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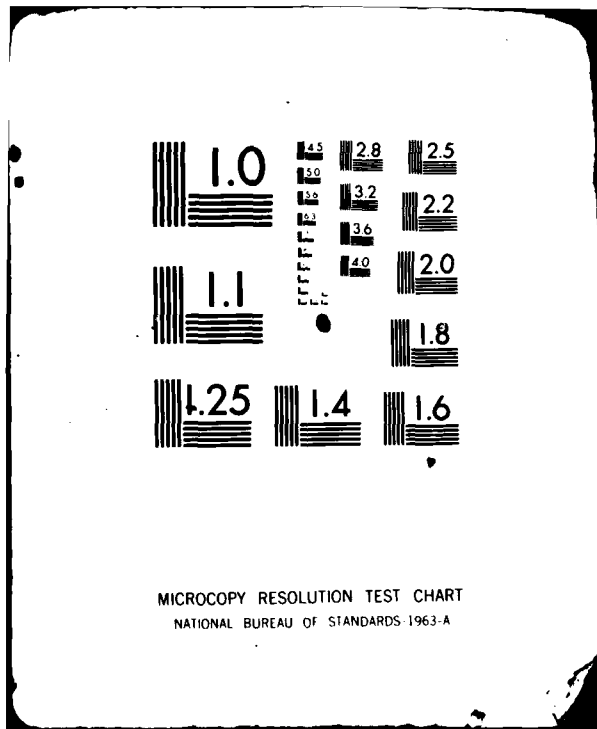
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ARMY PROCUREMENT RESEARCH OFFICE

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FINAL

PAMUPS WORKLOAD PROJECTION MODELS

MAY 1982

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U.S. ARMY MATERIEL SYSTEMS ANALYSIS ACTIVITY  
ARMY PROCUREMENT RESEARCH OFFICE  
FORT LEE, VIRGINIA 23801

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## EXECUTIVE SUMMARY

A. BACKGROUND. In October 1977 the Comptroller General determined that the Army was using inadequate work measurement systems to support manpower requirements in the procurement activities. DARCOM decided to make maximum use of existing and planned automated systems and to propose a new system designated the Procurement Automated Manpower Utilization and Projection System (PAMUPS). The objective of PAMUPS is to automate work measurement principles within the central procurement activities of DARCOM's major subordinate commands and to combine these principles with procurement workload projections to justify manpower needs for support of budget execution under the central procurement program.

B. STUDY OBJECTIVES. This study develops mathematical models to make workload projections at MICOM, TACOM, CECOM, TSARCOM, and ARRCOM using Box-Jenkins univariate time series methodology on data unique to each command.

C. STUDY APPROACH. Quarterly procurement actions accomplished from FY 70 to FY 81 are used to develop the workload projection models. The mean absolute percentage error is used to verify the fit of the model to FY 80 and FY 81 data, and forecasts are made for FY 82 through FY 86.

D. FINDINGS AND RECOMMENDATIONS. Models were developed for CECOM, MICOM, TACOM and TSARCOM. No unique model was developed for ARRCOM, which in the interim can use the methodology suggested on page 2 of this study to forecast workload. Although the models developed appear to be adequate, further improvement may be possible as more data becomes available. It is recommended that the models be used with PAMUPS and updated as new data becomes available.

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CHAPTER I  
INTRODUCTION

A. BACKGROUND:

In October 1977 the Comptroller General determined that the Army was using inadequate work measurement systems to support manpower requirements in the procurement activities.<sup>1</sup> A search for a viable work measurement system of a procurement activity resulted in the discovery of the Air Force E-841 system which was endorsed by the General Accounting Office. The DARCOM Directors of Procurement and Production in a conference in March of 1979 concluded that a system patterned after the E-841 concept was feasible and could be adopted by making maximum use of existing and planned automated systems such as the Procurement Automated Document and Data System (PADDS) and the Acquisition Planning and Tracking System (APATS). The proposed new system was designated the Procurement Automated Manpower Utilization and Projection System (PAMUPS).

The objective of PAMUPS is to automate work measurement principles within the central procurement activities of DARCOM's major subordinate commands, and to combine these principles with procurement workload projections to justify manpower needs for support of budget execution under the central procurement program. Specifically, PAMUPS will document procurement workload by type of instrument (i.e., contract, BOA, purchase order) and complexity (FFP, CPAF, service contract, etc.) along with time standards showing the necessary manhours to accomplish various tasks. The documented workload will then be integrated with forecasting models to arrive at an expected workload, and the standards will dictate the manpower required to accomplish the future effort.

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<sup>1</sup>GAO Report, "Development and Use of Military Service Staffing Standards; More Direction, Emphasis and Consistency Needed." October 1977.

The Army Procurement Research Office recently completed a study, APRO 80-04, "Central Procurement Workload Projection Model," [see Reference 2] to assist in making central procurement workload forecasts for the Procurement and Production Directorate of the US Army Materiel Development and Readiness Command (DARCOM). This workload model was to serve as the vehicle by which workload projection would take place within the Procurement Automated Manpower Utilization and Projection System (PAMUPS). The study model uses the Box-Jenkins Time Series Forecasting Technique to forecast total accumulated procurement actions for all of DARCOM. While the model was not designed to forecast procurement actions for each individual subordinate command, estimates can nonetheless be made for the commands as follows:

1. Record what percentage of the total number of DARCOM Procurement Actions each subordinate command has had over the last two years.
2. Find the average percentage.
3. Take the average percentage of each command to the total forecast.
4. The results are the workload which each command may expect in terms of total actions.

These forecasts may understandably be less accurate than is desirable. More accurate forecasts at the individual commands can be made by tailoring models appropriate for the needs of each command. Individual models were not initially considered for each subordinate command due to the lack of continuous time series data. This discontinuity of data was a consequence of the separation of the readiness and development commands (as suggested by the 1974 AMARC study). Now that most readiness and development commands have been re-combined, taking on a pre-AMARC appearance, enough data exists to attempt the development of models using the Box-Jenkins technique for each individual command.

## B. STUDY OBJECTIVES.

This study attempts to develop mathematical models to forecast procurement workload using data internal to the automated procurement system, PADDs, and to integrate the use of these models into PAMUPS where feasible. Specifically, the objectives are:

1. To develop individual workload projection models for the US Army Communications-Electronics Command (CECOM), US Army Missile Command (MICOM), US Army Tank-Automotive Command (TACOM), US Army Troop Support and Aviation Materiel Readiness Command (TSARCOM), and the US Army Armament Materiel Readiness Command (ARRCOM) using Box-Jenkins methodology on data unique to each command.

2. To ensure the adaptability of the workload projection models with PAMUPS.

## C. STUDY APPROACH.

One of the most common forecasting procedures is time series forecasting in which a number of observations are taken over several time periods and a forecast for some future period is made. Time series forecasting methods assume a basic underlying pattern represented by historical data and in addition to that pattern some randomness (or error). The objectives of the forecasting method is to separate the basic pattern from the error component and to use the former as the basis for future forecasts. There are relatively simple time series methods such as exponential smoothing suitable for short term forecasting, but in many situations the time series are complex, and the pattern made up of combinations of trend, a seasonal factor, and cyclical factor as well as the usual random fluctuations.

The Box-Jenkins forecasting method is particularly well suited to handling complex time series and other forecasting situations in which a variety of patterns exists. It uses the most recent observation as the

starting value then analyzes recent forecasting errors to determine the proper adjustments for future time periods. It is based on engineering control theory where an examination is made of the desired state and the actual state, and an adjustment based on the difference is made in the process. A special computer routine is required to use the Box-Jenkins Forecasting Technique.

The Box-Jenkins technique is applied to quarterly procurement actions accomplished, some of which have been normalized, from FY 70 to FY 81 to develop the workload projection models at each respective command. Forecasts are made for FY 82 through FY 86.

The performance measure which will be used to measure forecast accuracy and aid in selecting the proper Box-Jenkins model is the mean absolute percentage error (MAPE), which is used to verify the fit of the model to FY 80 and FY 81 data. The MAPE is appropriate when measurement is concerned with the percentage error of the forecast, rather than statistical error. It is easier to relate to and more useful to decision makers than the root mean squared error. The MAPE is calculated from the following:

$$\text{MAPE} = \frac{\sum_{t=1}^h \left| \frac{A_t - F_t}{A_t} \right|}{h} (100)$$

where

A = actual result

F = forecast

t = time interval

h = number of periods in the forecast horizon.

It is planned that APRO will provide consultation in use and maintenance of the individual models to the respective commands when requested.

