U.S. ARMY DARCOM

APRO 80-04

FINAL

CENTRAL PROCUREMENT WORKLOAD PROJECTION MODEL

FEBRUARY 1981

APRO

ARMY PROCUREMENT RESEARCH OFFICE

U.S. ARMY LOGISTICS MANAGEMENT CENTER
FORT LEE, VIRGINIA 23801

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by

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The pronouns "he," "his," and "him," when used in this publication represent both the masculine and feminine genders unless otherwise specifically stated.

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EXECUTIVE SUMMARY

A. BACKGROUND. In the past few years there has been a continuing increase in DARCOM's procurement workload while the manpower in the Procurement and Production (P&P) Directorate have remained relatively constant. Before any manpower increases are authorized HQ DARCOM and P&P Directorates must document its future resource needs. DARCOM is presently developing an automated system, Procurement Automated Manpower Utilization and Projection Systems (PAMUPS), to document their workload and manpower needs. However, PAMUPS is not designed to forecast what future workload may be. There is a need for a reliable model to forecast procurement workload.

B. STUDY OBJECTIVES. The study objectives are:

1. Identify methodology which will forecast procurement workload using data internal to the procurement system.

2. Tie in this methodology with a way of categorizing the projected workload as to complexity.

3. Devise a method to apply manpower standards to the categorized workload forecast to obtain required manpower projections.

4. Attempt to incorporate into the system model a subjective estimation methodology to update manpower requirements based on the most recent information.

C. STUDY APPROACH. In order to have a forecasting model to work within PAMUPS, the model would have to use data internal to procurement operations. Regression models depend on a cause and effect relationship, and hence would require the examination of data external to procurement operations. Therefore, univariate time series models using only data generated by the P&P Directorates such as procurement actions (PA's) are pursued. Specifically, Box-Jenkins Autoregressive Integrated Moving Average process is used to develop a model to forecast quarterly procurement actions. The projected quarterly forecasts are added to arrive at an annual forecast.

D. FINDINGS AND RECOMMENDATIONS. The forecasting model developed using Box-Jenkins gives reliable estimates of future procurement actions awarded, outperforming the present regression model. Based on results of the study, recommendations are made for HQ DARCOM to adopt the model to assist them in procurement workload forecasts and to use Box-Jenkins to develop forecasting models at the Readiness Commands for use within PAMUPS.

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INTRODUCTION

A. BACKGROUND OF PROBLEM.

Department of Army civilians have always been instrumental in helping the Army accomplish its mission. The support role the civilian workforce plays has been so essential that budgetary and other constraints imposed upon civilian manpower acutely affects the Army's preparedness. While the authorized military strength has remained relatively constant, civilian manpower authorization has steadily declined during the past five years. These reductions can decrease the Army's ability to support the forward deployed forces and may be detrimental to unit readiness and mission effectiveness.

The US Army Materiel Development and Readiness Command (DARCOM) is responsible for the acquisition of Army equipment. DARCOM is involved from the inception of the design through the testing, production, distribution, and maintenance. This command is the Army's largest employer of civilians; however, its authorized strength has declined dramatically, going from 191,000 in 1962 to a projected 112,800 in 1980.[1] Less than 10,300 of the 1980 total will be military personnel.

During recent years, while the reduction in force continued, several developments have increased the DARCOM workload. One has been a shift from 13 to 16 divisions, with an increase in the density of equipment per division. Another has been a requirement for DARCOM to furnish direct

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[1] Association of the United States Army. Special Report, "Where Did All the People Go? The Army's Vanishing Civilian Work Force," 1980.

support to US Army, Europe because of the closing of overseas depots. Also, DARCOM has assumed Defense-wide responsibility as the single manager for conventional ammunition. In addition, DARCOM has been heavily involved in Foreign Military Sales, an area in which the workload continues to increase.

This added responsibility to support material has increased the workload in the procurement directorates of DARCOM's Commodity Commands. Figure 1 shows the relationship between procurement workload and the personnel available to accomplish it. Since the procurement workforce has not increased commensurately with the workload, a substantial backlog has developed. This procurement backlog will have an adverse effect on timely obligations of procurement programs and adequate procurement planning, resulting in a decrease in the quality of procurement operations. Figure 2 illustrates how this may eventually affect mission effectiveness.

In order for procurement directorates of the Commodity Commands to attain an appropriate increase in their workforce, they must be able to effectively document their civilian manpower needs by obtaining reliable forecasts of what their future workload and manpower requirements may be. Hence, there is a definite need for a reasonable method of forecasting procurement workload and the required manpower to accomplish it.

Presently, Headquarters, DARCOM Procurement and Production Directorate is developing an automated system, Procurement Automated Manpower Utilization and Projection System (PAMUPS), to 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. However, within PAMUPS, there is still a need for a way to forecast what the workload may be.

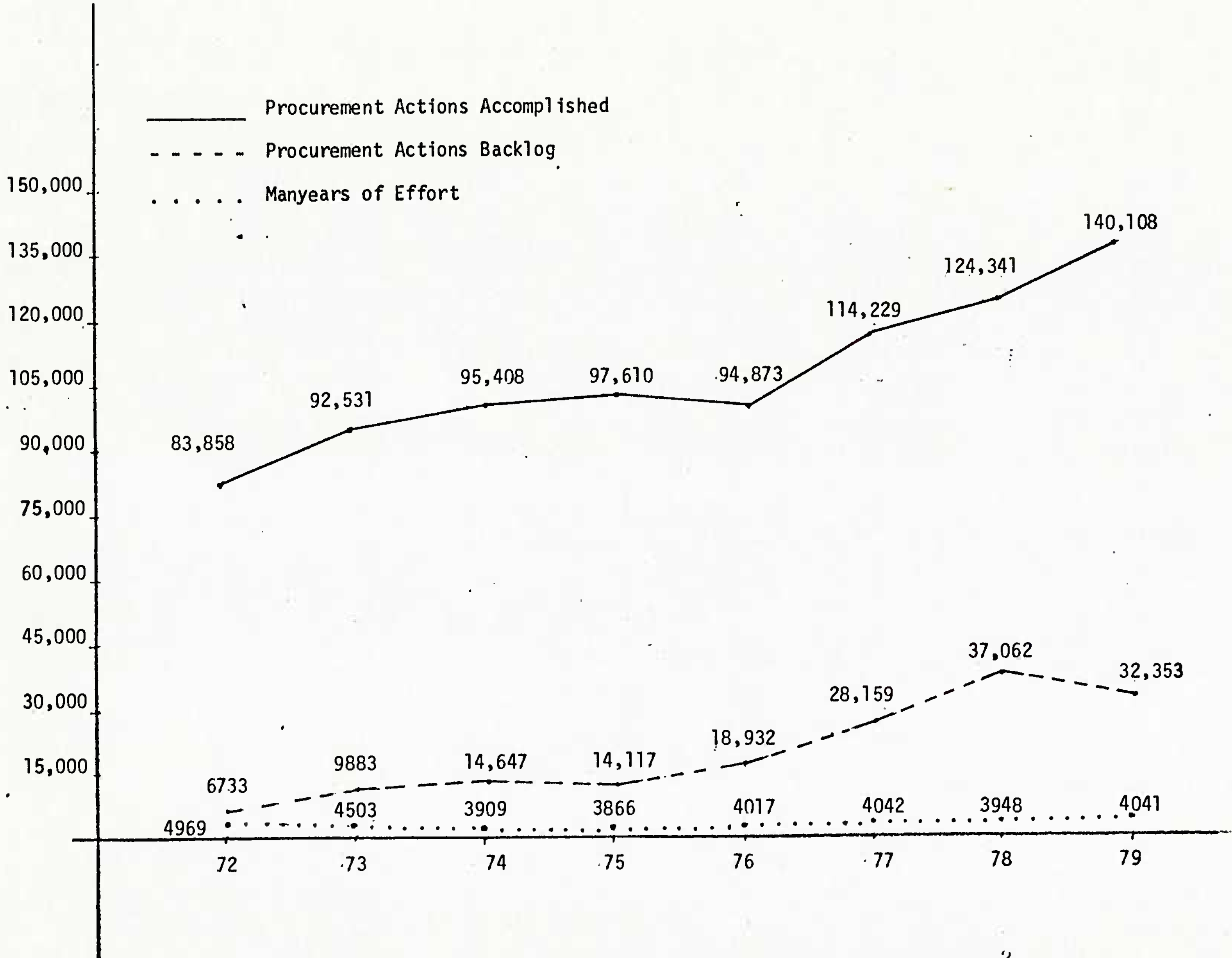

FIGURE 1. DARCOM CENTRAL PROCUREMENT WORKLOAD/MANPOWER[2]

[2]Based on Information Paper, Mr. Frank Kelsey, DRCPP-SO, Directorate for Procurement and Production, HQ DARCOM, Nov. 1979.

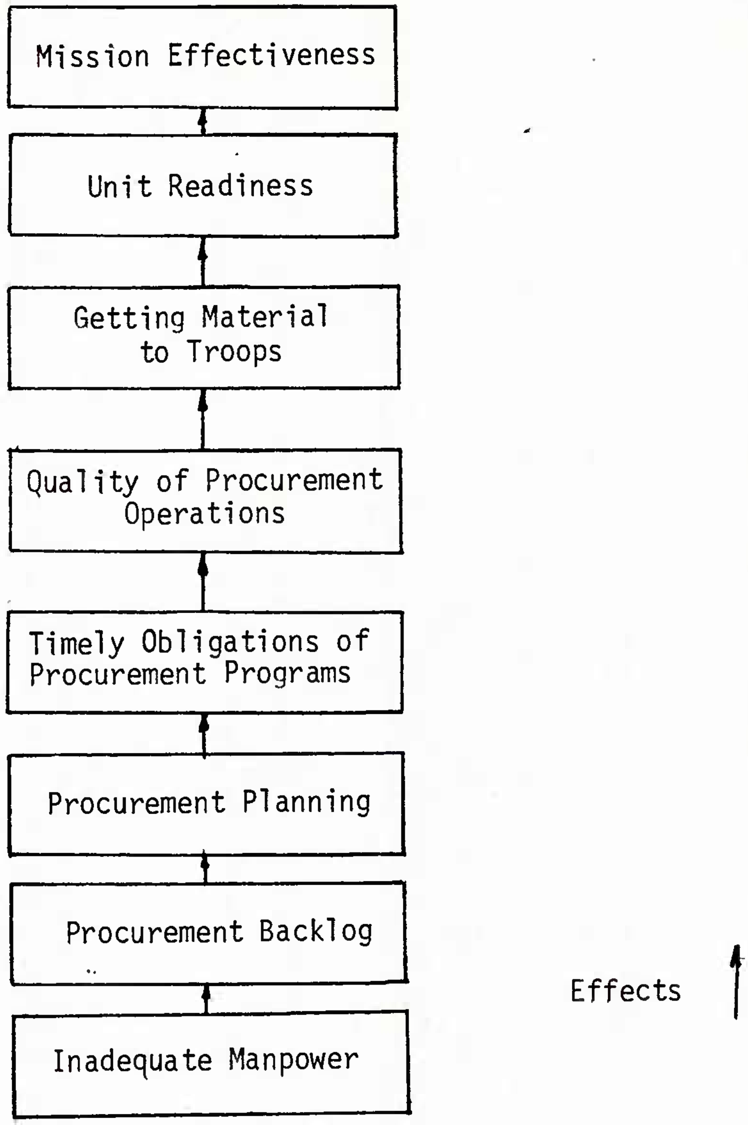

FIGURE 2. EFFECTS OF INADEQUATE MANPOWER IN PROCUREMENT DIRECTORATE

B. STUDY OBJECTIVE.

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

1. Identify methodology which will forecast procurement workload using data internal to the procurement system.

2. Tie in this methodology with a way of categorizing the projected workload as to complexity.

3. Devise a method to apply manpower standards to the categorized workload forecast to obtain required manpower projections.

