.5882
  19          5.1060              8.1029          -.0725          .6979             5.6550         -.5490
  20          8.8290              8.0304          -.0725          .8337             6.6947         2.1343
  21         12.1880              7.9579          -.0725         1.3107            10.4305         1.7575
  22         13.5640              7.8854          -.0725         1.5483            12.2091         1.3549
  23         15.4560              7.8129          -.0725         1.8106            14.1462         1.3098
  24          5.8870              7.7405          -.0725         1.0577             8.1867        -2.2997
  25          7.3840              7.6680          -.0725          .9026             6.9208          .4632
  26          5.4260              7.5955          -.0725          .6399             4.8604          .5656
  27          5.4550              7.5230          -.0725          .7864             5.9163         -.4613
  28         12.3590              7.4505          -.0725          .9760             7.2720         5.0870
  29          4.6770              7.3780          -.0725          .6393             4.7167         -.0397
  30          6.0820              7.3056          -.0725          .7969             5.8217          .2603
  31          5.0920              7.2331          -.0725          .6979             5.0480          .0440
  32          5.3370              7.1606          -.0725          .8337             5.9696         -.6326
  33          8.1520              7.0881          -.0725         1.3107             9.2904        -1.1384
  34         10.3260              7.0156          -.0725         1.5483            10.8624         -.5364
  35          9.8740              6.9431          -.0725         1.8106            12.5714        -2.6974
  36          7.5020              6.8707          -.0725         1.0577             7.2668          .2352
SUM OF RESIDUALS =    13.8873     AVERAGE RESIDUAL =       .3858     VARIANCE =     3.4538     STANDARD DEVIATION =     1.8584
MEAN ABSOLUTE DEVIATION =       .9827
NUMBER OF RESIDUALS EXCEEDING TWO STANDARD DEVIATIONS =   2
```

Figure H-8. Output of the Initialization Phase - HHG

```
                                   LENGTH OF THE SEASON IS  12 PERIODS    FORECAST LEAD TIME IS  12 PERIODS
PERIOD     OBSERVATION     PERMANENT COMPONENT     TREND     SEASONAL FACTOR     FORECAST     ERROR           TRACKING SIGNALS
                                                                                                        CUM. ERROR  SMOOTHED ERROR
  37          6.4010             6.7982           -.0725          .9026           6.1357       .2653       .2912        .0291
  38          7.3680             6.7257           -.0725          .6399           4.3038      3.0642      2.9561        .2933
  39          8.7320             6.6532           -.0725          .7064           5.2323      3.4997      5.0080        .4746
  40          6.1260             6.5807           -.0725          .9760           6.4230      -.2970      5.3063        .4532
  41          6.4820             6.5082           -.0725          .6393           4.1607      2.3213      6.5988        .5443
  42          5.4340             6.4358           -.0725          .7969           5.1286       .3054      7.3972        .5555
  43          4.9880             6.3633           -.0725          .6979           4.4413       .5470      8.3016        .5761
  44          6.2470             6.2908           -.0725          .8337           5.2445      1.0025      9.2910        .6126
  45          9.8190             6.2183           -.0725         1.3107           8.1504      1.6665     10.2788        .6659
  46         10.1790             6.1458           -.0725         1.5483           9.5157       .6633     11.3395        .6851
  47          8.3080             6.0733           -.0725         1.6106          10.9965     -2.6885      7.9649        .3395
  48          7.5030             6.0009           -.0725         1.0577           6.3468      1.1562      8.9525        .3985
SUM OF FORECAST ERRORS =   11.5980     MEAN FORECAST ERROR =     .9665     VARIANCE =    2.6469     STANDARD DEVIATION =    1.6259
ROOT MEAN SQUARE ERROR =    1.8332     MEAN OBSERVATION =    7.3064
MEAN ERROR AS FRACTION OF MEAN OBSERVATION =      .1323     RMS ERROR AS FRACTION OF MEAN OBSERVATION =     .2509
```

Figure H-9. Output of Forecasting Phase - HHG

```
ALPHA           BETA            GAMMA           RESIDUAL SUM OF SQUARES

  .0000          .8900           .0000                     .1224654+005
  .0000          .9000           .0000                     .1224656+005
  .0000          .8900           .0100                     .1232437+005
  .0000          .9000           .0100                     .1232439+005
  .0000          .8900           .0200                     .1240184+005
  .0000          .9000           .0200                     .1240186+005
  .0000          .8900           .0300                     .1247694+005
  .0000          .9000           .0300                     .1247696+005
  .0000          .8900           .0400                     .1255568+005
  .0000          .9000           .0400                     .1255569+005
  .0100          .8900           .0000                     .5137646+005
  .0100          .8900           .0100                     .5144456+005
  .0100          .8900           .0200                     .5149444+005
  .0100          .8900           .0300                     .5152681+005
  .0100          .8900           .0400                     .5154231+005
  .0100          .9000           .0000                     .5207419+005
  .0100          .9000           .0100                     .5213635+005
  .0100          .9000           .0200                     .5218389+005
  .0100          .9000           .0300                     .5221154+005
  .0100          .9000           .0400                     .5222208+005
  .0200          .8900           .0400                     .7772438+005
  .0200          .8900           .0300                     .7785537+005
  .0200          .8900           .0200                     .7798082+005
  .0200          .8900           .0100                     .7810782+005
  .0200          .9000           .0400                     .7816768+005
  .0200          .8900           .0000                     .7823565+005
  .0200          .9000           .0300                     .7828672+005
  .0200          .9000           .0200                     .7840633+005
  .0200          .9000           .0100                     .7852764+005
  .0200          .9000           .0000                     .7864613+005
  .0400          .9000           .0400                     .8451678+005
  .0400          .8900           .0400                     .8474710+005
  .0400          .9000           .0300                     .8509282+005
  .0400          .8900           .0300                     .8531601+005
  .0400          .9000           .0200                     .8557180+005
  .0400          .8900           .0200                     .8589148+005
  .0400          .9000           .0100                     .8625401+005
  .0400          .8900           .0100                     .8646783+005
  .0400          .9000           .0000                     .8683973+005
  .0400          .8900           .0000                     .8734743+005
THE OPTIMUM SMOOTHING CONSTANTS ARE

ALPHA =       .0000     BETA =       .8900     GAMMA =       .0000
```

Figure H-10. Smoothing Constant Optimization Routine - Coal