CHAPTER II  
TIME SERIES MODELS TO FORECAST PROCUREMENT  
ACTIONS ACCOMPLISHED

A. INTRODUCTION.

This chapter presents the time series models developed to forecast procurement actions accomplished at the major subordinate commands involved with PAMUPS. A time series is a sequence of data which occurs at regular intervals of time. The study of the time series of procurement actions involves the separation of the series into individual components such as secular trend, seasonal, cyclical, and irregular variation. These particular components are then examined to see whether they may re-occur.

Unlike regression models, time series models do not predict future movements in a variable by relating it to a set of other variables in a causal framework. Time series models base their prediction on the behavior of a variable through time. There may be some overall trend or seasonal relationship which, because it has dominated the past behavior of the series, might determine how it will act in the future. In time series forecasting the objective is to build a model which captures the dominant features of the series and to use this model to forecast future series behavior.

In multiple regression, the causal model is of the form:

$$Y = b_0 + b_1 X_1 + b_2 X_2 + \dots + b_p X_p + e \quad (1)$$

where  $X_1, X_2, \dots, X_p$  represent factors such as requisition line items processed, total tons in storage, active military manyears, etc. to explain the variable  $Y$  which may be procurement actions, and where  $e$  is a residual or error value.

Suppose the X's are defined as  $X_1 = Y_{t-1}$ ,  $X_2 = Y_{t-2}$ , . . . ,  $X_p = Y_{t-p}$ .

Then equation (1) becomes

$$Y_t = b_0 + b_1 Y_{t-1} + b_2 Y_{t-2} + \dots + b_p Y_{t-p} + e_t \quad (2)$$

which is still a regression equation but instead of the right-hand side variables being independent variables as in equation (1) they are now previous values of the dependent variable  $Y_t$  [See Reference 5]. Hence, these Y's are simply time-lagged values of the dependent variable, and the term autoregression (AR) is used to describe equations of this form.

Whereas AR models express  $Y_t$  as a linear function of  $n$  past values of  $Y_t$ , moving average (MA) models make forecasts of  $Y_t$  as a linear combination of past errors,  $\epsilon_t$ 's. The MA model is expressed as

$$Y_t = \epsilon_t + \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2} + \dots + \theta_q \epsilon_{t-q}. \quad (3)$$

Autoregressive models can be combined with moving average models to form the general class of time series models classified as autoregressive moving average (ARMA( $p$ ,  $q$ )) models and expressed in an equation as

$$Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \dots + \phi_p Y_{t-p} + \epsilon_t + \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2} \\ + \dots + \theta_q \epsilon_{t-q}. \quad (4)$$

where  $p$  is the number of AR parameters and  $q$  the number of MA parameters.

George Box and Gwilyn Jenkins have been closely associated with general ARMA models due to their extensive research in time series analysis, forecasting, and control [See Reference 1]. The Box-Jenkins approach is to select a specific ARMA model from the general class by using an iterative procedure of identification, estimating and testing, and application as illustrated in Figure 1.

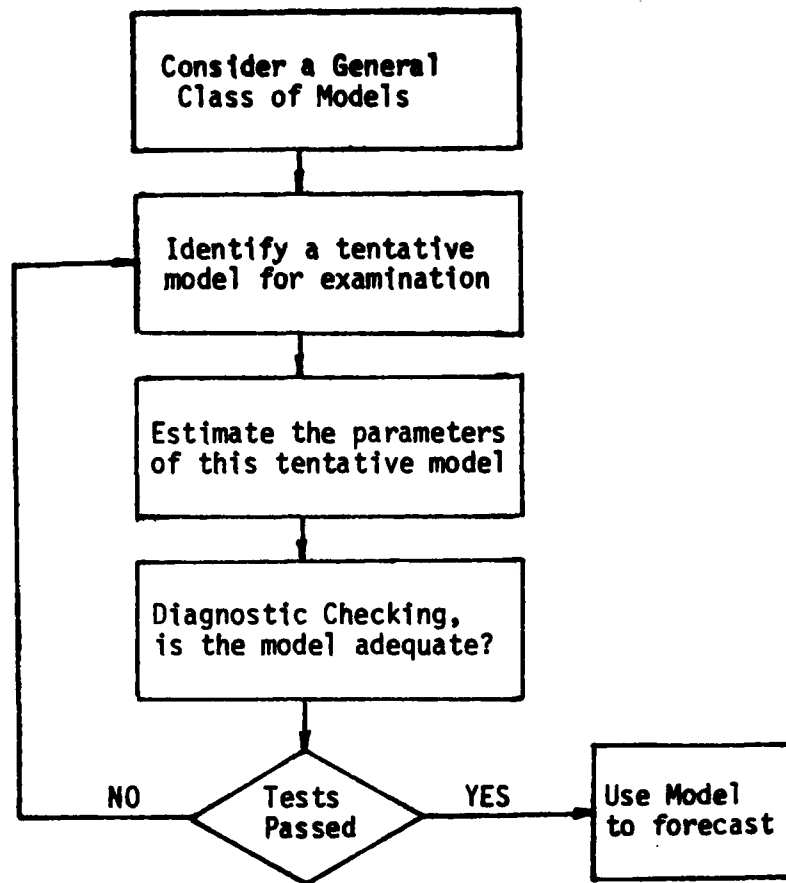


FIGURE 1. STAGES IN THE ITERATIVE BOX-JENKINS MODEL BUILDING METHODOLOGY<sup>2</sup>

The choice of the appropriate  $p$  and  $q$  values (autoregressive and moving average terms, respectively) is determined by examining the autocorrelation and partial autocorrelation coefficients calculated from the data.

The data is examined for some existing pattern and randomness (or error). The objective is to separate the pattern from the error component and to use the former for forecasting. To identify a pattern it is necessary to determine whether a relationship exists between successive data points

<sup>2</sup>Box, G.E.P., and G.M. Jenkins, Time Series Analysis, Forecasting and Control, San Francisco: Holden-Day, 1970.

of the series. Autocorrelations are used to determine whether a pattern exists by examining the autocorrelation coefficients of several time lags to see if any are significantly different from zero. When a forecasting model is identified, the autocorrelations are computed for the series residual errors to determine whether they are random. If the autocorrelation of the errors are random then future diagnostic checking is done to determine the adequacy of the model. When seasonality is present in the data it is often difficult to identify the proper model unless an adequate number of data points exist.

The Box-Jenkins technique is essentially one of fitting empirically a mathematical model, based on the study of the autocorrelation function of the time series data. The number of terms to include in the model and the numerical values of parameters are estimated from the given data. The Box-Jenkins technique produces the best results when at least 50 but preferably 100 or more data points can be used.<sup>3</sup> When less than 50 are available, then experience and past information may yield a preliminary model which can be updated as more data becomes available.

No more than 49 data points are available for any of the commands addressed in the study.<sup>4</sup> In addition, seasonality and nonstationarity (i.e., it does not vary about some mean value over time) of the data is present in several of the commands making identifications of the proper model difficult. Nevertheless, the following results should still be analyzed as to the feasibility of using these models in PAMUPS.

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<sup>3</sup>Box, G.E.P., and G.M. Jenkins, Time Series Analysis, Forecasting and Control, San Francisco: Holden-Day, 1970.

<sup>4</sup>The number of procurement actions and all other data used in this study is found in the DARCOM Central Procurement Workloading Report, AMCRP-127.

B. CECOM MODEL.

Forty-nine data points were available to develop time series models for CECOM. Quarterly procurement actions from fiscal year 1981 back to fiscal year 1970 are illustrated in Figure 2. The data between FY'70 and FY'74 is normalized. Seasonality appears to be present in the data with a peak occurring in the fourth quarter, nine of the twelve years.

Since the data exhibits some degree of variability, the logarithms of the time series data was also analyzed to find the proper model. The log transformation resulted in the consideration of two models, one using transformed log data, the other actual data.

1. CECOM Model I.

$$\text{Let } Z_t = \log y_t$$

$$(1 - \phi_4 L^4) (Z_t - \bar{Z}) = \epsilon_t + \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2}$$

$$Z_t = 2.7059 + (0.23410) Z_{t-4} + \epsilon_t - 0.09317 \epsilon_{t-1} - 0.33218 \epsilon_{t-2}$$

CECOM Model I contains a seasonal fourth difference parameter,  $\phi_4$ , along with two moving average terms,  $\epsilon_{t-1}$  and  $\epsilon_{t-2}$  fitted to the log data. To verify how well the model forecasts, the FY 80 and FY 81 forecasts were made at the end of FY 79. The actual values are compared to their respective estimates in Table I along with the mean absolute percentage errors (MAPE). The forecasts for FY 82 through FY 86 are made in Table II.