4. Attempt to incorporate into the system model a subjective estimation methodology to update manpower requirements based on the most recent information.

C. STUDY APPROACH.

The study addresses first the development of mathematical models to forecast DARCOM's central procurement workload. A previous APRO study[3] developed a multiple linear regression model where the variable of interest (procurement actions) was a function of variables, external to procurement operations, but identified as drivers of procurement workload. The model was to forecast annual workload but had few data points (nine years) and a high degree of multicollinearity raising doubts as to the confidence of the forecast of the independent variable. In addition, the data external to

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[3]Correia, Charles A., Launer, Robert L., Carter, Shirley H., Models to Forecast Workload of Central Procurement Offices in AMC's Major Subordinate Commands, Army Procurement Research Office, Ft. Lee, VA, October, 1974.

procurement was often difficult to obtain, and finally, since there were so few data points the model had to be continually updated and refined. These reasons contributed to the model not being used.

PAMUPS accentuates the need for a reliable model to forecast procurement workload. PAMUPS is a system designed to measure the requirements internal to procurement operations; that is, all the required data will come from within the procurement directorates. If a forecasting model is to have use within PAMUPS, the input to the model will need to come from within the procurement system. Therefore, the idea arose as to the possibility of forecasting the procurement workload with data internal only to procurement operations.

An approach yet untried to forecast procurement workload is a time series model. A time series is any series of data recorded at regular intervals of time. For example, the total number of procurement actions recorded on a monthly, quarterly, or annual basis. Time series models, using only procurement data such as procurement actions and procurement work directives (PWD's), can be developed provided enough data points are available. Such data does exist. However, a good deal of analysis is required before it can be used in a time series model. The early data must be normalized so as to be as characteristic of the present data as possible. In the late sixties and very early seventies, central and local procurement actions were recorded together. Also, up until 1975 "no cost actions" as well as "exclusions" were not counted in the total number of procurement actions recorded. Therefore, all the data used in the univariate time series models of this study had to be analyzed and normalized. Total procurement actions as far back as fiscal year 1965 are now recorded and normalized to the present. Quarterly data is available from FY 65 and monthly from FY 71 to the present.

The variable, procurement actions, is used to develop a time series model to forecast the total number of procurement actions accomplished for all of DARCOM. A time series forecasting technique which has become prominent within the past decade has been the Box-Jenkins Autoregressive Integrated Moving Average Process (ARIMA). The ARIMA looks at a time-series (procurement actions) and models what the procurement actions will be at time t based on (1) previous values, (2) previous forecasting errors, and (3) the incremental difference from one period to the next. These differences are studied for any correlation and summed in the analysis of the process. (1), (2), and (3) above are the autoregressive, moving average, and integrated portions of an ARIMA process.

Box-Jenkins is used to develop the model to forecast the number of quarterly procurement actions accomplished. Although analysis was done on monthly time series data, it is not included since it only provides short term monthly forecasting. Management is concerned primarily with forecasting annual or quarterly requirements; therefore only the model making quarterly forecasts is presented in the study.

CHAPTER II

TIME SERIES MODEL TO FORECAST PROCUREMENT ACTIONS ACCOMPLISHED

A. INTRODUCTION.

This chapter presents a time series model developed to forecast procurement actions accomplished. As noted earlier 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. Appendix 1 discusses in more detail the theory behind the model developed in this section.

B. PROCUREMENT ACTION MODEL.

The Box-Jenkins Autoregressive Integrated Moving Average Process fits a mathematical model to time series data. This fit is accomplished by studying the autocorrelation function of the time series. In this case the time series, is quarterly procurement actions going back from fiscal years 79 to 65, including 7T. In order for Box-Jenkins to produce a reliable model at least fifty data points should be available.[4] A total of sixty-one data points were available for procurement actions.[5]

Figure 3 describes the procurement action time series. Note that it is seasonal, peaking each fourth quarter of the fiscal year. This is expected since there is usually increased spending activity in the last quarter of a fiscal year. Note, also that the data is nonstationary, that is, it does not vary about some mean value over time, but instead follows a trend.

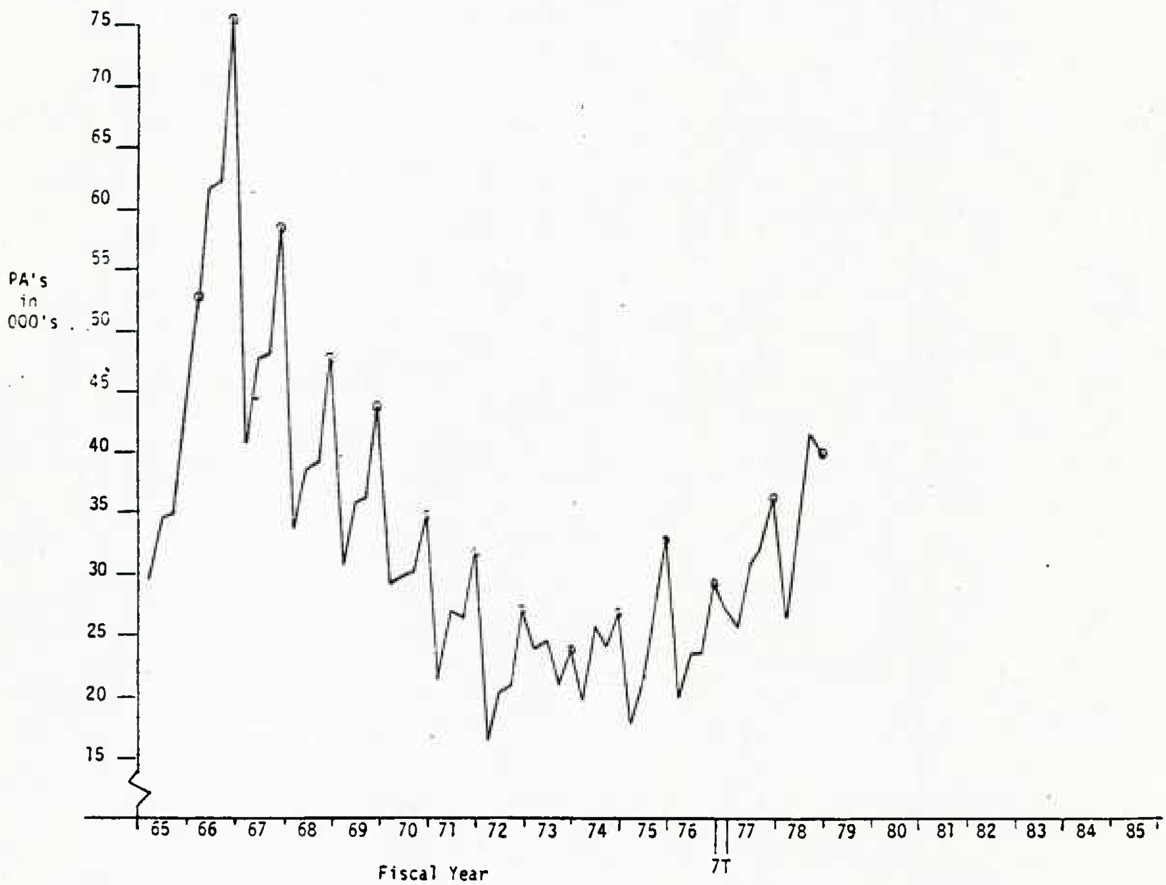

FIGURE 3. QUARTERLY PROCUREMENT ACTIONS

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[4]Box, G.E.P., and G.M. Jenkins, Time Series Analysis, Forecasting and Control. San Francisco: Holden-Day, 1970.

[5]The number of procurement actions and all other data used in this study is found in the DARCOM Central Procurement Workloading Report, AMCRP-127.

Before a forecasting model can be developed these variations must be taken into account. The Box-Jenkins ARIMA process corrects the time series both for seasonality and nonstationarity, and identifies a tentative model for examination. Parameters are then estimated for the tentative model and verified for accuracy.

The seasonal ARIMA model which best fits empirically the procurement action (PA) time series is represented mathematically by the following difference equation:

$$PA_T = PA_{T-1} + 0.51982PA_{T-4} - 0.51982PA_{T-5} + E_T - 0.28952\ E_{T-1} - 0.13664E_{T-2} - 0.60893E_{T-3} \qquad (1)$$

where

PA_T = procurement actions in T quarter

PA_{T-1} = procurement actions in T-1 quarter

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.
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E_T = error between actual number of PA's and the estimate in T quarter

E_{T-1} = error between actual number of PA's and estimate in T-1 quarter

.
.
.

To forecast h quarters into the future, T is replaced by T + h. For example, to forecast 1 quarter, h = 1, into the future we have

$$PA_{T+1} = PA_T + 0.51982PA_{T-3} - 0.51982PA_{T-4} + E_{T+1} - 0.28952E_T - 0.13664E_{T-1} - 0.60893E_{T-2} \qquad (2)$$

Note, that since the actual value of PA_{T+1} is not known, no error term for E_{T+1} is known. The assumption is made that the model will predict the actual values and hence the error will be zero. Therefore, after forecasting 3 quarters into the future no error terms remain in the model. Likewise, after 6 quarters into the future no actual values of PA's exist; that is, for $h \geq 6$ only estimates of PA's are used.

The model is developed to forecast quarterly PA's; however, if four quarters are added an annual forecast is available. No reliable confidence interval with respect to forecast error can be given about the annual forecast since the residual standard deviation is for the quarterly estimates. Nonetheless, this does not prevent a point estimate based on the sum of the four quarters. Even with this limitation the annual forecast obtained while verifying the model is good.

To verify how well the model forecasts, the FY 79 and FY 80 forecasts were made at the end of FY 78, thereby forecasting eight periods into the future. The actual values are compared to their respected estimates in Table 1. The annual differences are 6.5% and 0.64%, respectively.