```
PERIOD    OBSERVATION    PERMANENT COMPONENT   TREND      SEASONAL FACTOR    FITTED MODEL    RESIDUAL

   1        61.7490            47.9115         -.2827          .8873            .0000           .0000
   2        39.8610            47.6288         -.2827          .8125            .0000           .0000
   3        58.9880            47.3461         -.2827          .9436            .0000           .0000
   4        21.2340            47.0634         -.2827          .7127            .0000           .0000
   5        42.2440            46.7806         -.2827          .9675            .0000           .0000
   6        55.2310            46.4979         -.2827         1.1560            .0000           .0000
   7        39.9020            46.2152         -.2827         1.1061            .0000           .0000
   8        40.6600            45.9325         -.2827         1.0634            .0000           .0000
   9        58.0030            45.6498         -.2827         1.3628            .0000           .0000
  10        60.9250            45.3670         -.2827         1.1604            .0000           .0000
  11        59.1300            45.0843         -.2827         1.2019            .0000           .0000
  12        19.3400            44.8016         -.2827          .6257            .0000           .0000
  13        30.2670            44.5189         -.2827          .8873            .0000         30.2670
  14        18.5990            44.2362         -.2827          .8125          35.9433        -17.3443
  15        20.9670            43.9534         -.2827          .9436          41.4755        -20.5085
  16        32.4480            43.6707         -.2827          .7127          31.1247          1.3233
  17        17.5330            43.3890         -.2827          .9675          41.9767        -24.4437
  18        35.4080            43.1053         -.2827         1.1560          49.8310        -14.4230
  19        40.2750            42.8226         -.2827         1.1061          47.3673         -7.0923
  20        41.3810            42.5398         -.2827         1.0634          45.2363         -3.8553
  21        63.1420            42.2571         -.2827         1.3628          57.5898          5.5522
  22        16.4230            41.9744         -.2827         1.1604          48.7059        -32.2829
  23        17.5960            41.6917         -.2827         1.2019          50.1081        -32.5121
  24        14.7770            41.4090         -.2827          .6257          25.9090        -11.1320
  25        20.4500            41.1262         -.2827          .8873          36.4927        -16.0427
  26        21.3720            40.8435         -.2827          .8125          33.1867        -11.9147
  27        22.1760            40.5608         -.2827          .9436          38.2741        -16.0981
  28        21.5210            40.2781         -.2827          .7127          28.7067         -7.1857
  29        45.8590            39.9954         -.2827          .9675          38.6945          7.1645
  30        44.6730            39.7127         -.2827         1.1560          45.9090         -1.2360
  31        55.6230            39.4299         -.2827         1.1061          43.6146         12.0084
  32        58.0270            39.1472         -.2827         1.0634          41.6286         16.3984
  33        57.4620            38.8645         -.2827         1.3628          52.9662          4.4958
  34        60.8510            38.5818         -.2827         1.1604          44.7692         16.0818
  35        58.0400            38.2991         -.2827         1.2019          46.0306         12.0094
  36        19.4920            38.0163         -.2827          .6257          23.7863         -4.2943
  37        21.5640            37.7336         -.2827          .8873          33.4823        -11.9183
  38        42.7610            37.4509         -.2827          .8125          30.4301         12.3309
  39        46.2650            37.1682         -.2827          .9436          35.0728         11.1922
  40        40.7350            36.8655         -.2827          .7127          26.2888         14.4462
  41        41.9670            36.6028         -.2827          .9675          35.4122          6.5548
  42        43.8660            36.3201         -.2827         1.1560          41.9870          1.8790
  43        37.8610            36.0373         -.2827         1.1061          39.8620         -2.0010
  44        46.1380            35.7546         -.2827         1.0634          38.0210          8.1170
  45        57.7500            35.4719         -.2827         1.3628          48.3426          9.4074
  46        44.2760            35.1892         -.2827         1.1604          40.8326          3.4434
  47        61.9430            34.9065         -.2827         1.2019          41.9532         19.9898
  48        44.7790            34.6238         -.2827          .6257          21.6636         23.1154
  49        41.7800            34.3410         -.2827          .8873          30.4719         11.3081
  50        39.9490            34.0583         -.2827          .8125          27.6735         12.2755
  51        41.5780            33.7756         -.2827          .9436          31.8715          9.7065
  52        19.6390            33.4929         -.2827          .7127          23.8708         -4.2318
  53        42.9240            33.2102         -.2827          .9675          32.1300         10.7940
  54        43.0600            32.9275         -.2827         1.1560          38.0651          4.9949
  55        34.3070            32.6448         -.2827         1.1061          36.1094         -1.8024
  56        16.0400            32.3620         -.2827         1.0634          34.4134        -18.3734
  57        17.9520            32.0793         -.2827         1.3628          43.7191        -25.7671
  58        42.1530            31.7966         -.2827         1.1604          36.8959          5.2571
  59        36.4900            31.5139         -.2827         1.2019          37.8757         -1.3857
  60        19.2550            31.2312         -.2827          .6257          19.5409          -.2859

SUM OF RESIDUALS =   -15.9183     AVERAGE RESIDUAL =     -.2653     VARIANCE =   164.7487     STANDARD DEVIATION =     12.8354

MEAN ABSOLUTE DEVIATION =      9.[illegible]691

NUMBER OF RESIDUALS EXCEEDING TWO STANDARD DEVIATIONS =    4
```

Figure H-11. Output of the Initialization Phase - Coal

```
                                   LENGTH OF THE SEASON IS  12 PERIODS     FORECAST LEAD TIME IS  12 PERIODS
PERIOD      OBSERVATION      PERMANENT COMPONENT      TREND      SEASONAL FACTOR      FORECAST      ERROR           TRACKING SIGNALS
                                                                                                            CUM. ERROR  SMOOTHED ERROR
  61          19.8880               30.9465           -.2827            .6873          27.4616      -7.5736      -.8323       -.0832
  62          64.1163               30.6658           -.2827            .8125          24.9173      39.1990      2.6116        .2674
  63          41.7760               30.3031           -.2827            .9436          28.6702      13.1358      3.6638        .3451
  64          19.0280               30.1003           -.2827            .7127          21.4529      -2.4249      3.7670        .3173
  65          40.9160               29.8176           -.2827            .9675          28.8478      12.0682      4.8058        .3898
  66          38.1470               29.5349           -.2827           1.1560          34.1432       4.0038      5.5160        .4129
  67          19.1970               29.2522           -.2827           1.1061          32.3567     -13.1597      4.1711        .2414
  68          33.0850               28.9695           -.2827           1.0634          30.8058       2.2792      4.7570        .2597
  69          41.5670               28.6868           -.2827           1.3626          39.0955       2.4715      5.4117        .2786
  70          19.1030               28.4041           -.2827           1.1604          32.9593     -13.8563      3.7246        .0958
  71          19.4050               28.1214           -.2827           1.2019          33.7983     -14.3933      2.1366       -.0593
  72          19.7120               27.8386           -.2827            .6257          17.4182       2.2938      2.5605       -.0334

SUM OF FORECAST ERRORS =   24.0135     MEAN FORECAST ERROR =     2.0011     VARIANCE =  224.9176     STANDARD DEVIATION =   14.9973

ROOT MEAN SQUARE ERROR =   14.4976     MEAN OBSERVATION =   31.3283

MEAN ERROR AS FRACTION OF MEAN OBSERVATION =      .0639     RMS ERROR AS FRACTION OF MEAN OBSERVATION =      .4628
```

Figure H-12. Output of Forecasting Phase - Coal

```
ALPHA            BETA             GAMMA              RESIDUAL SUM OF SQUARES

 .0200            .0100            .0000                   .3740632+004
 .0200            .0100            .0100                   .3762219+004
 .0100            .0100            .0000                   .3762405+004
 .0200            .0000            .0000                   .3763193+004
 .0300            .0100            .0000                   .3764707+004
 .0300            .0000            .0000                   .3773682+004
 .0100            .0100            .0100                   .3781630+004
 .0200            .0100            .0200                   .3783939+004
 .0200            .0000            .0100                   .3784013+004
 .0200            .0100            .0100                   .3786704+004
 .0100            .0000            .0000                   .3789443+004
 .0200            .0000            .0100                   .3795274+004
 .0100            .0100            .0200                   .3801459+004
 .0400            .0000            .0000                   .3803952+004
 .0200            .0000            .0200                   .3804951+004
 .0200            .0100            .0300                   .3805771+004
 .0100            .0000            .0100                   .3807922+004
 .0200            .0100            .0200                   .3808835+004
 .0400            .0100            .0000                   .3811217+004
 .0300            .0000            .0200                   .3816961+004
 .0100            .0100            .0300                   .3821252+004
 .0400            .0000            .0100                   .3825577+004
 .0100            .0000            .0300                   .3825990+004
 .0100            .0000            .0200                   .3826605+004
 .0200            .0100            .0400                   .3827698+004
 .0300            .0100            .0300                   .3831078+004
 .0400            .0100            .0100                   .3832932+004
 .0300            .0000            .0300                   .3838724+004
 .0100            .0100            .0400                   .3841200+004
 .0100            .0000            .0300                   .3845473+004
 .0200            .0000            .0000                   .3845478+004
 .0300            .0000            .0400                   .3847115+004
 .0400            .0000            .0200                   .3847295+004
 .0200            .0100            .0400                   .3853412+004
 .0400            .0100            .0200                   .3854793+004
 .0300            .0000            .0400                   .3859546+004
 .0200            .0000            .0400                   .3864513+004
 .0100            .0000            .0100                   .3866751+004
 .0400            .0000            .0300                   .3869065+004
 .0200            .0100            .0000                   .3869670+004
THE OPTIMUM SMOOTHING CONSTANTS ARE
ALPHA =        .0200      BETA =        .0100      GAMMA =        .0000
```

Figure H-13. Smoothing Constant Optimization Routine - Ammunition