CECOM

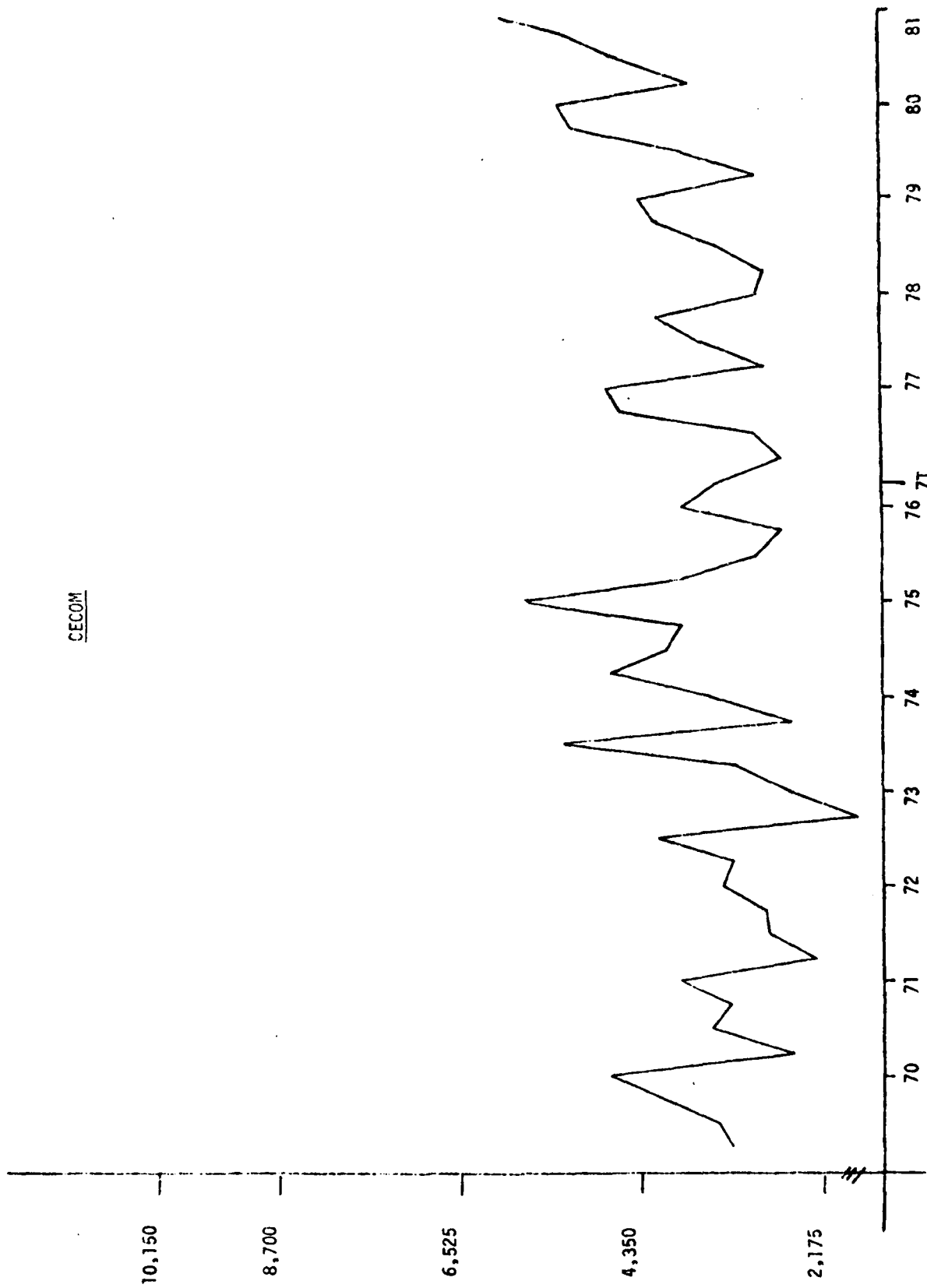


FIGURE 2. QUARTERLY PROCUREMENT ACTIONS FOR FY '70 THROUGH FY '81

TABLE I. VERIFICATION OF CECOM MODEL I ON KNOWN DATA

<u>FY 80</u>	<u>ACTUAL</u>	<u>FORECAST</u>	<u>DIFFERENCE</u>
1st Qtr	2,931	3,046	-115
2nd Qtr	3,822	3,090	732
3rd Qtr	5,118	3,473	1,645
4th Qtr	<u>5,318</u>	<u>3,518</u>	<u>1,800</u>
Total	17,189	13,127	4,062

MAPE over 4 time horizons is 22.27%.

<u>FY 81</u>	<u>ACTUAL</u>	<u>FORECAST</u>	<u>DIFFERENCE</u>
1st Qtr	3,661	3,238	423
2nd Qtr	4,521	3,248	1,273
3rd Qtr	5,167	3,339	1,828
4th Qtr	<u>5,997</u>	<u>3,349</u>	<u>2,648</u>
Total	19,346	13,174	6,172

MAPE over 8 time horizons is 26.04%.

TABLE II. FORECASTS FOR QUARTERLY PA'S USING CECOM MODEL I

<u>FY 82</u>		<u>FY 83</u>		<u>FY 84</u>	
1st Qtr	3,175	1st Qtr	3,269	1st Qtr	3,292
2nd Qtr	3,699	2nd Qtr	3,388	2nd Qtr	3,319
3rd Qtr	3,664	3rd Qtr	3,380	3rd Qtr	3,317
4th Qtr	<u>3,796</u>	4th Qtr	<u>3,409</u>	4th Qtr	<u>3,324</u>
Total	14,334	Total	13,446	Total	13,252
<u>FY 85</u>		<u>FY 86</u>			
1st Qtr	3,297	1st Qtr	3,298		
2nd Qtr	3,303	2nd Qtr	3,300		
3rd Qtr	3,303	3rd Qtr	3,300		
4th Qtr	<u>3,304</u>	4th Qtr	<u>3,300</u>		
Total	13,207	Total	13,198		

Although the forecasts predicted by model I stay within a reasonable range, there is no variability after FY 84, and in addition the MAPE is large.

2. CECOM Model II.

$$(1 - \phi_4 L^4) (Y_t - \bar{Y}) = \epsilon_t + \theta_1 \epsilon_{t-1}$$

$$Y_t = 2,128 + (0.35755) Y_{t-4} + \epsilon_t + 0.65046 \epsilon_{t-1}$$

No logarithmic transformation was taken for CECOM Model II. The model fitted to the actual data contains a seasonal fourth difference parameter,  $\phi_4$ , along with a moving average term  $\epsilon_{t-1}$ . The results are listed in Tables III and IV.

TABLE III. VERIFICATION OF CECOM MODEL II ON KNOWN DATA			
<u>FY 80</u>	<u>ACTUAL</u>	<u>FORECAST</u>	<u>DIFFERENCE</u>
1st Qtr	2,931	3,725	-794
2nd Qtr	3,822	3,298	524
3rd Qtr	5,118	3,542	1,576
4th Qtr	<u>5,318</u>	<u>3,626</u>	<u>1,692</u>
Total	17,189	14,191	2,998
MAPE over 4 time horizons is 25.85%.			
<u>FY 81</u>	<u>ACTUAL</u>	<u>FORECAST</u>	<u>DIFFERENCE</u>
1st Qtr	3,661	3,404	257
2nd Qtr	4,521	3,252	1,269
3rd Qtr	5,167	3,339	1,828
4th Qtr	<u>5,997</u>	<u>3,369</u>	<u>2,628</u>
Total	19,346	13,364	5,982
MAPE over 8 horizons is 27.21%.			

TABLE IV. FORECASTS FOR QUARTERLY PA'S USING CECOM MODEL II

<u>FY 82</u>		<u>FY 83</u>		<u>FY 84</u>	
1st Qtr	2,371	1st Qtr	2,920	1st Qtr	3,116
2nd Qtr	3,689	2nd Qtr	3,391	2nd Qtr	3,284
3rd Qtr	3,920	3rd Qtr	3,474	3rd Qtr	3,314
4th Qtr	<u>4,217</u>	4th Qtr	<u>3,580</u>	4th Qtr	<u>3,352</u>
Total	14,197	Total	13,365	Total	13,066
<u>FY 85</u>		<u>FY 86</u>			
1st Qtr	3,186	1st Qtr	3,211		
2nd Qtr	3,246	2nd Qtr	3,233		
3rd Qtr	3,257	3rd Qtr	3,236		
4th Qtr	<u>3,271</u>	4th Qtr	<u>3,242</u>		
Total	12,960	Total	12,922		

The forecasts from model II are very similar to model I and within a reasonable range, however, II has a larger MAPE than I and hence may be limited in its use.