TABLE 1. VERIFICATION OF MODEL ON KNOWN DATA

FY 79	ESTIMATE	ACTUAL*	DIFFERENCE	
1st Qtr	29,899	25,962	3,937	
2nd Qtr	31,879	33,436	-1,557	
3rd Qtr	33,912	41,390	-7,478	
4th Qtr	35,816	39,920	-4,104	
TOTAL	131,506	140,708	-9,202	6.5%
FY 80				
1st Qtr	32,650	27,455	5,195	
2nd Qtr	33,679	35,034	-1,355	
3rd Qtr	34,736	36,864	-2,128	
4th Qtr	35,725	36,562	- 837	
TOTAL	136,790	135,915	875	.64%

*FY 79, FY 80 DARCOM AMCRP-127 Report

Using all data through FY 79, quarterly forecasts are made through FY 84, shown in Table 2 and illustrated by the dotted line in Figure 4. Note that a property of this type model is convergence to a mean value the further in time one attempts to forecast. This appears reasonable when it is recalled that after six quarters into the future all points used in the model are estimates, which have undergone a filtering process to achieve stationarity. Nonetheless, the model still appears to give very good results two years into the future and can be easily updated each time a new data point becomes available. There is a 5.1% difference between the FY 80 forecast and the actual FY 80 total.

Table 3 shows a 75% confidence interval about the quarterly point estimates through FY 83. A 75% confidence interval is used to keep the limit points reasonable.

C. PROCEDURE FOR UPDATING PA FORECASTS.

Once a forecasting equation is developed, it is usually not necessary to refit a new model each time a new data point becomes available, provided there is no drastic change to the general pattern of the time series. The following algorithm can be used to update previously computed forecasts:

$$PA_{T+1,h} = PA_{T,h+1} + C_h (PA_{T+1} - \hat{PA}_{T+1})$$

where $PA_{T+1} - \hat{PA}_{T+1}$ equals the error made in forecasting PA_{T+1} at time T, using the estimate $\hat{PA}_{T+1}$. In other words, the forecast of PA_{T+1+h} made at time T+1 may be found by adding to the forecast of the same quantity, made at time T, a multiple of the error made in forecasting PA_{T+1} at time T. The weights C_h have been derived for the model and is found in Table 4.

TABLE 2. FORECASTS FOR QUARTERLY PA'S

FY'80		ESTIMATE	ACTUAL*	DIFFERENCE
1st Qtr	-	32,364	27,455	4,909
2nd Qtr	-	32,854	35,034	-2,180
3rd Qtr	-	39,199	36,864	2,335
4th Qtr	-	38,435	36,562	1,873
TOTAL	-	142,852	135,915	6,937

FY'81			FY'82		
1st Qtr	-	34,507	1st Qtr	-	35,621
2nd Qtr	-	34,762	2nd Qtr	-	35,753
3rd Qtr	-	38,060	3rd Qtr	-	37,468
4th Qtr	-	37,663	4th Qtr	-	37,261
TOTAL	-	144,992	TOTAL	-	146,103

FY'83			FY'84		
1st Qtr	-	36,200	1st Qtr	-	36,501
2nd Qtr	-	36,268	2nd Qtr	-	36,536
3rd Qtr	-	37,160	3rd Qtr	-	37,234
4th Qtr	-	37,052	4th Qtr	-	37,178
TOTAL	-	146,680	TOTAL	-	147,449

*FY 80 DARCOM AMCRP-127 Report

TABLE 3. 75% CONFIDENCE INTERVAL ABOUT QUARTERLY PA ESTIMATES

Time			Quantity Forecast	75% Confidence Interval
FY'80	1st Qtr	-	32,364	24,775 - - - 39,953
	2nd Qtr	-	32,854	23,545 - - - 42,163
	3rd Qtr	-	39,199	28,922 - - - 49,476
	4th Qtr	-	38,435	28,154 - - - 48,716
FY'81	1st Qtr	-	34,507	23,586 - - - 45,428
	2nd Qtr	-	34,762	23,550 - - - 45,974
	3rd Qtr	-	38,060	26,671 - - - 49,449
	4th Qtr	-	37,663	26,267 - - - 49,059
FY'82	1st Qtr	-	35,621	21,107 - - - 44,135
	2nd Qtr	-	35,753	24,191 - - - 47,315
	3rd Qtr	-	37,468	25,882 - - - 49,054
	4th Qtr	-	37,261	25,666 - - - 48,856

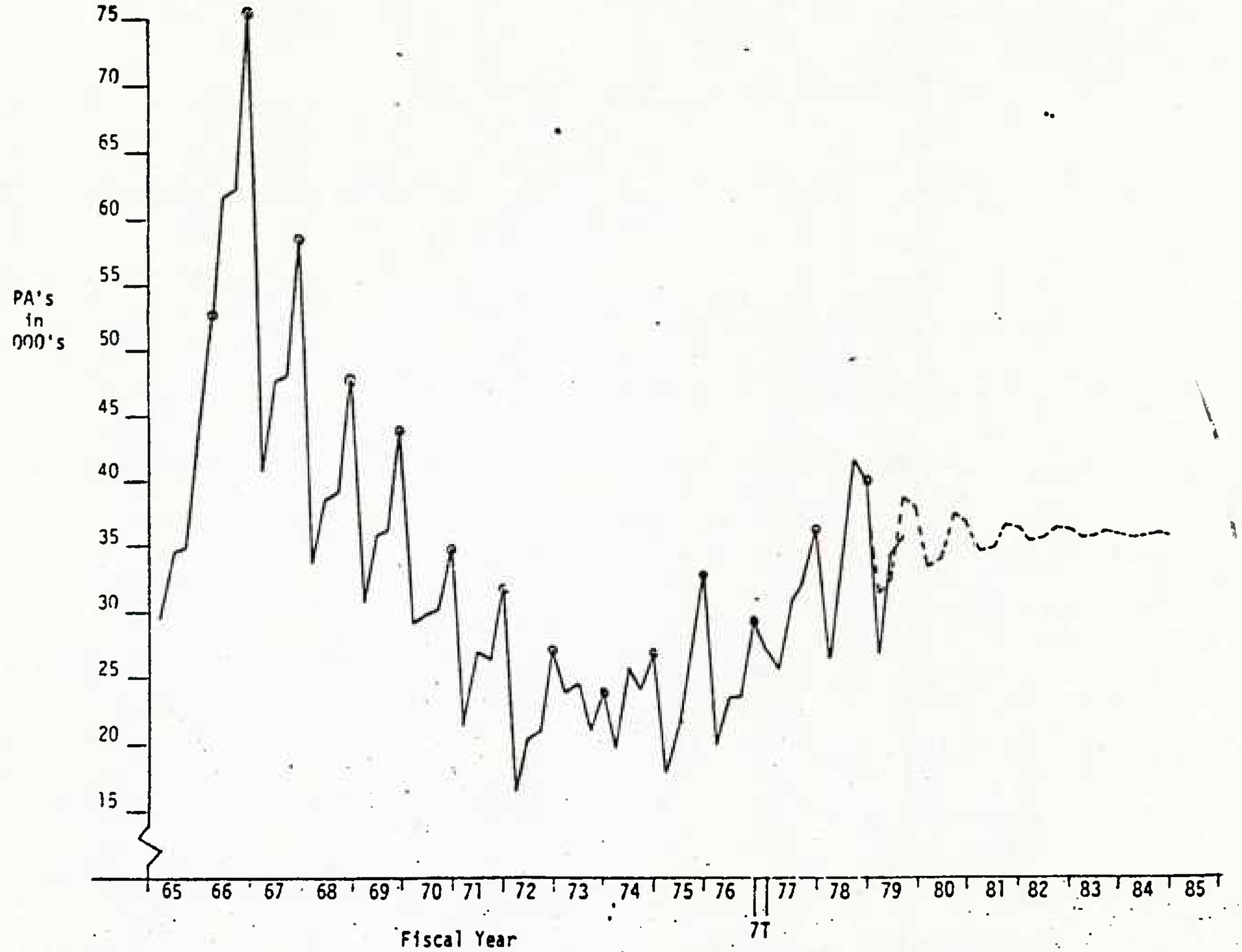

FIGURE 4. FORECASTED QUARTERLY PA DATA

TABLE 4. C_h WEIGHTS FOR QUARTERLY PA MODEL

h :	0	1	2	3	4	5	6	7
C_h:	1	0.71048	0.57384	-0.03509	0.48473	0.33423	0.26320	-0.05333
h :		8	9	10	11	12		
C_h:		0.21688	0.13865	0.10173	-0.06281	0.07765		

To illustrate the use of the algorithm the following updates are made on the FY 80 data:

FY 80 1st quarter - 27,455 actual number of PA's.

Error = $PA_{61+1} - \hat{PA}_{61+1}$ = 27,455 - 32,364 = -04,909

Updated 2nd quarter forecast is:

$$\hat{PA}_{61+1,\ 1} = \hat{PA}_{61,\ 1+1} + C_1\ (-4{,}909) = 32{,}854 + (0.71048)\ (-4{,}909) = 29{,}413$$

Updated 3rd quarter forecast is:

$$\hat{PA}_{61+1,\ 2} = \hat{PA}_{61,\ 2+1} + C_2\ (-4{,}909) = 39{,}199 + (0.57384)\ (-4{,}909) = 36{,}382$$

Updated 4th quarter forecast is:

$$\hat{PA}_{61+1,\ 3} = \hat{PA}_{61,\ 3+1} + C_3\ (-4{,}909) = 38{,}435 + (-0.03509)\ (-4{,}909) = 38{,}607$$

Similarily, more refined updates can be made when the actual 2nd quarter figure becomes available, likewise the 3rd quarter figure, etc. Table 5 gives the estimates based on an actual FY 80 first quarter number.

TABLE 5. UPDATED ESTIMATES USING C_h WEIGHTS

FY 80	UPDATED ESTIMATES	ACTUAL*	DIFFERENCE
2nd Qtr	29,413	35,034	-5,621
3rd Qtr	36,382	36,864	- 482
4th Qtr	38,607	36,562	2,045

*FY 80 DARCOM AMCRP-127 Report

CHAPTER III

MODEL USE WITH PAMUPS

A. INTRODUCTION.

In October 1977 the Comptroller General criticized the Army's progress in the area of reliable manpower staffing systems based on standards. This negative report acted as a stimulus for DARCOM to investigate the Air Force Logistics Command's "Manpower Productivity and Projection System" (E841). The E841 is an automated system which features engineered and statistical work standards assimilating complexity elements to procurement type documents. DARCOM decided to adopt and modify the E841 system concept to its procurement operations. This modified system is the Procurement Automated Manpower Utilization and Projection System (PAMUPS). PAMUPS is designed to:[6]

1. Use completed procurement milestones reflecting completed documentation as a base for building a monthly earned hour file based on engineering and statistical standards.

2. Process manpower utilization and workload projection report for procurement offices within DARCOM Readiness Commands on a demand basis from data contained in the earned hour file.

3. Process utilization and projections report for support functions by applying workload factors to manning equations.

4. Signal milestone document completion by accessing data recorded in other automated systems such as the Procurement Automated Document and Data Systems (PADDS), Acquisition Planning and Tracking Systems (APATS), and

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[6]PAMUPS briefing at HQ DARCOM, October 1979.

Commodity Command Standard System (CCSS).

5. Operate the system with no contract personnel input.

Included within PAMUPS is a complexity matrix which associates 17 types of procurement instruments with 125 complexity factors. Time standards will be incorporated into the matrix. The matrix is shown in Appendix III.