```
PERIOD      OBSERVATION      PERMANENT COMPONENT  TREND        SEASONAL FACTOR     FITTED MODEL    RESIDUAL

   1         25.2770              16.4325         -.0638             .9893            .0000          .0000
   2         18.6050              16.6094         -.0614             .6551            .0000          .0000
   3          5.6570              16.3551         -.0633             .8483            .0000          .0000
   4          8.4300              16.2763         -.0634             .5434            .0000          .0000
   5         21.6570              16.4348         -.0612             .7911            .0000          .0000
   6         15.3460              16.4361         -.0606             .7872            .0000          .0000
   7          6.6960              16.2273         -.0621             .7468            .0000          .0000
   8         14.5050              16.0389         -.0633            1.4725            .0000          .0000
   9         19.5950              15.9576         -.0635            1.2998            .0000          .0000
  10         19.0710              15.9442         -.0630            1.0365            .0000          .0000
  11         11.3190              15.7373         -.0645            1.3029            .0000          .0000
  12         24.7990              15.6829         -.0644            1.5272            .0000          .0000
  13         18.6330              15.6629         -.0637             .9893            .0000        18.6330
  14          7.9900              15.5507         -.0644             .6551          10.3976        -2.4076
  15         21.9550              15.6942         -.0623             .8483          13.2303         8.7247
  16         11.0740              15.7268         -.0614             .5434           8.4302         2.6438
  17         12.1960              15.6605         -.0614             .7911          12.4210         -.2250
  18         11.5160              15.5797         -.0616             .7872          12.3654         -.8494
  19         16.0170              15.6366         -.0604             .7468          11.5620         4.4550
  20         16.7200              15.4918         -.0613            1.4725          22.4983        -5.7783
  21         16.9510              15.3827         -.0618            1.2998          19.7508        -2.7998
  22         15.4440              15.3125         -.0618            1.0365          15.7417         -.2977
  23         14.8000              15.1729         -.0626            1.3029          19.4957        -4.6957
  24         10.4450              14.9448         -.0643            1.5272          22.7712       -12.3262
  25          9.7970              14.7610         -.0653             .9893          14.7590        -4.9620
  26         16.8710              14.9365         -.0631             .6551           9.6802         7.1908
  27          9.0940              14.7904         -.0639             .8483          12.6794        -3.5854
  28         15.9010              15.0173         -.0610             .5434           8.1451         7.7559
  29         19.5020              15.1502         -.0590             .7911          11.8065         7.6955
  30         27.9130              15.4985         -.0550             .7872          11.6816        16.2314
  31         18.9490              15.6421         -.0530             .7468          11.1357         7.8133
  32         39.4100              15.8127         -.0507            1.4725          21.7291        17.6809
  33         20.6080              15.7638         -.0507            1.2998          19.0312         1.5768
  34         30.3930              15.9852         -.0480            1.0365          15.1018        15.2912
  35         19.8860              15.9238         -.0481            1.3029          18.7893         1.0967
  36         30.8180              15.9617         -.0473            1.5272          21.6457         9.1723
  37          9.6240              15.7997         -.0485             .9893          13.8484        -4.2244
  38          9.8730              15.7288         -.0487             .6551           9.2885          .5845
  39         17.9400              15.7894         -.0476             .8483          11.8968         6.0432
  40          8.6190              15.7443         -.0475             .5434           7.7622          .8568
  41           .5150              15.3958         -.0505             .7911          11.4254       -10.9104
  42          6.4820              15.2031         -.0520             .7872          11.6806        -5.1986
  43         11.6870              15.1611         -.0519             .7468          11.2066          .4804
  44         23.4550              15.1256         -.0517            1.4725          22.3877         1.0673
  45         16.0200              15.0189         -.0523            1.2998          19.6985        -3.6785
  46         12.3600              14.9058         -.0529            1.0365          15.9710        -3.6110
  47         25.8790              14.9532         -.0519            1.3029          19.9938         5.8852
  48         22.4910              14.8978         -.0519            1.5272          23.5099        -1.0189
  49         13.4870              14.8217         -.0521             .9893          15.0461        -1.5591
  50          1.6280              14.5239         -.0546             .6551           9.9207        -8.2927
  51          9.1090              14.3946         -.0553             .8483          12.9105        -3.6015
  52          1.2350              14.0979         -.0576             .5434           8.2449        -7.0099
  53         10.9080              14.0351         -.0578             .7911          11.7004         -.7924
  54          5.5410              13.6386         -.0592             .7872          11.4764        -5.9354
  55          6.1860              13.6695         -.0603             .7468          10.8573        -4.6713
  56         22.2600              13.6393         -.0600            1.4725          21.3591          .9009
  57         24.6130              13.6665         -.0589            1.2998          18.7066         5.9064
  58          7.0730              13.4915         -.0603            1.0365          14.7919        -7.7189
  59         23.8430              13.5206         -.0593            1.3029          18.6712         5.1718
  60         27.3330              13.5578         -.0584            1.5272          21.8007         5.5323

SUM OF RESIDUALS =     52.0402     AVERAGE RESIDUAL =      .8673     VARIANCE =     40.7527     STANDARD DEVIATION =      6.3838

MEAN ABSOLUTE DEVIATION =      4.4123

NUMBER OF RESIDUALS EXCEEDING TWO STANDARD DEVIATIONS =    4
```

Figure H-14. Output of the Initialization Phase - Ammunition

```
                               LENGTH OF THE SEASON IS  12 PERIODS     FORECAST LEAD TIME IS  12 PERIODS
PERIOD     OBSERVATION     PERMANENT COMPONENT     TREND     SEASONAL FACTOR     FORECAST     ERROR          TRACKING SIGNALS
                                                                                                      CUM. ERROR  SMOOTHED ERROR
  61          .6620              13.2429           -.0610           .9893         14.0445    -13.3825    -2.5205        -.2521
  62        17.5570              13.4542           -.0583           .6551          9.0847      8.4723     -.8728        -.0635
  63         5.4820              13.2573           -.0596           .8463         11.6480     -6.1660    -1.9501        -.1652
  64         6.4560              13.1713           -.0599           .5434          7.2837      -.8277    -2.2916        -.1785
  65         7.3930              13.0361           -.0607           .7911         10.5550     -3.1620    -3.0185        -.2335
  66        21.0270              13.2502           -.0579           .7872         10.3341     10.6929     -.7863         .0061
  67        17.2280              13.3898           -.0559           .7468          9.6679      7.5601      .5532         .1365
  68        17.2190              13.3010           -.0563          1.4725         19.0241     -1.8051      .2576         .0983
  69        42.9030              13.6400           -.0523          1.2998         16.8707     26.0323     3.6885         .4141
  70        20.3420              13.7085           -.0511          1.0365         13.2337      7.1083     4.6653         .4739
  71        10.3940              13.5438           -.0522          1.3029         16.6987     -6.3047     3.8706         .3432
  72        12.6490              13.3873           -.0533          1.5272         19.6347     -6.9857     2.9246         .2140
SUM OF FORECAST ERRORS =   21.2322     MEAN FORECAST ERROR =    1.7693     VARIANCE =  113.9560     STANDARD DEVIATION =   10.6750
ROOT MEAN SQUARE ERROR =   10.3726     MEAN OBSERVATION =  14.9427
MEAN ERROR AS FRACTION OF MEAN OBSERVATION =     .1184     RMS ERROR AS FRACTION OF MEAN OBSERVATION =     .6942
```

Figure H-15. Output of Forecasting Phase - Ammunition

```
ALPHA          BETA          GAMMA          RESIDUAL SUM OF SQUARES

 .0000         .0000         .0000                    .2431589+005
 .0000         .0100         .0000                    .2431589+005
 .0000         .0000         .0100                    .2449296+005
 .0000         .0100         .0100                    .2449286+005
 .0000         .0000         .0200                    .2467207+005
 .0000         .0100         .0200                    .2467207+005
 .0100         .0000         .0000                    .2471109+005
 .0100         .0100         .0000                    .2478240+005
 .0000         .0100         .0300                    .2485335+005
 .0000         .0000         .0300                    .2485335+005
 .0100         .0000         .0100                    .2488754+005
 .0100         .0100         .0100                    .2496068+005
 .0000         .0100         .0400                    .2503653+005
 .0000         .0000         .0400                    .2503653+005
 .0100         .0000         .0200                    .2506587+005
 .0200         .0000         .0000                    .2512101+005
 .0100         .0100         .0200                    .2514082+005
 .0100         .0000         .0300                    .2524591+005
 .0200         .0000         .0100                    .2529436+005
 .0200         .0100         .0000                    .2529501+005
 .0100         .0100         .0300                    .2532266+005
 .0100         .0000         .0400                    .2542749+005
 .0200         .0000         .0200                    .2546931+005
 .0200         .0100         .0100                    .2547090+005
 .0100         .0100         .0400                    .2550603+005
 .0300         .0000         .0000                    .2551875+005
 .0200         .0000         .0300                    .2564569+005
 .0200         .0100         .0200                    .2564636+005
 .0300         .0000         .0100                    .2568776+005
 .0300         .0100         .0000                    .2580378+005
 .0200         .0000         .0400                    .2582335+005
 .0200         .0100         .0300                    .2582722+005
 .0300         .0000         .0200                    .2585815+005
 .0400         .0000         .0000                    .2589279+005
 .0300         .0100         .0100                    .2597536+005
 .0200         .0100         .0400                    .2600732+005
 .0300         .0000         .0300                    .2602975+005
 .0400         .0000         .0100                    .2605713+005
 .0300         .0100         .0200                    .2614626+005
 .0300         .0000         .0400                    .2620245+005
THE OPTIMUM SMOOTHING CONSTANTS ARE

ALPHA =      .0000      BETA =      .0000      GAMMA =      .0000
```

Figure H-16. Smoothing Constant Optimization Routine - Special