C. MICOM MODEL.

The MICOM models were developed using quarterly procurement actions from FY 70 up to FY 81. The data exhibits a non-stationary behavior, some seasonality, and a good deal of variability before FY 76. Figure 3 illustrates the MICOM data. The logarithms as well as the actual time series data were analyzed resulting in two possible models.

MICOM

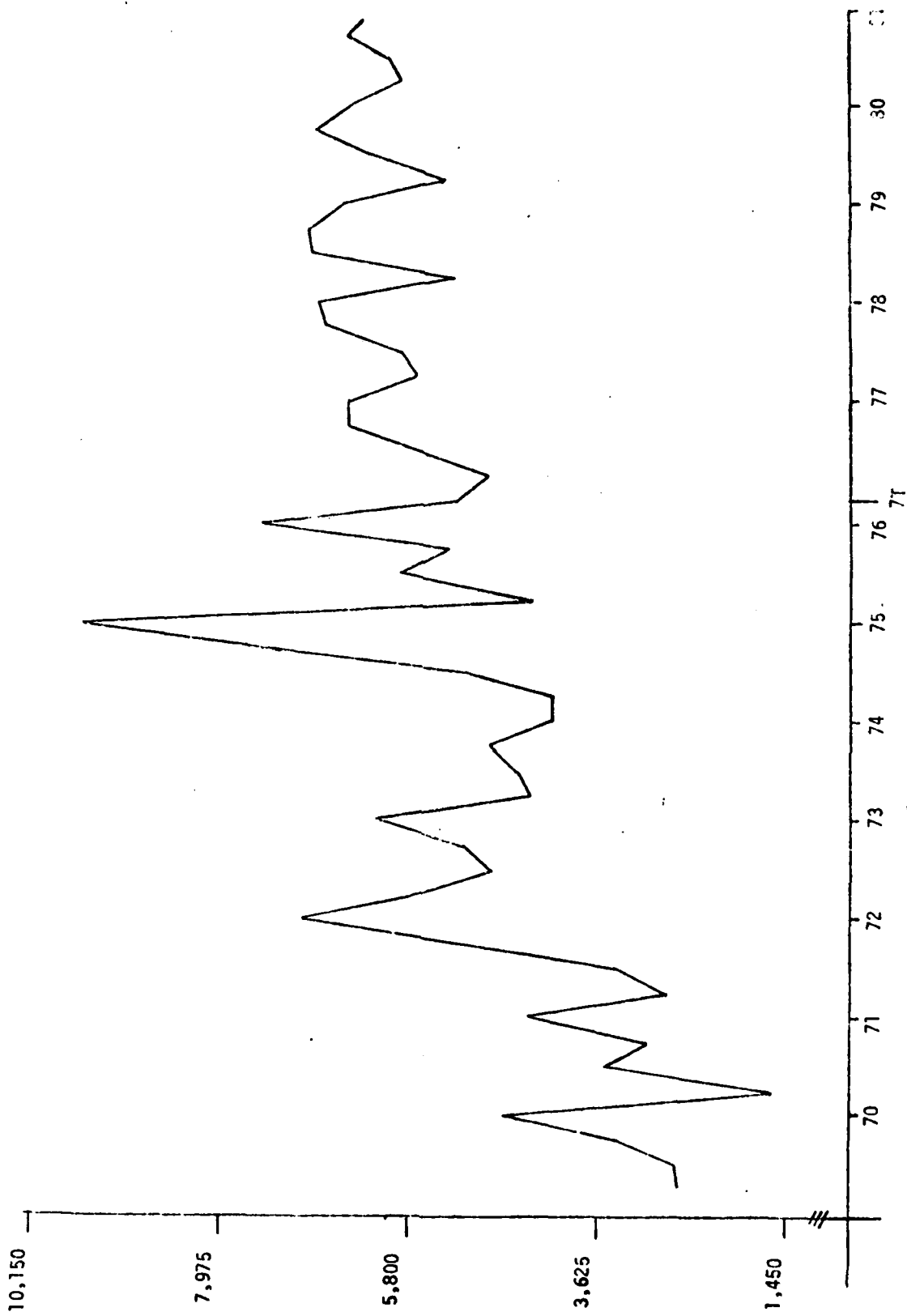


FIGURE 3. MICOM QUARTERLY PROCUREMENT ACTIONS FOR FY'70 THROUGH FY'81

1. MICOM Model I.

Let  $Z_t = \log y_t$  and consider the model

$$(1 - L^4) (1-L) Y_t = \epsilon_t$$

so that

$$Z_t = Z_{t-1} + Z_{t-4} - Z_{t-5}$$

or

$$Y_t = (Y_{t-1}) (Y_{t-4}) / Y_{t-5}.$$

A first difference of the log data with a seasonal fourth difference resulted in the autocorrelation of the residuals exhibiting a random pattern. Since this identification of the log data immediately showed a random pattern, no estimation of parameters was necessary. Table V shows the forecasts for FY 80 and FY 81 using data through FY 79 and Table VI lists the forecasts for FY 82 through FY 86.

TABLE V. VERIFICATION OF MICOM MODEL I ON KNOWN DATA

<u>FY 80</u>	<u>ACTUAL</u>	<u>FORECAST</u>	<u>DIFFERENCE</u>
1st Qtr	5,369	5,107	262
2nd Qtr	6,234	6,580	-346
3rd Qtr	6,843	6,665	178
4th Qtr	<u>6,427</u>	<u>6,286</u>	<u>141</u>
Total	24,873	24,638	235

MAPE over 4 horizons is 3.75%.

<u>FY 81</u>	<u>ACTUAL</u>	<u>FORECAST</u>	<u>DIFFERENCE</u>
1st Qtr	5,900	4,903	997
2nd Qtr	6,068	6,317	-249
3rd Qtr	6,520	6,399	121
4th Qtr	<u>6,293</u>	<u>6,035</u>	<u>258</u>
Total	24,781	23,654	1,127

MAPE over 8 horizons is 5.24%.

TABLE VI. FORECASTS FOR QUARTERLY PA'S USING MICOM MODEL I

<u>FY 82</u>		<u>FY 83</u>		<u>FY 84</u>	
1st Qtr	5,777	1st Qtr	5,657	1st Qtr	5,539
2nd Qtr	5,941	2nd Qtr	5,817	2nd Qtr	5,696
3rd Qtr	6,384	3rd Qtr	6,251	3rd Qtr	6,121
4th Qtr	<u>6,162</u>	4th Qtr	<u>6,034</u>	4th Qtr	<u>5,909</u>
Total	24,264	Total	23,759	Total	23,265
<u>FY 85</u>		<u>FY 86</u>			
1st Qtr	5,424	1st Qtr	5,311		
2nd Qtr	5,578	2nd Qtr	5,462		
3rd Qtr	5,994	3rd Qtr	5,869		
4th Qtr	<u>5,786</u>	4th Qtr	<u>5,666</u>		
Total	22,782	Total	22,308		

The forecasts using MICOM Model I appear to be reasonable, and the MAPE on FY 80 and FY 81 data are good. However, there are no parameters estimated in the model, only the logarithm of a seasonal fourth difference and 1st first difference. Although the results are good, there may be some questions whether this is the true model.

2. MICOM Model II.

$$(1 - \phi_4 L^4) (Y_t - \bar{Y}) = \epsilon_t + \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2} + \theta_3 \epsilon_{t-3}$$

$$Y_t = 8,430 - 0.40032 Y_{t-4} + \epsilon_t - 0.20854 \epsilon_{t-1} - 0.08288 \epsilon_{t-2}$$

$$- 0.09825 \epsilon_{t-3} + 0.33305 \epsilon_{t-4} - 0.50218 \epsilon_{t-5}$$

No logarithmic transformation was taken for model II. The model fitted to the actual data has a seasonal fourth difference parameter,  $\phi_4$ , along with five moving average terms,  $\epsilon_{t-1}, \epsilon_{t-2}, \dots, \epsilon_{t-5}$ . Tables VII and VIII show the fit and the forecasts, respectively.