The display of the workload of a procurement directorate simply in terms of total number of procurement actions may be misleading as to the necessary manpower requirements. Whereas 500 procurement actions of one kind may be completed in one manyear, a single procurement action of another kind may require five manyears. Therefore, if the workload can be categorized by type, it yields a better explanation of the manpower required to accomplish it. This explanation is a PAMUPS objective. PAMUPS is planned to be in operation by May of 1982.

B. <u>INTEGRATION OF MODEL WITHIN PAMUPS</u>.

As noted earlier PAMUPS does not contain a way to forecast future workload but simply records present workload. In order for PAMUPS to project workload and manpower requirements a projection scheme must be placed in the system.

The procurement action forecasting model developed in this study is a vehicle by which the workload projection can be accomplished. The model uses 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 (introduction of new weapon system, large cut in defense spending), then it can be evaluated, analyzed and included into the projection. Figure 7 illustrates how the workload model can be integrated within PAMUPS.

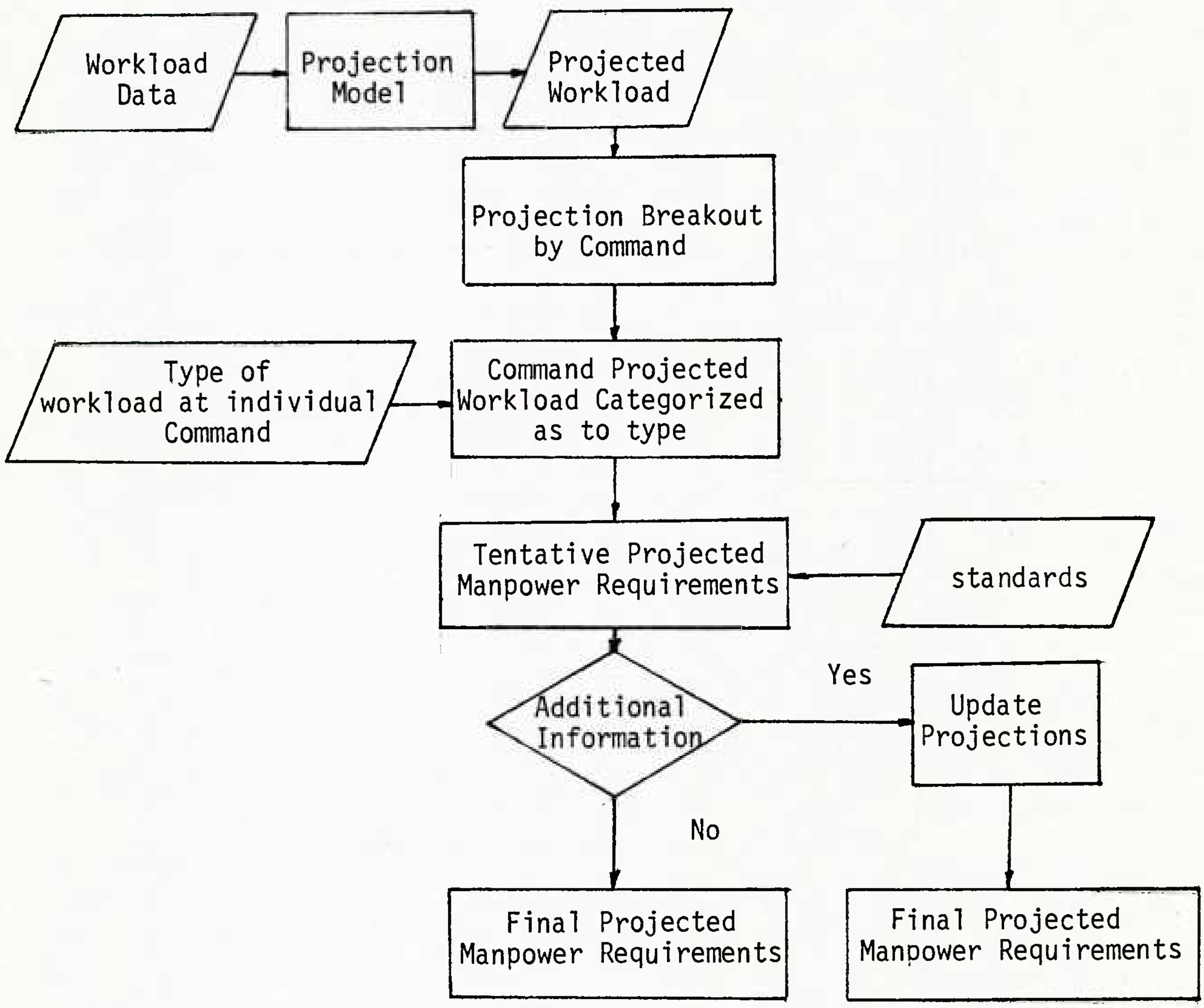

FIGURE 5. SYSTEM INTEGRATION

The model in this study forecasts total accumulated procurement actions for all of DARCOM, but not the procurement actions for each individual subordinate command. One way in which this model can be used to make forecasts about the individual subordinate command would be as follows:

1. Record what percentage of the total number of DARCOM Procurement Actions (PA's) 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.

Using the above concept, Table 10 gives a forecast of the total number of actions each subordinate command may expect for FY 80 through FY 82 based on the forecasts generated by the time series model of this study.

TABLE 6. FORECASTS OF EXPECTED NUMBER OF PROCUREMENT ACTIONS BY COMMAND

COMMAND	AVERAGE PERCENTAGE	FY 80	FY 81	FY 82
ARRADCOM	3.60	5,143	5,220	5,260
ARRCOM	17.14	24,485	24,852	25,042
AVRADCOM	.91	1,300	1,319	1,330
CERCOM	9.22	13,171	13,368	13,471
CORADCOM	1.41	2,014	2,044	2,060
ERADCOM	7.04	10,057	10,207	10,286
MERADCOM	7.32	10,457	10,613	10,695
MIRADCOM	2.78	3,971	4,031	4,062
MIRCOM	16.63	23,756	24,112	24,297
TARADCOM	.72	1,028	1,044	1,052
TARCOM	16.43	23,471	23,822	24,005
TSARCOM	12.83	18,328	18,602	18,745

Table 7 shows the comparison of the FY 80 forecast to actual FY 80 values.

TABLE 7. COMPARISON OF FORECAST TO ACTUAL PROCUREMENT ACTIONS BY SUBORDINATE COMMANDS FOR FY 80

COMMAND	FY 80 FORECAST	ACTUAL FY 80*	DIFFERENCE
ARRADCOM	5,143	7,547	-2,404
ARRCOM	24,485	21,956	2,529
AVRADCOM	1,300	1,304	- 4
CERCOM	13,171	15,212	-2,041
CORADCOM	2,014	1,977	37
ERADCOM	10,057	11,428	-1,371
MERADCOM	10,457	12,781	-2,324
MICOM**	27,727	24,873	2,854
TACOM**	24,499	20,313	4,186
TSARCOM	18,328	14,064	4,264

*FY 80 DARCOM AMCRP-127 Report

**MICOM and TACOM FY 80 forecasts are the sum of MIRADCOM and MIRCOM, and TARADCOM and TARCOM, respectively.

The PAMUPS matrix will record the number of manhours associated with those instruments which result in actions. Using the forecast, 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 manhours. Figure 8 illustrates the above concept.

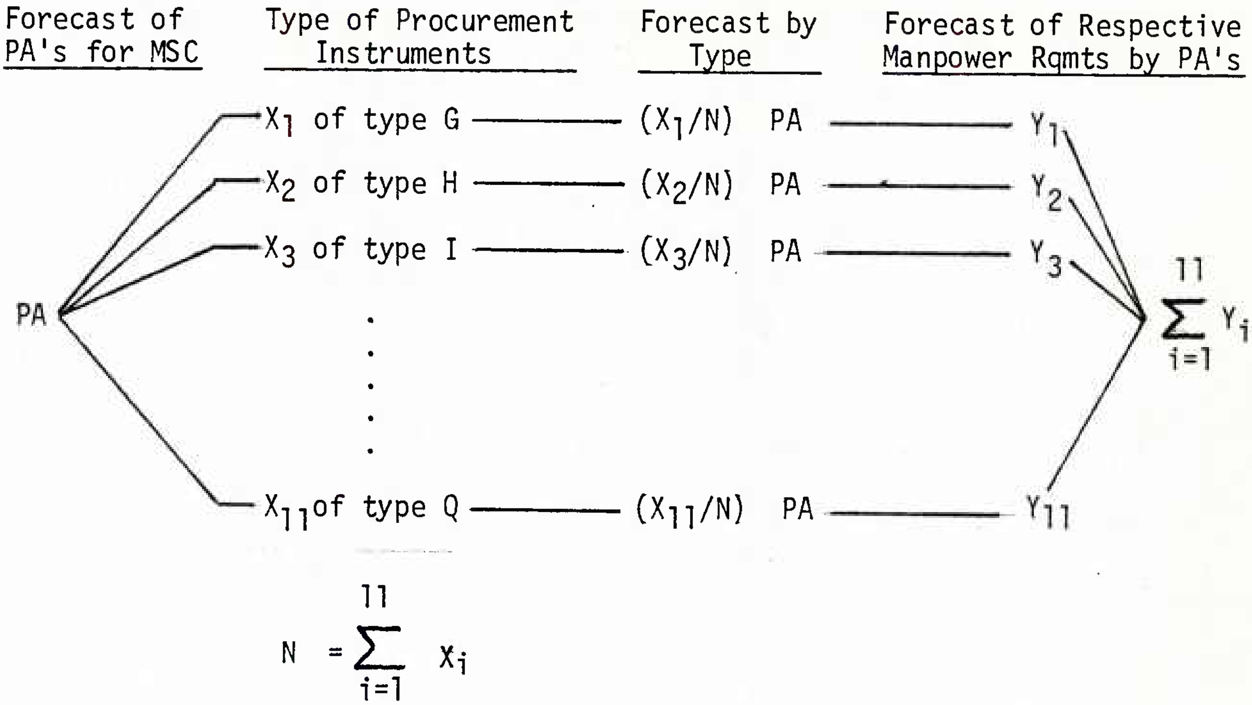

FIGURE 6. FORECASTING NUMBER OF PROCUREMENT ACTIONS BY TYPE

Since PAMUPS is designed for use within each major subordinate command, it would be more efficient if each command developed its own forecasting model within the PAMUPS system. Due to the continuing reorganization which has gone on within DARCOM, there was not enough data to consider a time series model using Box-Jenkins for each individual command. However, MIRADCOM and MIRCOM have merged as have TARADCOM and TARCOM, returning to MICOM and TACOM, respectively. It is possible that time series models using Box-Jenkins can be developed at these commands. Since the technique has given good results for the aggregate of procurement actions throughout all DARCOM, the same may be true at certain subordinate commands and should be considered.

C. BREAKOUT OF PA'S TO OVER AND UNDER $10,000.

Small purchases were reclassifed in August 1974 from equal to or under $2,500 to equal to or under $10,000. Due to this classification there are not enough data points to apply the Box-Jenkins technique to the time series for small purchases. However, small purchases have averaged 83% of the total number of procurement actions for the last five years. Using this mean value of 83% , applied to the annual forecastss, a breakout of under and over $10,000 can be made through FY'84. Table 12 shows this breakout.