```
 PERIOD     OBSERVATION       PERMANENT COMPONENT  TREND       SEASONAL FACTOR     FITTED MODEL    RESIDUAL

    1        133.1570               56.8662        -.0698          1.3510              .0000          .0000
    2         58.8710               56.7964        -.0698           .9311              .0000          .0000
    3         39.4600               56.7265        -.0698          1.0358              .0000          .0000
    4         26.4770               56.6567        -.0698           .8144              .0000          .0000
    5         37.8540               56.5868        -.0698           .8785              .0000          .0000
    6         31.7930               56.5170        -.0698           .9097              .0000          .0000
    7         41.1710               56.4472        -.0698           .9003              .0000          .0000
    8         43.1400               56.3773        -.0698          1.0104              .0000          .0000
    9         63.5140               56.3075        -.0698           .9389              .0000          .0000
   10         71.2890               56.2376        -.0698          1.0699              .0000          .0000
   11         90.1430               56.1678        -.0698          1.2253              .0000          .0000
   12         67.3350               56.0979        -.0698           .9347              .0000          .0000
   13         81.1700               56.0281        -.0698          1.3510              .0000        81.1700
   14         35.1170               55.9583        -.0698           .9311            52.1052       -16.9882
   15         35.6830               55.8684        -.0698          1.0358            57.8870       -22.2040
   16         35.5450               55.8186        -.0698           .8144            45.4570        -9.9120
   17         39.0760               55.7487        -.0698           .8785            48.9743        -9.8983
   18         46.1390               55.6789        -.0698           .9097            50.6532        -4.5142
   19         39.6840               55.6091        -.0698           .9003            50.0646       -10.3806
   20         45.7730               55.5392        -.0698          1.0104            56.1187       -10.3457
   21         47.0490               55.4694        -.0698           .9389            52.0817        -5.0327
   22         48.9940               55.3995        -.0698          1.0699            59.2716       -10.2776
   23         71.4610               55.3297        -.0698          1.2253            67.7959         3.6651
   24         34.8690               55.2598        -.0698           .9347            51.6492       -16.7802
   25         86.1510               55.1900        -.0698          1.3510            74.5610        11.5900
   26         47.3930               55.1202        -.0698           .9311            51.3248        -3.9318
   27         92.1620               55.0503        -.0698          1.0358            57.0189        35.1431
   28         61.2190               54.9805        -.0698           .8144            44.7744        16.4446
   29         75.7660               54.9106        -.0698           .8785            48.2380        27.5280
   30         89.7010               54.8408        -.0698           .9097            49.8908        39.8102
   31         71.4100               54.7710        -.0698           .9003            49.3100        22.1000
   32         97.9750               54.7011        -.0698          1.0104            55.2718        42.7032
   33         60.3280               54.6313        -.0698           .9389            51.2947         9.0333
   34         51.0960               54.5614        -.0698          1.0699            58.3750        -7.2790
   35         54.6590               54.4916        -.0698          1.2253            66.7689       -12.1099
   36         64.1870               54.4217        -.0698           .9347            50.8659        13.3211
   37         34.2000               54.3519        -.0698          1.3510            73.4287       -39.2287
   38         66.9290               54.2821        -.0698           .9311            50.5444        18.3846
   39         50.7160               54.2122        -.0698          1.0358            56.1509        -5.4349
   40         62.8360               54.1424        -.0698           .8144            44.0919        18.7441
   41         41.7540               54.0725        -.0698           .8785            47.5018        -5.7478
   42         48.8690               54.0027        -.0698           .9097            49.1283         -.2593
   43         35.9820               53.9329        -.0698           .9003            48.5555       -12.5735
   44         42.7400               53.8630        -.0698          1.0104            54.4250       -11.6850
   45         45.3860               53.7932        -.0698           .9389            50.5078        -5.1218
   46         79.0210               53.7233        -.0698          1.0699            57.4783        21.5427
   47         54.1670               53.6535        -.0698          1.2253            65.7420       -11.5750
   48         51.7480               53.5836        -.0698           .9347            50.0825         1.6655
   49         72.3280               53.5138        -.0698          1.3510            72.2965          .0315
   50         46.7730               53.4440        -.0698           .9311            49.7641        -2.9911
   51         77.3000               53.3741        -.0698          1.0358            55.2828        22.0172
   52         39.0460               53.3043        -.0698           .8144            43.4094        -4.3634
   53         52.0460               53.2344        -.0698           .8785            46.7655         5.2805
   54         41.8100               53.1646        -.0698           .9097            48.3659        -6.5559
   55         64.5550               53.0947        -.0698           .9003            47.8010        16.7540
   56         57.8100               53.0249        -.0698          1.0104            53.5781         4.2319
   57         43.3390               52.9551        -.0698           .9389            49.7209        -6.3819
   58         40.2290               52.8852        -.0698          1.0699            56.5816       -16.3526
   59         60.6740               52.8154        -.0698          1.2253            64.7151        -4.0411
   60         42.0650               52.7455        -.0698           .9347            49.2992        -7.2342
SUM OF RESIDUALS =    131.9603     AVERAGE RESIDUAL =      2.1993     VARIANCE =    325.0415     STANDARD DEVIATION =     18.0289
MEAN ABSOLUTE DEVIATION =     11.5060
NUMBER OF RESIDUALS EXCEEDING TWO STANDARD DEVIATIONS =    4
```

Figure H-17. Output of the Initialization Phase - Special

```
                                     LENGTH OF THE SEASON IS  12 PERIODS     FORECAST LEAD TIME IS  12 PERIODS
PERIOD     OBSERVATION     PERMANENT COMPONENT     TREND     SEASONAL FACTOR     FORECAST     ERROR          TRACKING SIGNALS
                                                                                                      CUM. ERROR  SMOOTHED ERROR
  61        91.3830             52.6757           -.0696          1.3510          71.1642     20.2188     1.6335        .1634
  62        41.0210             52.6059           -.0698           .9311          48.9837     -7.9627     1.0268        .0857
  63        32.7280             52.5360           -.0696          1.0358          54.4147    -21.6867     -.7304       -.0966
  64        21.8590             52.4662           -.0698           .8144          42.7269    -20.8679    -2.2105       -.2342
  65        17.8240             52.3963           -.0698           .8785          46.0292    -28.2052    -3.8600       -.3767
  66        23.5261             52.3265           -.0696           .9097          47.6034    -24.0774    -5.1457       -.4702
  67        24.9940             52.2566           -.0696           .9003          47.0464    -22.0524    -6.2847       -.5434
  68        25.4000             52.1868           -.0698          1.0104          52.7313    -27.3313    -7.4984       -.6113
  69        30.0900             52.1170           -.0698           .9389          48.9340    -18.8440    -8.4582       -.6524
  70        44.2220             52.0471           -.0698          1.0699          55.6849    -11.4629    -9.4381       -.6755
  71        70.0030             51.9773           -.0698          1.2253          63.6881      6.3149    -9.6835       -.6098
  72        66.8270             51.9074           -.0696           .9347          48.5158     18.3112    -8.4311       -.4293
SUM OF FORECAST ERRORS = -137.6457     MEAN FORECAST ERROR =  -11.4705     VARIANCE =  297.2146     STANDARD DEVIATION =   17.2399
ROOT MEAN SQUARE ERROR =   20.1002     MEAN OBSERVATION =  40.8231
MEAN ERROR AS FRACTION OF MEAN OBSERVATION =    -.2810     RMS ERROR AS FRACTION OF MEAN OBSERVATION =     .4924
```

Figure H-18. Output of the Forecasting Phase - Special

```
ALPHA            BETA            GAMMA          RESIDUAL SUM OF SQUARES
 .0500           .0000           .0000                .8153288+002
 .0600           .0000           .0000                .8156373+002
 .0400           .0100           .0000                .8162324+002
 .0400           .0000           .0000                .8169379+002
 .0700           .0000           .0000                .8171627+002
 .[illegible]00  .0100           .0000                .8176192+002
 .0300           .0100           .0000                .8180094+002
 .0500           .0000           .0100                .8193405+002
 .[illegible]00  .0000           .0000                .8194604+002
 .[illegible]00  .0000           .0100                .8197487+002
 .0400           .0100           .0100                .8202024+002
 .0700           .0100           .0000                .8206615+002
 .0400           .0000           .0100                .8207756+002
 .0700           .0000           .0100                .8213204+002
 .0300           .0100           .0100                .8217686+002
 .0300           .0200           .0000                .8217731+002
 .0200           .0100           .0100                .8217956+002
 .1900           .0000           .0000                .8223332+002
 .0500           .0000           .0200                .8233499+002
 .[illegible]00  .0000           .0100                .8236538+002
 .0600           .0000           .0200                .8238544+002
 .0400           .0100           .0200                .8243283+002
 .[illegible]00  .0100           .0000                .8245671+002
 .0400           .0000           .0200                .8245992+002
 .[illegible]00  .0100           .0100                .8248326+002
 .0200           .0000           .0100                .8252294+002
 .1700           .0000           .0200                .8254713+002
 .0300           .0100           .0200                .8255904+002
 .0200           .0100           .0000                .8258738+002
 .[illegible]00  .0100           .0200                .8259098+002
 .[illegible]00  .0000           .0100                .8265043+002
 .[illegible]00  .0000           .0300                .8273574+002
 .[illegible]00  .0000           .0200                .8278205+002
 .1600           .0000           .0300                .8279546+002
 .0400           .0100           .0300                .8283704+002
 .0400           .0000           .0300                .8284286+002
 .[illegible]00  .0000           .0200                .8287084+002
 .[illegible]00  .0100           .0100                .8287452+002
 .[illegible]00  .0100           .0200                .8289955+002
 .[illegible]00  .0100           .0000                .8290001+002
THE OPTIMUM SMOOTHING CONSTANTS ARE
ALPHA =        .0500     BETA =        .0000     GAMMA =        .0000
```

Figure H-19. Smoothing Constant Optimization Routine - CONEX