TABLE VII. VERIFICATION OF MICOM MODEL II ON KNOWN DATA

<u>FY 80</u>	<u>ACTUAL</u>	<u>FORECAST</u>	<u>DIFFERENCE</u>
1st Qtr	5,369	5,391	-22
2nd Qtr	6,234	5,934	300
3rd Qtr	6,843	5,605	1,238
4th Qtr	<u>6,427</u>	<u>5,472</u>	<u>955</u>
Total	24,873	22,402	2,471

MAPE over 4 horizons is 9.54%.

<u>FY 81</u>	<u>ACTUAL</u>	<u>FORECAST</u>	<u>DIFFERENCE</u>
1st Qtr	5,900	5,840	60
2nd Qtr	6,068	6,054	14
3rd Qtr	6,520	6,186	334
4th Qtr	<u>6,293</u>	<u>6,239</u>	<u>54</u>
Total	24,781	24,319	462

MAPE over 8 horizons is 5.68%.

TABLE VIII. FORECASTS FOR QUARTERLY PA'S USING MICOM MODEL II

<u>FY 82</u>		<u>FY 83</u>		<u>FY 84</u>	
1st Qtr	5,540	1st Qtr	5,934	1st Qtr	6,055
2nd Qtr	5,838	2nd Qtr	5,526	2nd Qtr	5,991
3rd Qtr	5,907	3rd Qtr	6,065	3rd Qtr	5,775
4th Qtr	<u>5,679</u>	4th Qtr	<u>6,157</u>	4th Qtr	<u>5,738</u>
Total	22,964	Total	23,682	Total	23,559
<u>FY 85</u>		<u>FY 86</u>			
1st Qtr	6,055	1st Qtr	5,779		
2nd Qtr	5,805	2nd Qtr	5,879		
3rd Qtr	5,891	3rd Qtr	5,845		
4th Qtr	<u>5,906</u>	4th Qtr	<u>5,839</u>		
Total	23,657	Total	23,342		

The MAPE for Model II is not as good as I, but the forecasts for FY 82 through FY 86 are very similar to those made by I. Although the results using model II are satisfactory, there is still some doubt whether this is the true model since no unusual significant pattern was established analyzing the data. It may be that the data is a result of a random walk in which case no model can be developed.

D. TACOM MODEL.

Forty-nine quarterly procurement actions from FY 70 to FY 81 were used to develop two possible TACOM models. Figure 4 shows the data to be stationary over the entire series, but an increase in procurement actions every fourth quarter through FY 77 indicates seasonality. Since FY 78

there has been a downward trend as well as a decrease in the workload every fourth quarter. This decrease may be the result of a policy change as to procuring methods. These changes in the time series data make analysis difficult; however, there are two models to consider - one the result of a logarithmic transformation, the other on the actual data.

1. TACOM Model I.

Let  $Z_t = \log Y_t$  and consider

$$(1-L) (1-L) Y_t = \epsilon_t$$

$$\text{such that } Z_t = Z_{t-1} + Z_{t-4} - Z_{t-5}$$

$$\text{or } Y_t = (Y_{t-1}) (Y_{t-4})/Y_{t-5}.$$

This is the same model as that used at MICOM on the logarithmic transformation. Table IX shows the fit to FY 80 and FY 81 data, while Table X lists the forecasts for FY 82 through FY 86.

TACOM

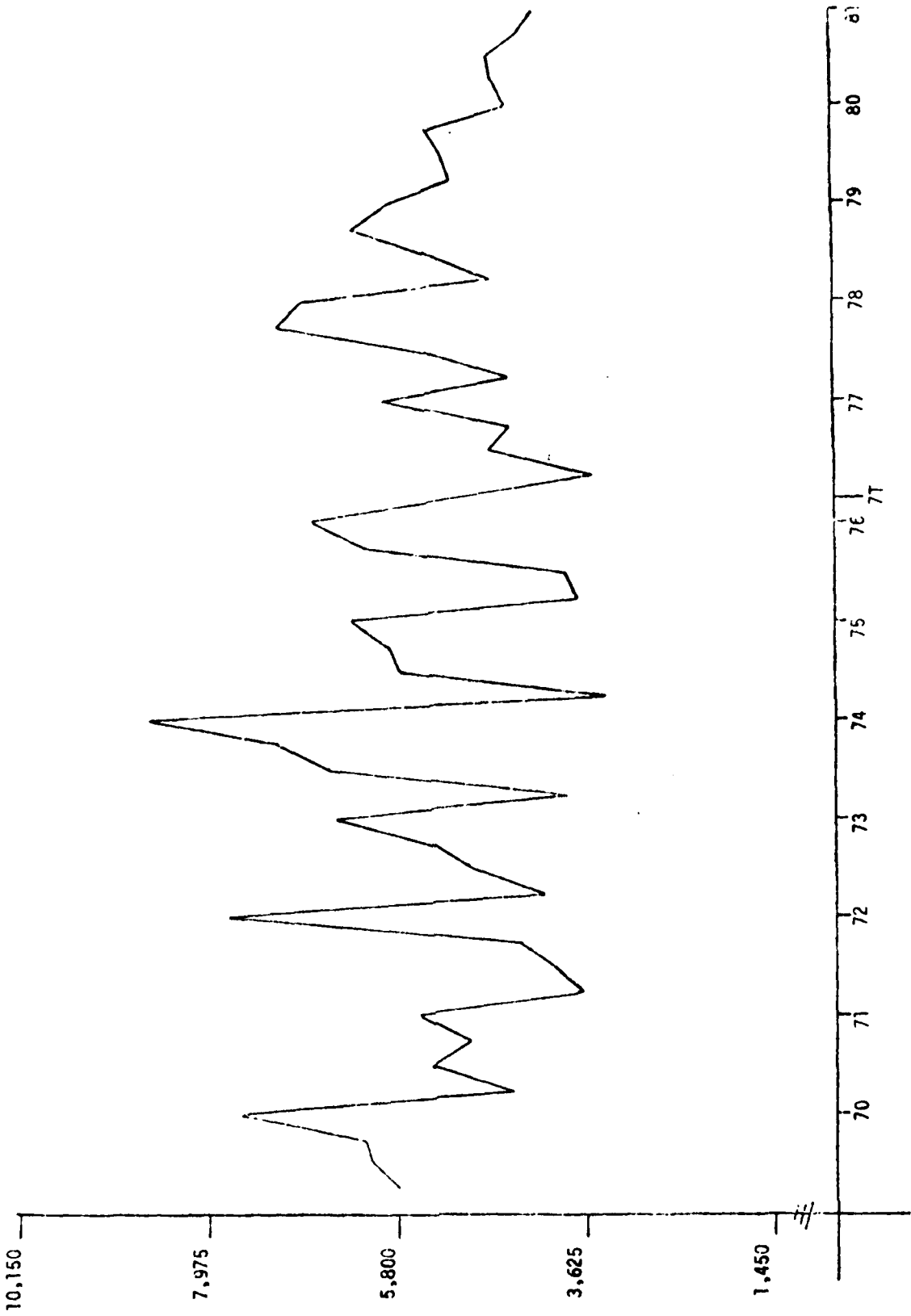


FIGURE 4. TACOM QUARTERLY PROCUREMENT ACTIONS FOR FY '70 THROUGH FY '81

TABLE IX. VERIFICATION OF TACOM MODEL I ON KNOWN DATA

<u>FY 80</u>	<u>ACTUAL</u>	<u>FORECAST</u>	<u>DIFFERENCE</u>
1st Qtr	5,131	4,041	1090
2nd Qtr	5,251	4,644	607
3rd Qtr	5,430	5,356	74
4th Qtr	<u>4,501</u>	<u>5,011</u>	<u>-510</u>
Total	20,313	19,052	1,261

MAPE over 4 horizons is 11.37%.

<u>FY 81</u>	<u>ACTUAL</u>	<u>FORECAST</u>	<u>DIFFERENCE</u>
1st Qtr	4,661	3,451	1,210
2nd Qtr	4,715	3,966	749
3rd Qtr	4,350	4,573	-223
4th Qtr	<u>4,200</u>	<u>4,279</u>	<u>-79</u>
Total	17,926	16,269	1,657

MAPE over 8 horizons is 11.79%.