TABLE 8. FORECAST - BREAKOUT OF PROCUREMENT ACTIONS AS TO SMALL PURCHASES

YEAR	LESS THAN OR EQUAL TO 10K	OVER 10K
FY'80*	118,567	24,285
FY'81	120,343	24,649
FY'82	121,265	24,838
FY'83	121,744	24,936
FY'84	122,383	25,066

*FY'80 DARCOM AMCRP-127 Report

Actual number of PA $\leq$ 10K is 111,111, a difference of 7,456 or 6.7%.

PA $\geq$ 10K is 24,804, a difference of 519 or 2.1%.

CHAPTER IV

FINDINGS AND RECOMMENDATIONS

A. GENERAL.

There is a continuing need to pursue methods which will give DARCOM management a credible, effective and reliable way to better forecast its resource needs. In a period when the Government is trying to curb inflation by reduced spending, federal agencies need to examine the most efficient techniques available to forecast what resources are required to handle future workload.

Previous model building has centered around regression techniques where causal effects were examined. This study has investigated a relatively new univariate time series technique, Box-Jenkins, to use in developing models to forecast procurement workload.

B. FINDINGS.

1. Forecasting models applying the Box-Jenkins technique to a time series of quarterly procurement actions from FY'65 to FY'79 give good estimates of future procurement actions. The forecasts of total PA's for FY'80 was within 5.1% of the actual figure (142,852 to actual of 135,915). A regression model presently in use by DARCOM Headquarters forecasted 150,304 procurement actions for FY'80, a 10.6% error.

2. The convergence property of the time series model limits its use in long range forecasting (over three years). However, this property does provide a good mean value from which revised estimates can be made based on special information and expert opinions. After all, a forecasting model provides an objective method of giving an estimate, but judgment in conjunction with insight, and subjective information about the particular problem at hand, may be supplemented.

3. The time series model can be used to forecast the expected number of procurement actions for the individual subordinate commands, and hence used to project workload for use within PAMUPS.

4. If Readiness and Development Commands merge (such as MIRCOM and MIRADCOM and TARCOM and TARADCOM have done), it is feasible individual time series models using Box-Jenkins may be developed at each command to be used directly within PAMUPS.

5. The time series model developed in this study only forecasts total number of procurement actions and can give an expected breakout as to the number of actions under and over $10,000. Other than the expected dollar breakout the model does not distinguish the projected workload as to type.

C. RECOMMENDATIONS.

Based on the results of this study the following recommendations are made:

1. Headquarters DARCOM should adopt this model to assist them in procurement workload forecasts.

2. DARCOM should employ the Box-Jenkins technique to develop forecasting models at the Readiness Commands for use within PAMUPS.

3. To continually improve the model DARCOM should update it as new data becomes available.

4. Future research should be undertaken to introduce a means of incorporating subjective estimation methodology to make the model more responsive to changes in policy and national/international occurrences.

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APPENDIX I

MODEL DEVELOPMENT THEORY

A. Introduction:

One method used to predict future movements of a variable is to relate it to a set of other variables in a cause and effect connection. Using this method the variable under study (dependent) is explained by a single function (linear or nonlinear) of explanatory variables (independent). The equation developed is usually time dependent so that a prediction of the response over time of the dependent variable can be made in relation to changes in one or more of the explanatory variables. Models developed through the investigation of causal or explanatory relationships are often known as regression or explanatory forecasting models. The extent of the relationship between the variables in the model is measured by the correlation coefficient.

In contrast to explanatory forecasting, time series models are not built by relating the variable of interest to a set of other variables in a causal framework. Instead the past behavior of the variable over time is examined in order to infer something about its future behavior. An observed series is considered as a sample of some theoretical random process, and the objective of time series analysis is to make inferences about the properties of the random process based on the information contained in the observed series. A model is constructed from the data which hopefully has properties similar to those of the generating mechanism of the random process. The data is described by some 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 of the series. This relationship is measured by the coefficient of autocorrelation.

B. Time Series Analysis.

In order to select a proper model, the characteristics of a time series need to be studied. Identifying characteristics such as stationarity, and seasonality, requires time series analysis utilizing the autocorrelation coefficients of the variable to be forecasted.

1. Autocorrelation.

The simple correlations between Y_t and Y_{t-1}, Y_t and Y_{t-2}, or any Y_t and Y_{t-k}, that is correlations of the same (auto) variable, but different time periods, are called autocorrelations. Hence, the autocorrelation of Y_t and Y_{t-k} indicates how Y_t and Y_{t-k} relate to each other. If the time series is completely random then the correlation between Y_t and Y_{t-k} would be close to zero, since each value of the time series would be unrelated to other values. However, if the autocorrelation between Y_t and Y_{t-k} show a value close to $\pm$ 1 then a relationship exists. The autocorrelations of time periods is used to learn whether the data is random, stationary, non-stationary, seasonal, nonseasonal and is defined as

$$r_{y_t, y_{t-k}} = \frac{\sum_{t=1}^{n-k} (Y_t - \bar{Y}_t)(Y_{t-k} - \bar{Y}_{t-k})}{S_{y_t} S_{y_{t-k}}}$$

where

$$S_{y_t} = \sqrt{\frac{\sum(Y_t - \overline{Y}_t)^2}{n-k-1}} \quad \text{and} \quad S_{y_{t-k}} = \sqrt{\frac{\sum(Y_{t-k} - \overline{Y}_{t-k})^2}{n-k-1}}$$

2. Stationarity.

A stationary time series shows no real growth or decline in the data, but only a fluctuation around a constant mean value; where as, a nonstationary series displays some sort of trend. The distribution of autocorrelation coefficients indicate the presence of stationarity or seasonality. The autocorrelation function of a stationary series drops to zero after the second or third time lag, while being significantly different from zero for time periods beyond the third lag in a nonstationary series. Note Figure 11.

Trends in a series introduce spurious autocorrelations that dominate an autocorrelation pattern. Therefore, it is important to remove the nonstationarity from the series before proceeding with any further analysis. A trend can be removed by differencing the data. For example, note the series 5, 10, 15, ..., 50 which has a linear trend. Subtracting consecutive values, 10-5, 15-10, 20-15, . . ., 50-45, gives as the first difference, the series 5, 5, 5, . . ., 5 which is certainly stationary. If the first differences are still nonstationary then a second difference is taken and so on until the autocorrelations drop to zero after two or three time lags. Usually stationarity is achieved after a second difference. Figure 12 shows the autocorrelation function after differencing.

3. Seasonality.

Seasonality can be noted in the autocorrelation function as a pattern that repeats itself over fixed intervals of time. For example, the greatest number of procurement actions appears to occur in the fourth quarter of the fiscal year. Note the pattern of the autocorrelation function in Figure 11, where there is a consistent high positive peak every fourth lag. Such a pattern indicates the existence of seasonality. If every fourth value were not siginficantly different from the immediately preceeding or succeeding value, then it would indicate that fourth quarters one year apart are unrelated and that no consistent pattern emerges from one year to the next.

4. Fitting the Model.

Once the nonstationarity and seasonality have been removed, the remaining pattern indicates which time series model is most appropriate. If the correct model is fitted to the data then the autocorrelation function for the series residual error will exhibit complete randomness, that is, no discernable pattern of autocorrelation.

C. Box-Jenkins Forecasting Model

A model used to handle nonstationary time series is an autoregressive-integrated moving average (ARIMA) model. The process by which an ARIMA model is constructed and the generation of forecasts from that model is often referred to as the Box-Jenkins forecasting method.[7] The ARIMA process provides a wide class of both stationary and nonstationary models that adequately represent most time series encountered in practice. Basically, the objective of the Box-Jenkins technique is to reduce any series to uncorrelated random variables, u , with constant

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[7]Granger, C.W.J., and Paul Newbold, Forecasting Economic Time Series, Academic Press, 1977, p. 149.

variance σ_u^2, by applying a linear filter indicated by the data. These random variables are usually assumed to be normally distributed with mean zero and variance σ_u^2. Engineers call a sequence of random variables such as u_t, u_{t-1}, u_{t-2}, . . . a "white noise" process.

The general ARIMA model is generated from a white noise process by the use of three filtering operations: moving average filter, stationary autoregressive filter, and nonstationary summation filter. Figure 9 illustrates the filtering operations of the ARIMA models which undergoes the following steps:[8]

1. The first filter, Moving Average, takes white noise input u_t, through a transfer function θ (B), and releases it as output e_t, where

$$e_t = u_t - \theta_1 u_{t-1} - \cdots - \theta_q u_{t-q}$$

2. The second filter, Autoregressive, takes the input e_t, through a transfer function $\phi^{-1}(B)$, and releases it as output x_t, according to

$$x_t = \phi_1 x_{t-1} + \cdots + \phi_p x_{t-p} + e_t$$

3. The third filter, Nonstationary Summation, receives the input x_t, performs the summation for the differenced terms of the process to achieve stationarity, and releases it as the time series y_t, i.e.,

$$y_t = Sx_t = \sum_{j=o}^{\infty} x_{t-j}$$

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[8]Box, G.E.P., and G.M. Jenkins, Time Series Analysis, Forecasting and Control, Holden-Day, 1970, p. 12.

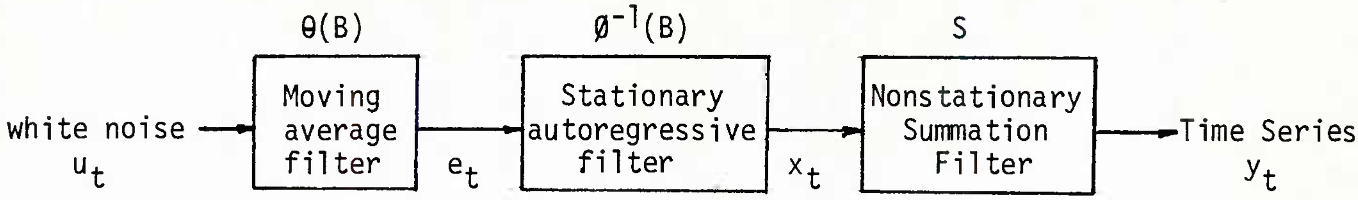

FIGURE 7. BLOCK DIAGRAM FOR ARIMA MODEL

Many empirical time series appear to be nonstationary, exhibiting no equilibrium about a fixed mean. However, they exhibit homogeneity in the sense that one part of the series behaves similar to any other part. When such homogeneous nonstationary behavior exists, then some difference of the process will be stationary. That is, when taking the difference of successive terms in a nonstationary time series, these differences form a stationary time series.

Recall, Box-Jenkins employs stochastic models of time series whose successive values are highly dependent; this means that the neighboring values of the time series are correlated. The covariance between Y_t and its value Y_{t+k}, separated by k intervals of time, is defined to be the autovariance at lag k, or

$$C_k = \text{cov}\ (Y_t, Y_{t+k}).$$

Given that the process is stationary, then the autocorrelation at lag k is

$$r_k = \frac{\text{Cov}\ (Y_t, Y_{t+k})}{\text{Variance Y}}$$

The autocorrelation function describes the behavior of stationary processes; hence the objective is to identify which terms should be in the model based on the study of the relationships between values k periods apart as measured by the autocorrelation function.