```
PERIOD   OBSERVATION     PERMANENT COMPONENT  TREND      SEASONAL FACTOR    FITTED MODEL   RESIDUAL

  1        4.5660             4.2179           .0397          1.1035           .0000         .0000
  2        4.7970             4.2483           .0397          1.1783           .0000         .0000
  3        4.0850             4.3153           .0397           .8452           .0000         .0000
  4        3.4350             4.3763           .0397           .7187           .0000         .0000
  5        3.0350             4.3779           .0397           .8304           .0000         .0000
  6        4.6190             4.4059           .0397          1.1044           .0000         .0000
  7        5.4030             4.4818           .0397          1.0454           .0000         .0000
  8        6.9250             4.6034           .0397          1.1243           .0000         .0000
  9        2.7400             4.5771           .0397           .8246           .0000         .0000
 10        3.4360             4.5285           .0397          1.2058           .0000         .0000
 11        5.4230             4.5625           .0397          1.1171           .0000         .0000
 12        4.5850             4.6452           .0397           .9025           .0000         .0000
 13        5.3320             4.6923           .0397          1.1035           .0000        5.3320
 14        7.5000             4.8137           .0397          1.1783          5.5676        1.9324
 15        4.8090             4.8952           .0397           .8452          4.0500         .7590
 16        3.0080             4.8975           .0397           .7187          3.4877        -.4797
 17        4.4840             4.9603           .0397           .8304          4.0313         .4527
 18        4.9550             4.9744           .0397          1.1044          5.3925        -.4375
 19        5.3120             5.0175           .0397          1.0454          5.1835         .1285
 20        4.5180             5.0053           .0397          1.1243          5.7114       -1.1934
 21        4.7760             5.0824           .0397           .8246          4.1675         .6085
 22        6.8900             5.1517           .0397          1.2058          6.0352         .8548
 23        4.5300             5.1346           .0397          1.1171          5.6520       -1.1220
 24        3.0410             5.0841           .0397           .9025          4.6226       -1.5816
 25        4.9920             5.0939           .0397          1.1035          5.7038        -.7118
 26        4.7090             5.0767           .0397          1.1783          6.2338       -1.5248
 27        2.4590             5.0061           .0397           .8452          4.5402       -2.0812
 28        3.5360             5.0396           .0397           .7187          3.8623        -.3263
 29        4.1390             5.0746           .0397           .8304          4.5149        -.3759
 30        6.3030             5.1439           .0397          1.1044          6.0203         .2827
 31        4.5670             5.1429           .0397          1.0454          5.7435       -1.1765
 32        5.0770             5.1493           .0397          1.1243          6.1633       -1.0863
 33        2.8100             5.1000           .0397           .8246          4.5841       -1.7741
 34        6.9620             5.1714           .0397          1.2058          6.7867         .1753
 35        6.6080             5.2464           .0397          1.1171          6.2688         .3392
 36        5.3200             5.3165           .0397           .9025          5.0187         .3013
 37        5.1520             5.3219           .0397          1.1035          6.1470        -.9950
 38        5.0690             5.3086           .0397          1.1783          6.5438       -1.4748
 39        3.1950             5.2700           .0397           .8452          4.6339       -1.4389
 40        3.4650             5.2853           .0397           .7187          3.9644        -.4994
 41        3.7070             5.2820           .0397           .8304          4.6098        -.9028
 42        5.6340             5.3107           .0397          1.1044          6.2076        -.5736
 43        4.5470             5.3004           .0397          1.0454          5.8746       -1.3276
 44        5.2680             5.3074           .0397          1.1243          6.3252       -1.0572
 45        4.6010             5.3558           .0397           .8246          4.5986         .0024
 46        6.3580             5.3922           .0397          1.2058          6.8104        -.4524
 47        6.2410             5.4397           .0397          1.1171          6.3936        -.1526
 48        5.1700             5.4919           .0397           .9025          5.2284        -.0584
 49        6.6990             5.5536           .0397          1.1035          6.3986         .3004
 50        6.6250             5.5995           .0397          1.1783          6.8171        -.1921
 51        6.5710             5.7460           .0397           .8452          4.8569        1.7141
 52        4.3210             5.7971           .0397           .7187          4.1410         .1800
 53        5.5640             5.8800           .0397           .8304          4.7820         .7820
 54        6.1660             5.9029           .0397          1.1044          6.3917        -.2257
 55        6.6960             5.9658           .0397          1.0454          6.0392         .6568
 56        6.7180             6.0040           .0397          1.1243          6.5029         .2151
 57        6.8410             6.1564           .0397           .8246          4.8120        2.0290
 58        7.9620             6.2165           .0397          1.2058          7.0767         .8853
 59        6.1880             6.2293           .0397          1.1171          6.6395        -.4215
 60        5.5940             6.2564           .0397           .9025          5.3967         .1973
SUM OF RESIDUALS =    -5.5144      AVERAGE RESIDUAL =     -.0919      VARIANCE =     1.2152      STANDARD DEVIATION =     1.1024
MEAN ABSOLUTE DEVIATION =      .6962
NUMBER OF RESIDUALS EXCEEDING TWO STANDARD DEVIATIONS =   1
```

Figure H-20. Output of the Initialization Phase - CONEX

```
                                  LENGTH OF THE SEASON IS  12 PERIODS     FORECAST LEAD TIME IS  12 PERIODS
PERIOD      OBSERVATION      PERMANENT COMPONENT     TREND     SEASONAL FACTOR     FORECAST     ERROR          TRACKING SIGNALS
                                                                                                        CUM. ERROR  SMOOTHED ERROR
  61          5.9680                6.2518          .0397          1.1035          6.6598       -.6918      -.9943       -.0994
  62          5.6200                6.2154          .0397          1.1763          7.1598      -1.5398     -2.4604       -.2772
  63          6.3060                6.3155          .0397           .8452          5.2592       1.0468     -1.4685       -.1115
  64          4.2890                6.3358          .0397           .7187          4.5088       -.2198     -1.8776       -.1376
  65          5.4150                6.3828          .0397           .8304          5.2786        .1364     -1.8463       -.1153
  66          6.7180                6.4056          .0397          1.1044          7.0458       -.3278     -2.4516       -.1596
  67          5.6220                6.3922          .0397          1.0454          6.7348      -1.1068     -3.8801       -.2931
  68          6.0430                6.3791          .0397          1.1243          7.2861      -1.2431     -5.2525       -.4131
  69          5.3790                6.4241          .0397           .8246          5.4697       -.0907     -5.8912       -.4179
  70          7.4990                6.4516          .0397          1.2058          8.0705       -.5715     -6.8388       -.4677
  71          8.4320                6.5441          .0397          1.1171          7.4816        .9504     -5.2144       -.2685
  72          7.1730                6.6521          .0397           .9025          6.0767       1.0963     -3.4570       -.0809
SUM OF FORECAST ERRORS =   -2.5615     MEAN FORECAST ERROR =    -.2135     VARIANCE =      .7985     STANDARD DEVIATION =      .8936
ROOT MEAN SQUARE ERROR =     .8817     MEAN OBSERVATION =    6.2058
MEAN ERROR AS FRACTION OF MEAN OBSERVATION =    -.0344     RMS ERROR AS FRACTION OF MEAN OBSERVATION =      .1421
```

Figure H-21. Output of the Forecasting Phase - CONEX