TABLE X. FORECASTS FOR QUARTERLY PA'S USING TACOM MODEL I

<u>FY 82</u>		<u>FY 83</u>		<u>FY 84</u>	
1st Qtr	4,349	1st Qtr	4,058	1st Qtr	3,786
2nd Qtr	4,400	2nd Qtr	4,106	2nd Qtr	3,831
3rd Qtr	4,059	3rd Qtr	3,787	3rd Qtr	3,534
4th Qtr	<u>3,919</u>	4th Qtr	<u>3,657</u>	4th Qtr	<u>3,412</u>
Total	16,727	Total	15,608	Total	14,563
	<u>FY 85</u>		<u>FY 86</u>		
	1st Qtr	3,533	1st Qtr	3,297	
	2nd Qtr	3,575	2nd Qtr	3,336	
	3rd Qtr	3,298	3rd Qtr	3,077	
	4th Qtr	<u>3,184</u>	4th Qtr	<u>2,971</u>	
	Total	13,590	Total	12,681	

The MAPE is not as good for this model as it was on the MICOM data; in addition, the model is questionable for the same reason as MICOM Model I.

2. TACOM Model II.

$$(1 - \phi_{-4} L^4) (Y_t - \bar{Y}) = \epsilon_t + \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2} + \dots + \theta_8 \epsilon_{t-8}$$

$$Y_t = 4,115 + (0.23785) Y_{t-4} + \epsilon_t + 0.29512 \epsilon_{t-1} - 0.28901 \epsilon_{t-2}$$

$$-0.21726 \epsilon_{t-3} - 0.05316 \epsilon_{t-4} - 0.06180 \epsilon_{t-5} - 0.35236 \epsilon_{t-6}$$

$$-0.63901 \epsilon_{t-7} + 0.29726 \epsilon_{t-8}$$

No logarithmic transformation was made on the data to fit model II. The model has a seasonal fourth difference parameter,  $\phi_4$ , as well as eight moving average terms. The fit of the model and the forecasts for FY 82 through FY 86 are given in Tables XI and XII, respectively.

TABLE XI. VERIFICATION OF TACOM MODEL II ON KNOWN DATA

<u>FY 80</u>	<u>ACTUAL</u>	<u>FORECAST</u>	<u>DIFFERENCE</u>
1st Qtr	5,131	4,872	259
2nd Qtr	5,251	4,845	406
3rd Qtr	5,430	5,845	-415
4th Qtr	<u>4,501</u>	<u>5,615</u>	<u>-1114</u>
Total	20,313	21,177	-864

MAPE over 4 horizons is 11.29%.

<u>FY 81</u>	<u>ACTUAL</u>	<u>FORECAST</u>	<u>DIFFERENCE</u>
1st Qtr	4,661	5,164	-503
2nd Qtr	4,715	5,267	-552
3rd Qtr	4,350	5,542	-1192
4th Qtr	<u>4,200</u>	<u>5,440</u>	<u>-1240</u>
Total	17,926	21,413	-3487

MAPE over 8 horizons is 15.57%.

TABLE XII. FORECASTS FOR QUARTERLY PA'S USING TACOM MODEL II

<u>FY 82</u>		<u>FY 83</u>		<u>FY 84</u>	
1st Qtr	5,761	1st Qtr	5,661	1st Qtr	5,338
2nd Qtr	6,099	2nd Qtr	6,120	2nd Qtr	5,448
3rd Qtr	5,847	3rd Qtr	5,648	3rd Qtr	5,335
4th Qtr	<u>4,883</u>	4th Qtr	<u>5,085</u>	4th Qtr	<u>5,201</u>
Total	22,590	Total	22,514	Total	21,322
<u>FY 85</u>		<u>FY 86</u>			
1st Qtr	5,262	1st Qtr	5,244		
2nd Qtr	5,288	2nd Qtr	5,250		
3rd Qtr	5,261	3rd Qtr	5,243		
4th Qtr	<u>5,229</u>	4th Qtr	<u>5,236</u>		
Total	21,040	Total	20,973		

The MAPE for model II is larger than desired, especially over the eight horizons. In addition, the forecasts for FY 82 through FY 86 appear large with respect to the recent TACOM trend.

E. TSARCOM MODEL.

To obtain 49 data points for TSARCOM, 96% of the former Aviation Systems Command (AVSCOM) quarterly procurement actions were added to 100% of the Troop System Command (TROSCOM) data points. It was felt that TSARCOM had taken over 96% of the procurement workload which AVSCOM had had and all of the TROSCOM workload. This synthesis of workload was done from FY 70 through FY 77. In the third quarter of FY 79 TSARCOM had an unusual number of no cost actions which was added to their usual workload, distorting their normal third quarter figure. Since this number was an obvious outlier it was normalized to put it in line with the other data. These corrections to the data resulted in the graph of Figure 5. A logarithmic transformation was attempted on the

TSARCOM

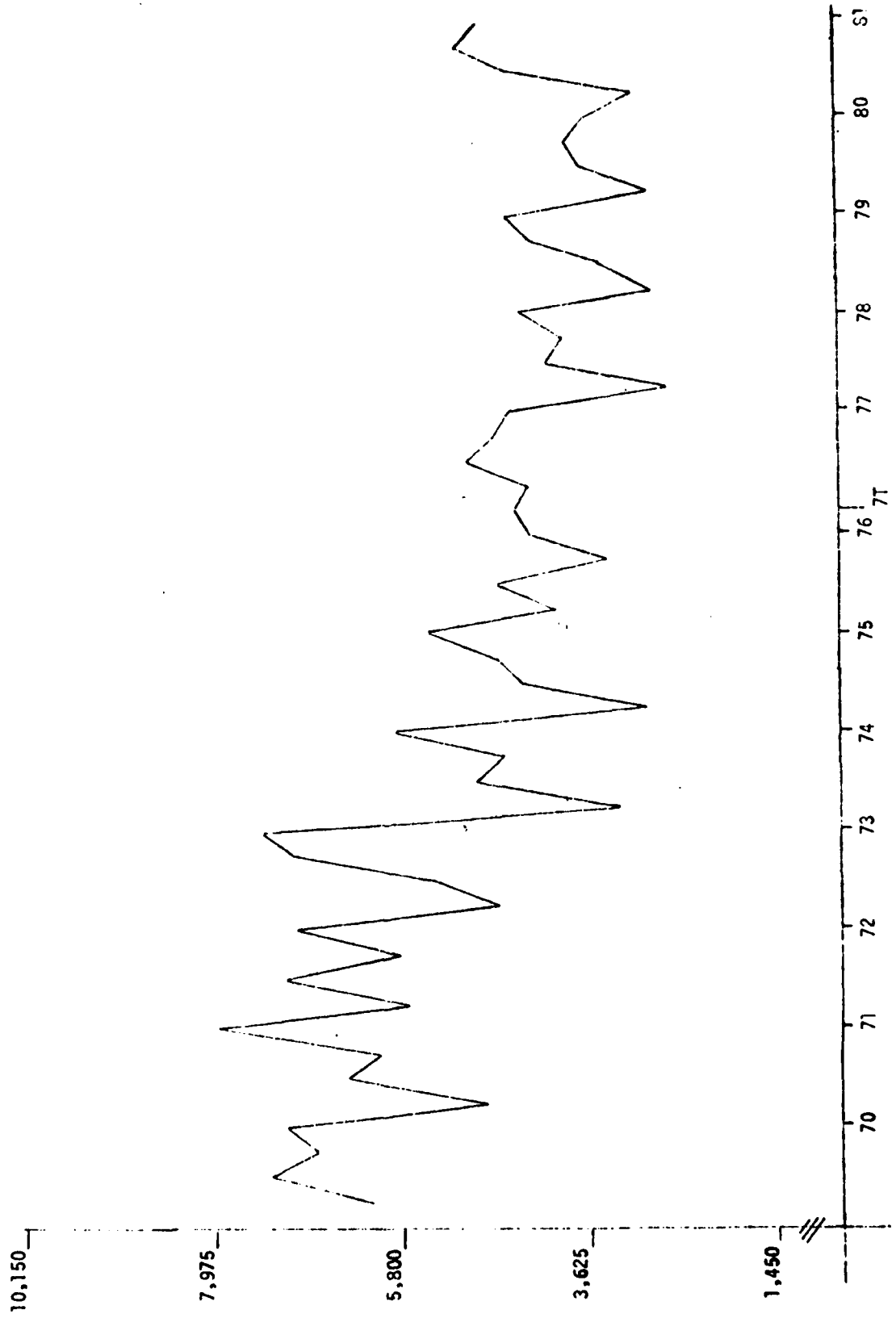


FIGURE 5. TSARCOM QUARTERLY PROCUREMENT ACTIONS FOR FY '70 THROUGH FY '81

data which produced a model that resulted in the explosive behavior of future forecasts; hence it was discarded.