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. 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.

Figure 10 illustrates the basic steps in using the Box-Jenkins iterative methodology to building a time series model.

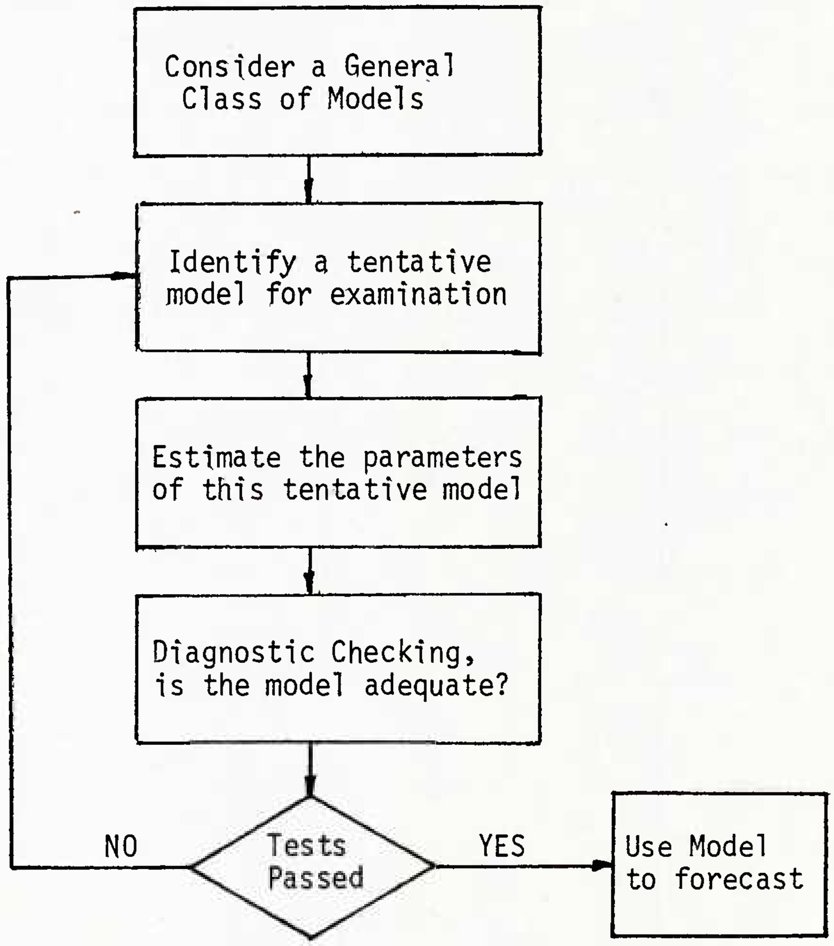

FIGURE 8. STAGES IN THE ITERATIVE BOX-JENKINS MODEL BUILDING METHODOLOGY

D. Procurement Action Model.

Figure 11 shows the autocorrelation function of the time series for quarterly procurement actions. This behavior of the function shows that the series is nonstationary and has a 4th quarter seasonal lag. Note how every fourth value does not follow the regular descending trend.

Figure 12 illustrates the function after the data has been corrected for seasonality and nonstationary, showing a significant autocorrelation only at lag 3. When all values fall within the 95% confidence limits, then the series is said to be white noise.

Figure 13 shows the function as white noise after the differenced data has gone through the autoregressive and moving average filters.

The model which best describes the quarterly PA time series is a Seasonal Autoregressive Integrated Moving Average, SARIMA (p, d, q, s), model where p, d, q, s, represent the number of autoregressive, difference, moving average, and seasonal terms respectively. These terms are p = o, d = 1, q = 3, and s = 4. Mathematically, the PA model is

$$(1-\emptyset B^4)\,(1-B)Y_t = (1 + \theta_1 B + \theta_2 B^2 + \theta_3 B^3)\, e_t$$

where B is the difference operator, that is, $B\, e_t = e_{t-1}$, $B^2\, e_t = e_{t-2}$, etc.

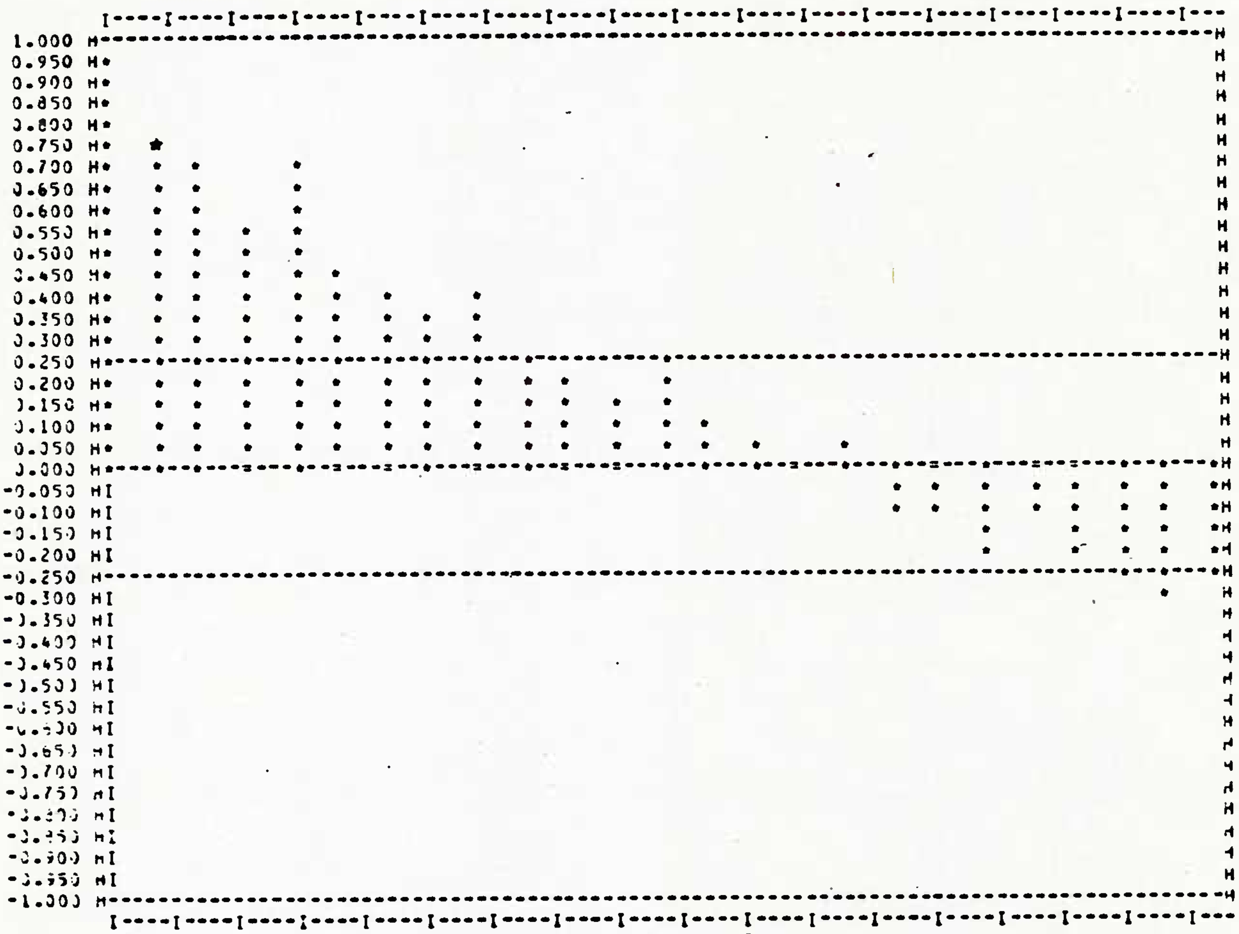

Figure 9. Autocorrelation Function for Quarterly Procurement Actions

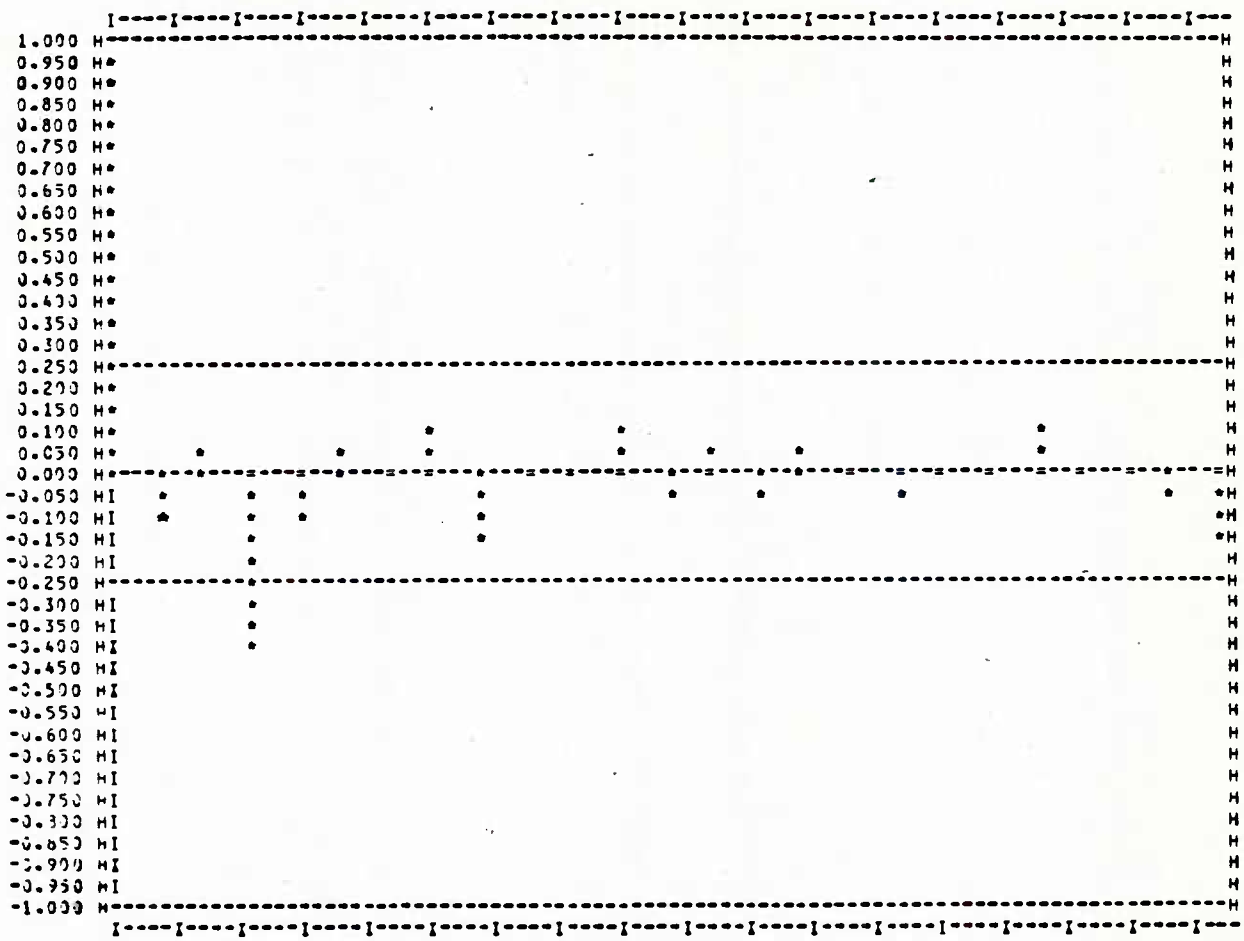

Figure 10. Autocorrelation Functions for Quarterly PA's Corrected for Seasonality and Stationarity