```
ALPHA          BETA           GAMMA          RESIDUAL SUM OF SQUARES

 .0000          .0000          .0000                  .1420587+002
 .0000          .0100          .0000                  .1420587+002
 .0100          .0100          .0000                  .1429075+002
 .0100          .0000          .0000                  .1429619+002
 .0000          .0000          .0100                  .1430023+002
 .0000          .0100          .0100                  .1430023+002
 .0100          .0100          .0100                  .1439093+002
 .0000          .0000          .0200                  .1439309+002
 .0000          .0100          .0200                  .1439309+002
 .0100          .0000          .0100                  .1439717+002
 .0200          .0000          .0000                  .1443698+002
 .0200          .0100          .0000                  .1444791+002
 .0100          .0000          .0300                  .1448446+002
 .0000          .0100          .0300                  .1448446+002
 .0100          .0100          .0200                  .1448921+002
 .0100          .0000          .0200                  .1449448+002
 .0100          .0000          .0100                  .1453616+002
 .0200          .0100          .0100                  .1455077+002
 .0000          .0000          .0400                  .1457435+002
 .0000          .0100          .0400                  .1457435+002
 .0100          .0100          .0300                  .1458591+002
 .0100          .0000          .0300                  .1459014+002
 .0300          .0000          .0000                  .1459761+002
 .0200          .0000          .0200                  .1463759+002
 .0300          .0100          .0000                  .1464118+002
 .0200          .0100          .0200                  .1465183+002
 .0100          .0100          .0400                  .1468095+002
 .0100          .0000          .0400                  .1468417+002
 .0300          .0000          .0100                  .1469932+002
 .0200          .0000          .0300                  .1473528+002
 .0300          .0100          .0100                  .1474478+002
 .0200          .0100          .0300                  .1475110+002
 .0400          .0000          .0000                  .1476429+002
 .0300          .0000          .0200                  .1479924+002
 .0200          .0000          .0400                  .1483124+002
 .0300          .0100          .0200                  .1484654+002
 .0400          .0100          .0000                  .1484747+002
 .0100          .0100          .0400                  .1484861+002
 .0400          .0000          .0100                  .1486536+002
 .0100          .0000          .0300                  .1489736+002

THE OPTIMUM SMOOTHING CONSTANTS ARE

ALPHA =        .0000     BETA =        .0000     GAMMA =        .0000
```

Figure H-22. Smoothing Constant Optimization Routine - Freeze

```
PERIOD     OBSERVATION     PERMANENT COMPONENT   TREND       SEASONAL FACTOR     FITTED MODEL    RESIDUAL

   1         1.8250                1.7660         .0134             .8398             .0000         .0000
   2         1.3770                1.7794         .0134             .8911             .0000         .0000
   3         1.7140                1.7929         .0134            1.0638             .0000         .0000
   4         1.9970                1.8063         .0134             .9619             .0000         .0000
   5         1.0200                1.8197         .0134             .8521             .0000         .0000
   6         1.6920                1.8331         .0134            1.0121             .0000         .0000
   7         1.7470                1.8465         .0134            1.0922             .0000         .0000
   8         2.1050                1.8599         .0134            1.2560             .0000         .0000
   9         2.2800                1.8733         .0134            1.0147             .0000         .0000
  10         1.5510                1.8867         .0134            1.0056             .0000         .0000
  11         2.1680                1.9001         .0134            1.0918             .0000         .0000
  12         2.5210                1.9135         .0134             .9189             .0000         .0000
  13         1.2970                1.9270         .0134             .8398             .0000        1.2970
  14         1.4330                1.9404         .0134             .8911            1.7291        -.2961
  15         3.2220                1.9538         .0134            1.0638            2.0784        1.1436
  16         1.5630                1.9672         .0134             .9619            1.8922        -.3292
  17         1.6200                1.9806         .0134             .8521            1.6878        -.0678
  18         2.1730                1.9940         .0134            1.0121            2.0182         .1548
  19         2.4830                2.0074         .0134            1.0922            2.1924         .2906
  20         2.5750                2.0208         .0134            1.2560            2.5382         .0368
  21         2.1260                2.0342         .0134            1.0147            2.0641         .0619
  22         2.7360                2.0476         .0134            1.0056            2.0591         .6769
  23         2.2490                2.0610         .0134            1.0918            2.2502        -.0012
  24         2.1560                2.0745         .0134             .9189            1.9062         .2498
  25         1.6030                2.0879         .0134             .8398            1.7534        -.1504
  26         2.0650                2.1013         .0134             .8911            1.8725         .1925
  27         2.4760                2.1147         .0134            1.0638            2.2496         .2264
  28         1.8540                2.1281         .0134             .9619            2.0470        -.1930
  29         2.6210                2.1415         .0134             .8521            1.8249         .7961
  30         1.9940                2.1549         .0134            1.0121            2.1810        -.1870
  31         2.6010                2.1683         .0134            1.0922            2.3682         .2328
  32         2.8080                2.1817         .0134            1.2560            2.7403         .0677
  33         2.0960                2.1951         .0134            1.0147            2.2274        -.1314
  34         2.1960                2.2086         .0134            1.0056            2.2209        -.0249
  35         2.6780                2.2220         .0134            1.0918            2.4259         .2521
  36         1.2050                2.2354         .0134             .9189            2.0541        -.8491
  37         1.7050                2.2488         .0134             .8398            1.8886        -.1836
  38         2.5100                2.2622         .0134             .8911            2.0159         .4941
  39         1.8490                2.2756         .0134            1.0638            2.4208        -.5718
  40         2.2930                2.2890         .0134             .9619            2.2018         .0912
  41         1.6580                2.3024         .0134             .8521            1.9620        -.3040
  42         2.5910                2.3158         .0134            1.0121            2.3439         .2471
  43         2.5100                2.3292         .0134            1.0922            2.5439        -.0339
  44         2.6220                2.3427         .0134            1.2560            2.9424        -.3204
  45         2.5330                2.3561         .0134            1.0147            2.3907         .1423
  46         2.5180                2.3695         .0134            1.0056            2.3827         .1353
  47         1.8560                2.3829         .0134            1.0918            2.6015        -.7455
  48         2.0110                2.3963         .0134             .9189            2.2019        -.1909
  49         2.3420                2.4097         .0134             .8398            2.0237         .3183
  50         2.0530                2.4231         .0134             .8911            2.1593        -.1063
  51         1.9490                2.4365         .0134            1.0638            2.5919        -.6429
  52         2.5430                2.4499         .0134             .9619            2.3566         .1864
  53         2.3660                2.4633         .0134             .8521            2.0991         .2669
  54         2.5250                2.4767         .0134            1.0121            2.5068         .0182
  55         2.5640                2.4902         .0134            1.0922            2.7196        -.1556
  56         3.7430                2.5036         .0134            1.2560            3.1445         .5985
  57         2.0030                2.5170         .0134            1.0147            2.5540        -.5510
  58         2.1440                2.5304         .0134            1.0056            2.5445        -.4005
  59         3.2400                2.5438         .0134            1.0918            2.7772         .4628
  60         2.2490                2.5572         .0134             .9189            2.3498        -.1008
SUM OF RESIDUALS =      2.1029      AVERAGE RESIDUAL =       .0350      VARIANCE =      .1463     STANDARD DEVIATION =       .3825
MEAN ABSOLUTE DEVIATION =      .2530
NUMBER OF RESIDUALS EXCEEDING TWO STANDARD DEVIATIONS =    4
```

Figure H-23. Output of the Initialization Phase - Freeze

```
                              LENGTH OF THE SEASON IS  12 PERIODS      FORECAST LEAD TIME IS  12 PERIODS
PERIOD      OBSERVATION       PERMANENT COMPONENT     TREND     SEASONAL FACTOR     FORECAST     ERROR          TRACKING SIGNALS
                                                                                                          CUM. ERROR  SMOOTHED ERROR
  61           3.3200               2.5706            .0134          .8398          2.1588      1.1612       3.3776       .3378
  62           2.3480               2.5840            .0134          .8911          2.3027       .0453       3.8430       .3473
  63           2.2250               2.5974            .0134         1.0638          2.7631     -.5561       1.9161       .1251
  64           3.5710               2.6108            .0134          .9615          2.5114     1.0596       4.1608       .3509
  65           2.5640               2.6243            .0134          .8521          2.2363      .3277       5.0613       .4038
  66           3.0120               2.6377            .0134         1.0121          2.6696      .3424       6.0018       .4553
  67           3.8070               2.6511            .0134         1.0922          2.8954      .9116       7.3469       .5662
  68           4.0760               2.6645            .0134         1.2560          3.3966      .7294       8.4448       .6327
  69           2.9530               2.6779            .0134         1.0147          2.7173      .2357       9.4152       .6519
  70           3.6630               2.6913            .0134         1.0056          2.7363      .9567      10.3735       .7132
  71           2.7140               2.7047            .0134         1.0918          2.9529     -.2389      10.4458       .6319
  72           2.1840               2.7181            .0134          .9189          2.4977     -.3137      10.1325       .5236
SUM OF FORECAST ERRORS =     4.6589      MEAN FORECAST ERROR =       .3882      VARIANCE =       .3354      STANDARD DEVIATION =       .5792
ROOT MEAN SQUARE ERROR =      .6769      MEAN OBSERVATION =     3.0347
MEAN ERROR AS FRACTION OF MEAN OBSERVATION =       .1279      RMS ERROR AS FRACTION OF MEAN OBSERVATION =       .2231
```

Figure H-24. Output of Forecasting Phase - Freeze