A model was derived, using no logarithmic transformation of the data, by taking the first difference to introduce stationarity and then estimating a quarterly seasonal parameter. This resulted in the following autoregressive moving average model exhibiting an AR and MA term along with a seasonal parameter  $\phi_4$ :

$$(1 - \phi_4 L^4) (1 - L) (Y - \bar{Y}) + \phi_1 (Y_{t-1} - \bar{Y}) = \epsilon_t + \theta_1 \epsilon_{t-1}$$

$$Y_t = 4,175 + 0.1464y_{t-1} + 0.43839 y_{t-4} - 0.43839 y_{t-5} + \epsilon_t + 0.80716 \epsilon_{t-1}$$

Table XIII shows how well the model forecasts FY 80 and FY 81 using data through FY 79 while Table XIV shows the forecasts for FY 82 through FY 86.

TABLE XIII. VERIFICATION OF TSARCOM MODEL ON KNOWN DATA

<u>FY 80</u>	<u>ACTUAL</u>	<u>FORECAST</u>	<u>DIFFERENCE</u>
1st Qtr	2,905	4,130	-1,225
2nd Qtr	3,689	5,028	-1,339
3rd Qtr	3,847	5,252	-1,405
4th Qtr	<u>3,623</u>	<u>5,068</u>	<u>-1,445</u>
Total	14,064	19,478	-5,414
MAPE over 4 horizons is 38.72%.			
<u>FY 81</u>	<u>ACTUAL</u>	<u>FORECAST</u>	<u>DIFFERENCE</u>
1st Qtr	3,134	4,746	-1,612
2nd Qtr	4,495	5,264	-769
3rd Qtr	5,131	5,044	87
4th Qtr	<u>4,834</u>	<u>4,833</u>	<u>1</u>
Total	17,594	19,887	2,293
MAPE over 8 horizons is 28.14%.			

TABLE XIV. FORECASTS FOR QUARTERLY PA'S USING TSARCOM MODEL

<u>FY 82</u>		<u>FY 83</u>		<u>FY 84</u>	
1st Qtr	4,508	1st Qtr	4,737	1st Qtr	4,829
2nd Qtr	5,432	2nd Qtr	5,274	2nd Qtr	5,117
3rd Qtr	5,249	3rd Qtr	4,867	3rd Qtr	4,746
4th Qtr	<u>4,813</u>	4th Qtr	<u>4,696</u>	4th Qtr	<u>4,795</u>
Total	20,002	Total	19,574	Total	19,487
<u>FY 85</u>		<u>FY 86</u>			
1st Qtr	4,935	1st Qtr	4,952		
2nd Qtr	5,024	2nd Qtr	4,939		
3rd Qtr	4,748	3rd Qtr	4,777		
4th Qtr	<u>4,892</u>	4th Qtr	<u>4,937</u>		
Total	19,599	Total	19,605		

On testing the fit of the model to the known data of FY 80 and FY 81 the MAPE was large, but the fit was better in the most recent FY'81 data. This prompted the verification of the model on the forecast for FY 81 using only data through FY 80, the results of which are shown in Table XV.

TABLE XV. VERIFICATION OF TSARCOM MODEL THROUGH FY'80 DATA

<u>FY 81</u>	<u>ACTUAL</u>	<u>FORECAST</u>	<u>DIFFERENCE</u>
1st Qtr	3,134	3,678	-544
2nd Qtr	4,495	5,057	-562
3rd Qtr	5,131	4,985	146
4th Qtr	<u>4,834</u>	<u>4,806</u>	<u>28</u>
Total	17,594	18,526	-932

MAPE over 4 horizon of 8.32%.

Using data through FY 80 the MAPE is 8.32%, a significant decrease from the fit using data through FY 79. The forecasts for FY 82 through FY 86 also appear reasonable based on FY 81 workload.

F. ARRCOM MODEL.

ARRCOM has undergone several reorganizations since FY 70. From FY 70 through FY 73 two commands existed representing some of the ARRCOM workload - the Munitions Command (MUCOM) and the Weapons Command (WECOM). In FY 74 these two commands merged to become the Armament Command (ARCOM) and remained as such until the second quarter of FY 77. In the second quarter of FY 77 ARCOM was broken out into two separate commands: Armament Readiness Command (ARRCOM) and the Armament Research and Development Command (ARRADCOM). These three reorganizations have presented a problem in obtaining a consistent, reliable data base to use in developing a time series model to forecast ARRCOM workload. Figure 6 describes the workloads of the commands mentioned above since FY 70 to the present along with the fiscal year totals. The dotted line represents the ARCOM workload, which prior to FY 73 is the sum of MUCOM and WECOM and after FY 77 the sum of ARRCOM and ARADCOM. All the graphs exhibit variability in the workload as can definitely be seen by the fiscal year totals. Due to the inconsistency of the data, no forecasting model was developed; however, more analysis should be attempted as data becomes available. In the meantime, forecasts can be made for ARRCOM using the central procurement workload projection model developed in APRC Project 80-04 [See Reference 2], following the scheme outlined on page 2 of this report.

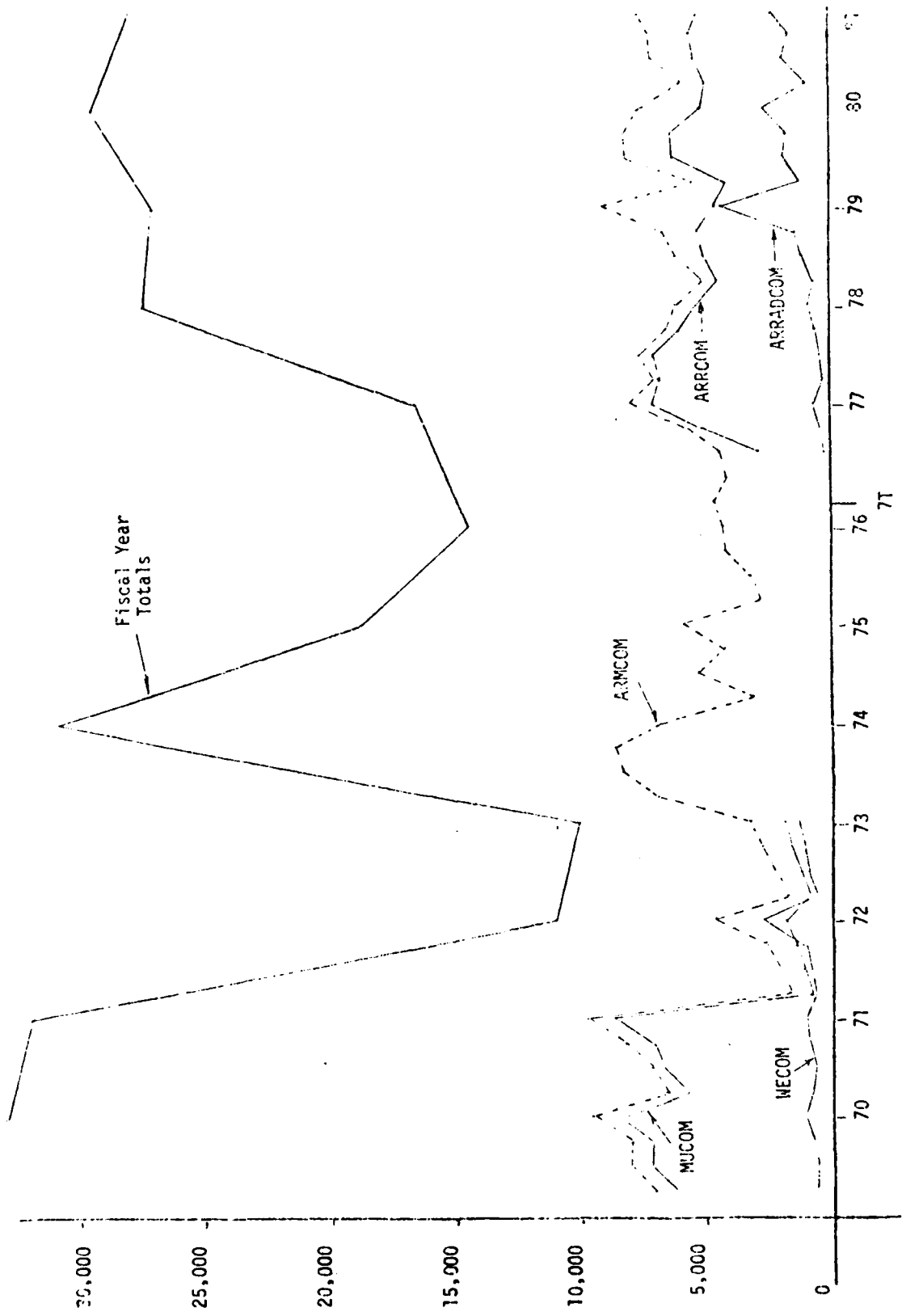


FIGURE 6. ARRCOM QUARTERLY PROCUREMENT ACTIONS FOR FY'70 THROUGH FY'81

CHAPTER III  
USE OF MODELS WITHIN PAMUPS

A. INTRODUCTION.

There is presently no uniform work measurement/staffing standards nor manpower projection system within the DARCOM Major Subordinate Commands. However, with the availability of the present automated systems in the procurement process, the capability now exists to implement a manpower utilization and projection system within the procurement organization of the Materiel Readiness Commands (MRC's). The Procurement Automated Manpower Utilization and Projection System (PAMUPS) will provide procurement manpower productivity and projection information which will enable managers to evaluate the effective use of procurement personnel and to determine the impact of projected workload on future manpower staffing.