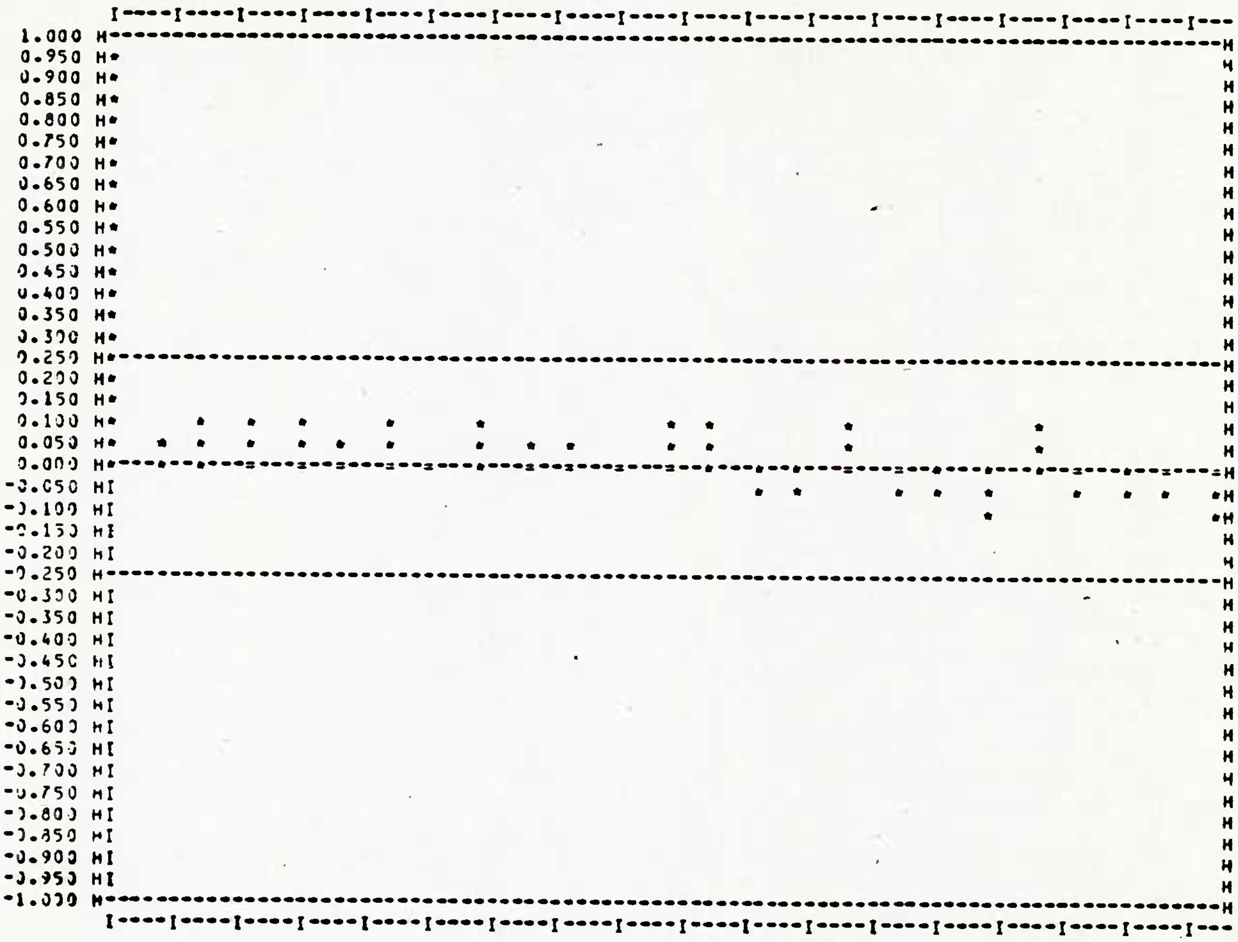

Figure 11. Autocorrelation Function Exhibiting
White Noise of PA Model

APPENDIX II

QUARTERLY PROCUREMENT ACTION DATA*

Fiscal Year	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr
65	29,689	34,701	35,027	42,567
66	52,669	61,560	62,140	75,515
67	40,686	47,555	48,002	58,334
68	33,234	38,844	39,210	47,650
69	30,600	35,765	36,102	43,873
70	28,961	29,935	30,200	34,778
71	21,245	26,765	26,286	31,412
72	16,143	19,994	20,765	26,956
73	23,874	24,503	20,626	23,528
74	19,256	25,789	23,695	26,659
75	17,842	21,299	25,741	32,728
76	19,602	23,145	23,103	29,023
7T	26,757			
77	23,011	26,394	30,259	34,565
78	25,616	30,407	32,327	35,991
79	25,962	33,436	41,390	39,920

*DARCOM AMCRP-127 Report

APPENDIX III

PAMUPS MASTER COMPLEXITY MATRIX

Appendix IV shows the most recent master complexity matrix which the DARCOM PAMUPS working group has developed. The original matrix was included in the PAMUPS Detail Functional System Requirement (DFSR), September 1979. Seventeen different procurement instruments are categorized as to complexity. There are 125 possible categories, however, not all of them apply to each procurement instrument. For example, only 25 categories of complexity apply to the first instrument, the PRON, procurement request order number.

Time standards will be listed in those areas of the table which are now blank, that is, the categories which apply to each instrument in the workflow.

COMPLEXITY FACTORS

Master Complexity Matrix

P A M U P S

TYPE INSTRUMENT		001 MAKE OR BUY DETERMINATION	002 FIXED PRICE REDTERMINATION TYPE A	003 FIXED PRICE REDETERMINATION TYPE E	004 FIXED PRICE REDETERMINATION OTHER	005 FIRM FIXED PRICE	006 FIXED PRICE WITH E.P.A.	007 FIXED PRICE INCENTIVE (WITHOUT PERFORMANCE)	008 FIXED PRICE INCENTIVE (WITH PERFORMANCE)	009 COST PLUS AWARD FEE	010 COST TYPE	011 COST SHARING TYPE	012 COST PLUS FIXED FEE	013 COST PLUS INCENTIVE FEE (WITH PERFORMANCE)	014 COST PLUS INCENTIVE FEE (WITHOUT PERFORMANCE)	015 TIME AND MATERIALS	016 LABOR HOUR	017 NO COST	018 SUPPLY CONTRACTS AND ORDERS	019 RESEARCH AND DEVELOPMENT CONTRACT
PRON	A		////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////		
PAN	B		////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////		
IFB	C	////	////	////	////			////	////	////	////	////	////	////	////	////	////	////		
RFP	D	////																////		
RFQ	E	////																////		
BPA	F	////	////	////	////		////	////	////	////	////	////	////	////	////	////	////	////		////
CONTRACT	G	////																		
IDTC	H	////																		
FACILITIES CONTRACT	I	////																	////	////
D.O. (O/S DOD)	J	////	////	////	////		////	////	////	////	////	////	////	////	////	////	////	////		////
BOA	K	////																		
AGREEMENTS	L	////																		
LEASE AGREEMENTS	M	////																		////
PURCHASE ORDERS	N	////	////	////	////		////	////	////	////	////	////	////	////	////	////	////			
D.O.-IDTC	O	////																		////
BOA ORDER	P	////																		
MODIFICATION	Q	////																		

40

COMPLEXITY FACTORS

Master Complexity Matrix

P A M U P S

TYPE INSTRUMENT		020 SYSTEM ACQUISITION CONTRACTS	021 MAINTENANCE CONTRACTS	022 SERVICE CONTRACTS	023 LETTER CONTRACT (REQUIRING DEFINITIZATION)	024 UNPRICED BOA ORDER	025 LETTER MODIFICATION	026 CHANGE ORDER (REQUIRING DEFINITIZATION)	027 CHANGE ORDER/ADMIN. NOTICE (NO DEFINITIATION REQUIRED)	028 SUPPLEMENTAL AGREEMENT (DOES NOT DEFINITIZE CHANGE ORDER)	029 TRANSFER CONTRACT BETWEEN PURCHASING ACTIVITIES	030 TRANSFER CONTRACT BETWEEN ADMINISTERING ACTIVITIES	031 CORRECTION OF HARD COPY ERROR	032 SUPPLEMENTAL AGREEMENT (DEFINITIZES CHANGE ORDER)	033 DEFINITIZED PROVISIONED ITEM ORDER	034 UNPRICED ORDER DEFINITIZATION	035 LETTER CONTRACT DEFINITIZATION	036 PARTIAL TERMINATION NOTICE (REQUIRES DEFINITIZATION)	037 PARTIAL TERMINATION NOTICE (DEFINITIZATION CODE "P")	038 OBLIGATION ADJUSTMENT AFTER CONTRACT COMPLETION
PRON	A		////	////		////	////	////	////	////	////	////	////	////	////	////	////	////	////	////
PAN	B		////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////
IFB	C				////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////
RFP	D				////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////
RFQ	E				////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////
BPA	F	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////
CONTRACT	G					////	////	////	////	////	////	////	////	////	////	////	////	////	////	////
IDTC	H					////	////	////	////	////	////	////	////	////	////	////	////	////	////	////
FACILITIES CONTRACT	I	////	////			////	////	////	////	////	////	////	////	////	////	////	////	////	////	////
D.O. (O/S DOD)	J	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////
BOA	K	////			////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////
AGREEMENTS	L	////			////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////
LEASE AGREEMENTS	M	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////
PURCHASE ORDERS	N	////			////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////
D.O.-IDTC	O	////			////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////
BOA ORDER	P	////			////		////	////	////	////	////	////	////	////	////	////	////	////	////	////
MODIFICATION	Q					////														