```
ALPHA          BETA           GAMMA          RESIDUAL SUM OF SQUARES
 .0200          .0100          .0000                  .5243611+001
 .0100          .0000          .0000                  .5250443+001
 .0100          .0000          .0000                  .5255757+001
 .0100          .0100          .0000                  .5257069+001
 .0300          .0100          .0000                  .5257933+001
 .0400          .0100          .0100                  .5264060+001
 .0100          .0000          .0000                  .5267105+001
 .0200          .0000          .0100                  .5270853+001
 .0400          .0000          .0000                  .5274083+001
 .0100          .0100          .0100                  .5275396+001
 .0100          .0000          .0100                  .5277457+001
 .0300          .0100          .0100                  .5280522+001
 .0100          .0000          .0100                  .5285410+001
 .0200          .0100          .0200                  .5286453+001
 .0400          .0100          .0000                  .5288439+001
 .0300          .0000          .0200                  .5291620+001
 .0100          .0100          .0200                  .5295342+001
 .0400          .0000          .0100                  .5297388+001
 .0300          .0000          .0200                  .5299468+001
 .0200          .0000          .0000                  .5302996+001
 .0200          .0100          .0200                  .5303415+001
 .0100          .0000          .0200                  .5304147+001
 .0200          .0100          .0300                  .5308380+001
 .0300          .0100          .0100                  .5311628+001
 .0200          .0000          .0300                  .5312734+001
 .0100          .0100          .0300                  .5315684+001
 .0000          .0100          .0000                  .5320065+001
 .0000          .0000          .0000                  .5320065+001
 .0400          .0000          .0200                  .5320176+001
 .0200          .0000          .0300                  .5321781+001
 .0100          .0000          .0300                  .5323302+001
 .0200          .0000          .0100                  .5326012+001
 .0300          .0100          .0300                  .5326600+001
 .0100          .0100          .0000                  .5328753+001
 .0300          .0100          .0400                  .5330631+001
 .0200          .0000          .0400                  .5334184+001
 .0000          .0100          .0100                  .5334651+001
 .0000          .0000          .0100                  .5334651+001
 .0100          .0100          .0400                  .5335041+001
 .0400          .0100          .0200                  .5335494+001
THE OPTIMUM SMOOTHING CONSTANTS ARE
ALPHA =        .0200     BETA =        .0100     GAMMA =        .0000
```

Figure H-25. Smoothing Constant Optimization Routine - Chill

```
PERIOD   OBSERVATION    PERMANENT COMPONENT   TREND     SEASONAL FACTOR    FITTED MODEL    RESIDUAL

   1       1.2420              1.2763          -.0044          .7757           .0000          .0000
   2       1.4210              1.2709          -.0044         1.1644           .0000          .0000
   3       1.0340              1.2696          -.0044          .7267           .0000          .0000
   4        .9660              1.2667          -.0043          .7220           .0000          .0000
   5        .6650              1.2553          -.0044          .7323           .0000          .0000
   6        .9730              1.2539          -.0044          .6929           .0000          .0000
   7       1.0980              1.2493          -.0044          .8877           .0000          .0000
   8       1.4680              1.2429          -.0044         1.2830           .0000          .0000
   9       1.1480              1.2379          -.0044          .9480           .0000          .0000
  10       1.6240              1.2317          -.0044         1.4193           .0000          .0000
  11       1.3980              1.2226          -.0045         1.4050           .0000          .0000
  12       1.9320              1.2249          -.0044         1.2429           .0000          .0000
  13       1.1340              1.2253          -.0044          .7757           .0000         1.1340
  14       1.0070              1.2138          -.0044         1.1644          1.4184         -.4114
  15       1.1010              1.2155          -.0044          .7267           .8846          .2164
  16        .6800              1.2057          -.0044          .7220           .8769         -.1969
  17        .8980              1.2018          -.0044          .7323           .8804          .0176
  18        .8040              1.1966          -.0044          .6929           .8323         -.0283
  19        .9540              1.1898          -.0045          .8877          1.0622         -.1062
  20       1.7450              1.1889          -.0044         1.2830          1.5266          .2184
  21       1.1800              1.1856          -.0044          .9480          1.1233          .0567
  22       1.5370              1.1793          -.0044         1.4193          1.6727         -.1357
  23       1.9270              1.1788          -.0044         1.4050          1.6422          .2848
  24       1.2690              1.1713          -.0044         1.2429          1.4565         -.1875
  25        .7540              1.1630          -.0045          .7757           .9098         -.1558
  26       1.7810              1.1660          -.0044         1.1644          1.3513          .4297
  27        .9070              1.1633          -.0044          .7267           .8451          .0619
  28        .9620              1.1624          -.0043          .7220           .8321          .1299
  29       1.3700              1.1723          -.0042          .7323           .8411          .5269
  30        .8420              1.1691          -.0042          .6929           .7923          .0497
  31       1.1740              1.1680          -.0041          .8877          1.0088          .1652
  32       2.0650              1.1728          -.0041         1.2830          1.4572          .6078
  33       1.1310              1.1692          -.0041          .9480          1.0739          .0571
  34       2.3250              1.1746          -.0040         1.4193          1.5983          .7267
  35       1.8610              1.1738          -.0039         1.4050          1.5822          .2788
  36       1.4760              1.1702          -.0039         1.2429          1.3899          .0861
  37        .7370              1.1619          -.0040          .7757           .8607         -.1237
  38       1.6020              1.1623          -.0039         1.1644          1.2964          .3056
  39        .5870              1.1514          -.0040          .7267           .8073         -.2203
  40        .9570              1.1509          -.0040          .7220           .8017          .1553
  41        .7330              1.1441          -.0040          .7323           .8216         -.0886
  42        .7810              1.1398          -.0040          .6929           .7753          .0057
  43       1.1110              1.1381          -.0040          .8877           .9927          .1163
  44       1.0650              1.1281          -.0040         1.2830          1.4422         -.3772
  45       1.1260              1.1253          -.0040          .9480          1.0623          .0637
  46       1.4620              1.1195          -.0040         1.4193          1.5997         -.1377
  47       1.5800              1.1156          -.0040         1.4050          1.5828         -.0028
  48       1.3050              1.1104          -.0040         1.2429          1.3959         -.0909
SUM OF RESIDUALS =      3.4331     AVERAGE RESIDUAL =       .0715     VARIANCE =      .0722     STANDARD DEVIATION =       .2688
MEAN ABSOLUTE DEVIATION =      .1659
NUMBER OF RESIDUALS EXCEEDING TWO STANDARD DEVIATIONS =     3
```

Figure H-26. Output of the Initialization Phase - Chill