Time standards for basic procurement efforts and additional tasks (complexity factors) performed in the execution of procurement actions will be established by the Integrated Methods and Standards Activity (IMSA). As data are recorded in the Commodity Command Standard System (CCSS), completed actions along with respective data will be signalled to the PAMUPS system where the applicable complexity factors found in the PAMUPS Master Complexity Matrix will be assigned and the respective standards applied. There will be a monthly computation of total manhours available along with earned personal equivalents. A record of completed actions and related detail information will be maintained in a file, and reports will be generated for different levels of management within the procurement organization.<sup>5</sup>

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<sup>5</sup>Automated Logistics Management Systems Activity (ALMSA) PAMUPS description paper, November 1981.

## B. INTEGRATION OF MODELS WITHIN PAMUPS.

The procurement action forecasting models developed in this study are vehicles by which the workload projection can be accomplished at the MRC's in PAMUPS.

The models use data internal to the procurement system, procurement actions, which is the designated performance indicator of procurement workload. The total number of procurement actions forecasted can be compared to the complexity matrix in PAMUPS and then categorized by type of instrument and complexity. An estimate of the type of work which is being accomplished can then be projected into the future along with the required manpower to accomplish it. If some new information becomes available which will have an effect on the forecast (e.g., introduction of new weapon system or large cut in defense spending), then it can be evaluated, analyzed and included into the projection.

PAMUPS will record the number of manhours associated with those procurement instruments which result in procurement actions. The procurement actions are accumulated and categorized by type along with the manhours expected to accomplish these actions. Assuming the type of workload will remain essentially the same, a forecast can then be made of how many actions of each type will be expected in the future along with the respective manhours needed to accomplish the actions. Figure 7 illustrates the concept. The PA is the forecast of total workload while the  $(X_1/N)$ ,  $(X_2/N)$ , . . .  $(X_{11}/N)$  are ratios of type to total workload. When these ratios are multiplied by the forecast, the future workload is categorized by type. If the Y's are the established manpower standards associated with type of workload, then the sum will give total projected

manpower requirements. If the distribution of workload can be defined by a probability distribution, then a calculated error value can be made with respect to projected requirements.

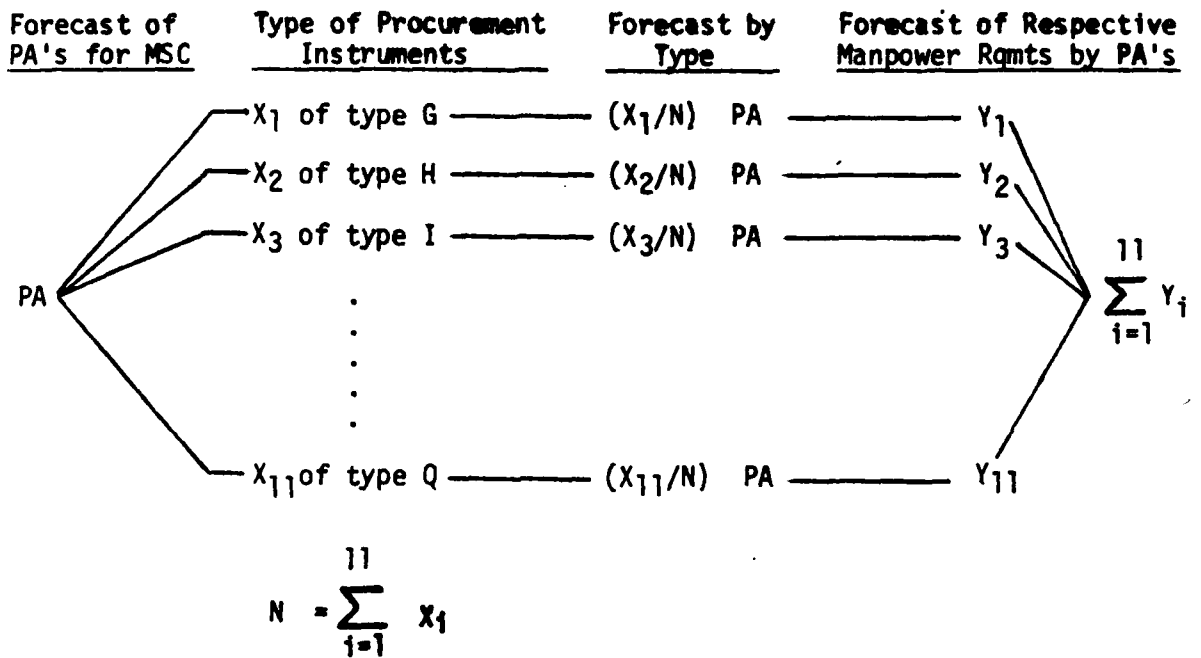


FIGURE 7. FORECASTING NUMBER OF PROCUREMENT ACTIONS BY TYPE

CHAPTER IV  
FINDINGS AND RECOMMENDATIONS

A. GENERAL.

An attempt has been made in this study to develop workload forecasting models using the Box-Jenkins univariate time series technique. The purpose for developing these models is to make them part of PAMUPS. Although the preliminary results of some models are not encouraging, the concept appears applicable and with more data and analysis an improved model may be found for each command in the study.

B. FINDINGS.

1. Both models developed for CECOM appear to underestimate what future workload may be, based on FY 80 and FY 81 data. Since the results are essentially the same, CECOM Model II should be used since it is a more simple model than CECOM I; that is, no logarithmic transformation is necessary, and there is one less moving average parameter. More data is necessary to be sure which model will work best.

2. MICOM Model I provides a better fit than Model II since it has a smaller mean absolute percentage error. It is also a more simple model having no parameters to estimate, although a logarithmic transformation of the data is required. The FY 82 forecast using MICOM Model I appears more in line with the workload which MICOM has had in FY 80 and 81; however the forecast decreases in FY 83-86. MICOM Model II, on the other hand, contains more parameters but requires no logarithmic transformation of the data. Although the FY 82 forecast is lower than what MICOM has been experiencing, the future years show an increase. More data and analysis are required to determine the true model.

3. TACOM has experienced a decrease in workload in FY 79, 80 and 81; nevertheless, there appears to be no reason for this decrease to continue. TACOM Model I forecasts a continued significant decrease, and for this reason it is suspect. TACOM Model II requires no logarithmic transformation and is not as parsimonious a model, having a total of eight moving average terms and a seasonal difference parameter; but, the forecasts made for FY 82-86 with Model II appear much more likely than those made with I. For this reason TACOM Model II is preferred to I.

4. There is only one model developed for TSARCOM. The forecasts made for FY 82 through FY 86 may be high; however, there was an increase in the workload in FY 81. The mean absolute percentage error on the FY 81 data is less than 10%; and if the TSARCOM workload continues to increase, this model will give excellent forecasts. Only the future will validate this model, but it appears credible.

5. More than forty-nine data points are necessary to develop models for each of the individual commands due to the seasonal and non-stationary characteristics. However, based on these preliminary results, it appears models can be developed which will give credible workload forecasts at the major readiness commands.

#### C. RECOMMENDATIONS.

1. CECOM Model II and TACOM Model II should be used at each respective command. MICOM Models I and II should be used and monitored. The TSARCOM model appears adequate and should be used.

2. More analysis should be done on ARRCOM data; meanwhile, the methodology outlined on page 2 should suffice.

3. All the models should be updated as more data becomes available.
4. The models are recommended to be used within PAMUPS.
5. It is recommended that command analysts familiarize themselves with their respective model(s) and that APRO provide consultation in the use and maintenance of the individual models when requested.

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## STUDY TEAM COMPOSITION

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