```
                                    LENGTH OF THE SEASON IS  12 PERIODS     FORECAST LEAD TIME IS  12 PERIODS
PERIOD     OBSERVATION     PERMANENT COMPONENT     TREND     SEASONAL FACTOR     FORECAST     ERROR          TRACKING SIGNALS
                                                                                                      CUM. ERROR  SMOOTHED ERROR
  49          1.0270                   1.1167     -.0040            .7757          .6644      .1646       .9930        .0993
  50          1.[illegible]30                   1.1033     -.0040           1.1644         1.2985    -.2105      -.2697       -.0366
  51          1.0760                   1.1069     -.0040            .7267          .8319      .2741      1.2634        .1237
  52           .3370                   1.1040     -.0039            .7220          .7967      .0403      1.6119        .1427
  53           .7770                   1.0993     -.0040            .7323          .8077     -.0257      1.5923        .1227
  54          1.2530                   1.1097     -.0038            .6929          .7566      .5014      3.9715        .3575
  55          1.3520                   1.1255     -.0036            .6877          .9681      .8839      6.3340        .5784
  56          1.6120                   1.1246     -.0036           1.2830         1.3853      .2267      7.3022        .6163
  57          1.3330                   1.1214     -.0036            .9480         1.3212      .0618      8.1632        .6251
  58           .9420                   1.1068     -.0037           1.4193         1.5202     -.5782      4.9736        .2768
  59          1.4040                   1.1030     -.0037           1.4050         1.4994     -.0954      4.9378        .2284
  60          1.1790                   1.0961     -.0037           1.2429         1.3197     -.1497      4.5266        .1523
SUM OF FORECAST ERRORS =     1.0935     MEAN FORECAST ERROR =     .0911     VARIANCE =     .1366     STANDARD DEVIATION =     .3597
ROOT MEAN SQUARE ERROR =      .3655     MEAN OBSERVATION =    1.1773
MEAN ERROR AS FRACTION OF MEAN OBSERVATION =     .0774     RMS ERROR AS FRACTION OF MEAN OBSERVATION =     .3104
```

Figure H-27. Output of Forecasting Phase - Chill

APPENDIX I

SPONSOR'S COMMENTS

DALO-TSP-C11 (30 Jan 84) 1st Ind
SUBJECT: Transportation Workload Forecasting (TWF) Study

DA Washington, D.C. 20310 (DALO-TSP-C11) 2 MAR 1984

TO: Director, US Army Concepts Analysis Agency, ATTN: CSCA-SPP, 8120
Woodmont Avenue, Bethesda, MD 20814

Completed Study Critique is furnished. There was one editorial comment, which is listed on a separate page and attached to the critique sheet.

FOR THE DEPUTY CHIEF OF STAFF FOR LOGISTICS:

1 Encl
as

BERNARD J. CLARK
Colonel, GS
Chief, Performance Management Division
Directorate of Transportation, Energy
and Troop Support

2

DEPARTMENT OF THE ARMY
US ARMY CONCEPTS ANALYSIS AGENCY
8120 WOODMONT AVENUE
BETHESDA, MARYLAND 20814

REPLY TO
ATTENTION OF

CSCA-SPP 30 JAN 1984

SUBJECT: Transportation Workload Forecasting (TWF) Study

Deputy Chief of Staff
 for Logistics
Department of the Army
ATTN: DALO-TSP
Washington, DC 20310

1. Reference:

a. Letter, DALO-TSP-C11, 11 May 1983, subject: Transportation Workload Forecasting (TWF) Study.

b. Letter, DACS-DMO, 19 October 1983, subject: Responsibility of Study Performing and Study Sponsoring Organizations.

2. The Deputy Chief of Staff for Logistics requested that the US Army Concepts Analysis Agency study US Army transportation workload forecasting and develop procedures to improve the system.

3. Attached are several copies of our Draft Study Report which describe the study approach, the current forecasting system, and several alternative systems and methods that should result in improved forecasts of over-ocean cargo transportation requirements. These drafts are being provided IAW reference b in order to obtain your comments prior to publication of the final report of study. A suggested Study Critique Sheet is provided for your use as you desire.

4. Request that your comments be provided to CAA within 30 days after receipt of the draft report. Your comments, if any, and our response to comments, if any, will be included in the final report if they are provided to CAA prior to our planned publication date.

David C. Hardison

2 Incl
as

DAVID C. HARDISON
Director

STUDY CRITIQUE

(This document may be modified to add more space for responses to questions.)

1. Were there any editorial comments? YES. If so, please list on separate page and attach to the critique sheet.

2. Was the work accomplished in a timely manner? YES. If not, please comment.

3. Does the work report address adequately the issues planned for the analysis? YES. If not, please comment.

4. Were appropriate analysis techniques used? YES. If not, please comment.

5. Are the findings fully supported by good analysis based on sound assumptions? YES. If not, please explain.

6. Does the report contain the preferred level of details of the analysis? YES. If not, please comment.

7. Is the written material fully satisfactory in terms of clarity of presentation, completeness, and style? YES. If not, please comment.

STUDY CRITIQUE (CONTINUED)

8. Are all Figures and Tables clear and helpful to the reader? YES.
If not, please comment.

9. Does the report satisfy fully the expectations that were present when the work was directed? YES. If not, please explain how not.

10. Will the Findings in this report be helpful to the organization which directed that the work be done? YES. If so, please indicate how, and if not, please explain why not.

11. Judged overall, how do you rate the study? (circle one)

Poor Fair Average Good [✓ Excellent]

PARAGRAPH 6-8a should read as follows:

a. Transportation arrangements for DOD-sponsored household goods (HHG) are made by MTMC, using primarily two methods: freight forward (Code 4), and those that are MSC processed (Code 5). Freight forward shipments are shipments of HHG that are contracted with private carriers from door-to-door; shipments of HHG that are shipped using the assets of MSC are Code 5 shipments. Additionally, some HHG are returned to CONUS via MAC when cargo space is available.

APPENDIX J

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GLOSSARY

1. ABBREVIATIONS, ACRONYMS, AND SHORT TERMS

AAFES	Army and Air Force Exchange Service
AFAC	US Army Finance and Accounting Center
AFLC	US Air Force Logistics Center
AR	autoregressive
ARFCOS	Armed Forces Courier Service
ARIMA	autoregressive integrated moving average
ARMA	autoregressive moving average
ASD(I&L)	Assistant Secretary of Defense (Installations and Logistics)
CAA	US Army Concepts Analysis Agency
DARCOM	US Army Materiel Development and Readiness Command
DTS	Defense Transportation System
EEA	essential elements of analysis
HHG	household goods
ICP	inventory control point
IRO	Inventory Research Office
K/MTON	thousands of measurement tons
LSC	Logistics Support Contractor
LIF	logistics intelligence file
LSAO	Logistics Systems Analysis Office
MA	moving
MAC	Military Airlift Command

MECHTRAM	mechanization of selected transportation movement reports
MILPERCEN	US Army Military Personnel Center
MPSA	Military Postal Service Agency
MSC	Military Sealift Command
MSE	mean square error
MTON	measurement tons
NAVMTO	Navy Material Transport Office
NMTO	Naval Material Transport Office
POD	port of debarkation
POE	port of embarkation
POV	privately owned vehicle
TAC	transportation account code
TAEDP	total Army equipment distribution program
TWF	transportation workload forecasting
USAMSSA	US Army Management System Support Agency
USARJ	US Army Japan

2. MODELS, ROUTINES, AND SIMULATIONS

Box-Jenkins	A flexible class of linear statistical models that are used to fit stochastic time series data and produce forecasts
Winters	A three-parameter exponential smoothing method that is used to adjust smoothed forecasts to reflect seasonality

CAA

TRANSPORTATION WORKLOAD FORECASTING (TWF) STUDY

ONE SHEET
STUDY GIST
CAA-SR-84-2

THE PRINCIPAL FINDINGS of the work reported herein are as follows:

(1) The transportation workload forecasting system has produced inaccurate forecasts resulting in inefficient Military Sealift Command (MSC) industrial fund operations.

(2) Accurate forecasting of cargo transportation requirements can be accomplished by forecasting at a single activity.

(3) Either HQ Military Traffic Management Command (MTMC) or HQ, US Army Materiel Development and Readiness Command (DARCOM) is a suitable location for a single point forecasting activity.

(4) The Box-Jenkins and Winters Forecasting Models can provide accurate forecasts when used in conjunction with program information.

(5) Changes to the allocation of transportation account codes and requirements for forecasting shipping mode are also required to improve forecasting accuracy.

THE MAIN ASSUMPTION on which the work reported herein rests is that transportation workload forecasting requirements, contained in JCS Publication 15, would not be changed.

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(2) Historical lift data was extracted exclusively from MSC records and could not be validated from Army sources.

THE SCOPE OF THE STUDY was taken to include an analysis of the Army's long-range cargo transportation requirements forecasting process and its impact on budgets and transportation costs.

THE STUDY OBJECTIVE was to develop cost effective systems and methods for improving the forecasting of Army over-ocean surface cargo transportation requirements.

THE BASIC APPROACH followed in this study can be defined as: research was conducted into the nature and extent of the forecasting problem, to identify its impact, and its systemic and methodological causes. Several alternative systems were evaluated based on their relative costs and efficiency. Then a series of mathematical techniques was evaluated for suitability as forecasting tools. Two of the techniques, the Box-Jenkins and Winters models, were used to forecast the 1982 cargo transportation requirements based on 1977 to 1981 MSC cargo lift data.

REASONS FOR PERFORMING THE STUDY are mainly as follows: recent forecasts of Army over-ocean surface cargo transportation requirements have been inaccurate. As a consequence MSC industrial funds have incurred significant losses and the MSC controlled fleet was not efficiently utilized for cargo transport. This study was directed to develop methods to improve the forecasts.

THE STUDY SPONSOR was the Deputy Chief of Staff for Logistics, who also established the objectives and monitored the study activities.

THE STUDY EFFORT was directed by LTC James N. Keenan, Strategy, Concepts and Plans Directorate.

COMMENTS AND QUESTIONS may be directed to CAA, ATTN: Assistant Director for Strategy, Concepts and Plans.

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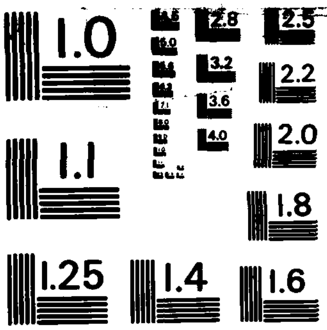

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