COMPLEXITY FACTORS

Master Complexity Matrix

PAMUPS

TYPE INSTRUMENT		039 PROVISIONED ITEM ORDER (REQUIRES DEFINITIZATION)	040 COMPLETE TERMINATION NOTICE (REQUIRES DEFINITIZATION)	041 COMPLETE TERMINATION NOTICE (DEFINITIZATION CODE "T")	042 PROVISIONED ITEM ORDER (DEFINITIZES CODE "S" DOCUMENT)	043 EXCESS FUNDS REMOVAL (DECOMMIT AND DE-OBLIGATE)	044 ADVANCE PROCUREMENT PLAN	045 MULTIPLE PWDs	046 RESERVED	047 IN-HOUSE PWD	048 RESERVED	049 FMS	050 DA FORM 1877	051 IGCE	052 DD FORM 1423	053 ACQUISITION OF SPECIAL TOOLING	054 MULTIPLE CLINs	055 DEFECTIVE TECH DATA PACKAGE (PASS CODE 11)	056 ENGINEERING RELEASE	057 WARRANTY PROVISIONS
PRON	A	////	////	////	////	////	////	////		////		////	////	////	////	////	////		////	////
PAN	B	////	////	////	////	////						////	////		////	////	////	////		////
IFB	C	////	////	////	////	////	////			////			////	////				////	////	
RFP	D	////	////	////	////	////	////			////			////	////				////	////	
RFQ	E	////	////	////	////	////	////			////			////	////				////	////	
BPA	F	////	////	////	////	////	////			////				////	////	////		////	////	////
CONTRACT	G	////	////	////	////	////	////			////				////				////	////	
IDTC	H	////	////	////	////	////	////			////				////				////	////	
FACILITIES CONTRACT	I	////	////	////	////	////	////			////		////		////				////	////	////
D.O. (O/S DOD)	J	////	////	////	////	////	////			////			////	////		////		////	////	////
BOA	K	////	////	////	////	////	////	////		////				////		////		////	////	
AGREEMENTS	L	////	////	////	////	////	////	////		////				////		////		////	////	
LEASE AGREEMENTS	M	////	////	////		////	////	////		////				////		////		////	////	
PURCHASE ORDERS	N	////	////	////	////	////	////			////				////		////		////	////	////
D.O.-IDTC	O	////	////	////	////	////	////			////			////	////				////	////	
BOA ORDER	P	////	////	////	////	////	////			////			////	////				////	////	
MODIFICATION	Q						////			////				////				////	////	

COMPLEXITY FACTORS

Master Complexity Matrix

PAMUPS

TYPE INSTRUMENT		058 GFP/E/M	059 FACILITIES USE	060 SECTION 8a CONTRACTING	061 MOB BASE (EXCEPT CLASS D & F)	062 SOLE OR RESTRICTED SOURCE	063 ADDITIONAL OFFERS OVER 2	064 PRE-SOLICITATION NOTICES AND CONFERENCES	065 SECURITY REQUIREMENTS	066 OPTION APPROVAL	067 VALUE ENGINEERING	068 SECRETARIAL D & F	069 OTHER D & F	070 LEGAL REVIEW	071 ORAL SOLICITATION (EXCLUDING SMALL PURCHASES)	072 LOCAL SOLICITATION REVIEW BOARD	073 LOCAL CONTRACT AWARD REVIEW BOARD	074 DARCOM SOLICITATION REVIEW BOARD	075 DARCOM CONTRACT AWARD REVIEW BOARD	076 SYNOPSIS OF PROPOSED PROCUREMENT
PRON	A	////	////	////	////		////	////	////	////	////		////	////	////		////	////	////	////
PAN	B	////	////	////	////	////	////		////	////	////		////	////	////	////	////			////
IFB	C			////	////	////		////				////	////		////		////	////	////	
RFP	D			////		////		////				////	////		////		////	////	////	
RFQ	E			////		////		////				////	////		////		////	////	////	
BPA	F	////	////		////	////	////	////	////	////	////	////	////	////	////	////	////	////	////	////
CONTRACT	G					////	////	////				////				////		////	////	////
IDTC	H					////	////	////		////		////				////		////	////	////
FACILITIES CONTRACT	I		////			////	////	////			////	////			////	////		////	////	////
D.O. (O/S DOD)	J			////	////	////	////	////			////	////	////			////		////	////	////
BOA	K	////	////			////	////	////		////		////	////		////	////		////	////	////
AGREEMENTS	L	////	////			////	////	////		////		////	////		////	////		////	////	////
LEASE AGREEMENTS	M	////	////			////	////	////				////			////	////		////	////	////
PURCHASE ORDERS	N			////	////	////	////	////			////	////	////		////	////	////	////	////	////
D.O.-IDTC	O					////	////	////				////				////		////	////	////
BOA ORDER	P					////	////	////				////				////		////	////	////
MODIFICATION	Q					////	////	////				////				////		////	////	////

COMPLEXITY FACTORS

Master Complexity Matrix

PAMUPS

TYPE INSTRUMENT		077 SYNOPSIS OF CONTRACT AWARD	078 COST ACCOUNTING STANDARDS	079 GOCO CONTRACTS	080 FIRST ARTICLE TESTING REQ'T	081 SOLICITATION AMENDMENT	082 RESERVED	083 BUY AMERICAN EXCEPTION	084 FORMAL SOURCE SELECTION	085 AUDIT (BUY STATION)	086 RESERVED	087 TRANSPORTATION EVALUATION	088 PROTEST BEFORE AWARD	089 PATENT/ROYALTY PAYMENTS	090 PRE-AWARD SURVEY	091 CERTIFICATE OF COMPETENCY (BY SBA)	092 AWARD TO OTHER THAN LOW OFFEROR	093 EQUAL EMPLOYMENT OPPORTUNITY COMPLIANCE	094 CONTRACTOR MAKE-OR-BUY PROGRAM	095 PRE-BID, PRE-PROPOSAL CONFERENCE
PRON	A	////	////		////	////		////	////	////		////		////				////	////	////
PAN	B	////	////	////	////	////		////	////			////	////	////		////	////	////	////	////
IFB	C	////	////	////				////	////	////		////	////	////		////	////	////	////	////
RFP	D	////		////				////	////	////		////	////	////		////	////	////	////	////
RFQ	E	////		////				////	////	////		////	////	////		////	////	////	////	////
BPA	F	////	////	////	////	////			////	////		////	////	////	////	////	////	////	////	////
CONTRACT	G			////		////				////			////			////	////			
IDTC	H			////		////				////			////			////	////			
FACILITIES CONTRACT	I		////	////	////	////		////	////	////		////	////	////	////	////	////	////	////	////
D.O. (O/S DOD)	J	////	////	////		////		////	////	////		////	////	////	////	////	////	////	////	////
BOA	K	////		////	////	////			////	////		////	////	////	////	////	////		////	////
AGREEMENTS	L	////		////	////	////			////	////		////	////	////	////	////	////	////	////	////
LEASE AGREEMENTS	M	////		////	////	////			////	////		////	////	////	////	////	////	////	////	////
PURCHASE ORDERS	N	////	////	////		////			////	////		////	////	////		////	////	////	////	////
D.O.-IDTC	O			////		////			////	////		////	////	////	////	////	////	////		////
BOA ORDER	P			////		////			////	////		////	////		////	////	////	////		////
MODIFICATION	Q			////		////			////	////		////	////			////	////	////		////

COMPLEXITY FACTORS

Master Complexity Matrix

P A M U P S

TYPE INSTRUMENT		096 SUB-CONTRACTING PROGRAMS	097 CONGRESSIONAL NOTIFICATION	098 DD FORM 350	099 100% SET-ASIDE	100 PARTIAL SET-ASIDE	101 MULTI-YEAR PROCUREMENT	102 SURPLUS MATERIAL BUY	103 QPL VERIFICATION	104 MISTAKE-IN-BID	105 RESERVED	106 NOTICE OF AWARD	107 PROGRESS PAYMENTS	108 TRANSFER OF REQUIREMENT	109 DAR/APP DEVIATIONS	110 SPECIAL TERMS AND CONDITIONS	111 SAFETY	112 RESERVED	113 PL 85-804	114 DESIGN-TO-COST
PRON	A	////	////	////	////	////	////		////			////	////		////	////	////		////	////
PAN	B	////	////	////	////	////	////	////	////	////		////	////	////		////	////		////	////
IFB	C		////	////	////	////		////		////		////	////	////	////				////	
RFP	D		////	////				////		////		////	////	////	////				////	
RFQ	E		////	////				////		////		////	////	////	////				////	
BPA	F	////	////	////	////	////	////	////	////	////		////	////	////	////		////		////	////
CONTRACT	G							////	////	////				////	////				////	////
IDTC	H							////	////	////				////	////				////	////
FACILITIES CONTRACT	I	////	////	////	////	////	////	////	////	////		////	////	////	////				////	////
D.O. (O/S DOD)	J	////	////		////	////	////	////	////	////		////	////	////	////				////	////
BOA	K	////	////	////	////	////	////	////	////	////		////	////	////	////				////	////
AGREEMENTS	L	////	////	////	////	////	////	////	////	////		////	////	////	////				////	////
LEASE AGREEMENTS	M	////	////	////	////	////	////	////	////	////		////	////	////	////				////	////
PURCHASE ORDERS	N	////	////	////		////	////	////	////	////		////	////	////	////				////	////
D.O.-IDTC	O						////	////	////	////		////		////	////				////	////
BOA ORDER	P						////	////	////	////		////		////	////				////	////
MODIFICATION	Q		////				////	////	////	////		////		////	////					////

COMPLEXITY FACTORS

Master Complexity Matrix

P A M U P S

TYPE INSTRUMENT		115 LIFE-CYCLE COSTING	116 TECHNICAL COMPETITION	117 DEFECTIVE PRICING	118 DD FORMS 1499/1500	119 MANUAL SOLICITATION AND/OR AWARD	120 WAIVER FROM MANDATORY SOURCE	121 PERSONAL SERVICES DETERMINATION	122 CANCELLATION OF REQUIREMENT	123 ADMINISTRATION BY PCO	124 PROVISIONING	125 PRICING	126	127	128	129	130	131	132	133
PRON	A	////	////	////	////	////		////		////	////	////								
PAN	B	////	////	////	////	////	////	////		////	////	////								
IFB	C			////	////		////	////		////	////	////								
RFP	D			////	////		////	////		////	////	////								
RFQ	E			////	////		////	////		////	////	////								
BPA	F	////	////	////	////		////	////	////		////	////								
CONTRACT	G	////	////	////			////		////											
IDTC	H	////	////	////			////		////		////									
FACILITIES CONTRACT	I	////	////	////	////		////	////	////		////	////								
D.O. (O/S DOD)	J	////	////	////	////		////	////	////		////	////								
BOA	K	////	////	////	////		////	////	////		////	////								
AGREEMENTS	L	////	////	////	////		////	////	////		////	////								
LEASE AGREEMENTS	M	////	////	////	////		////	////	////		////	////								
PURCHASE ORDERS	N	////	////	////	////		////	////			////	////								
D.O.-IDTC	O	////	////	////			////		////		////	////								
BOA ORDER	P	////	////	////			////		////		////									
MODIFICATION	Q	////	////				////		////		////									

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UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)

US Army Logistics Management Center
US Army Procurement Research Office
Fort Lee, Virginia 23801

2a. REPORT SECURITY CLASSIFICATION

UNCLASSIFIED

2b. GROUP

3. REPORT TITLE

Central Procurement Workload Projection Model

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final - Nov '79 to Feb '81

5. AUTHOR(S) (First name, middle initial, last name)

Charles A. Correia

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
February 1981	47	7

8a. CONTRACT OR GRANT NO.

b. PROJECT NO. N/A

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

80-04

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Approved for Public Release; Distribution Unlimited

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY

Office of the Assistant for Analysis
Directorate for Procurement & Production
HQ, DARCOM; Alexandria, VA

13. ABSTRACT

A Seasonal Autoregressive Moving Average model is developed to forecast the total number of procurement actions awarded each quarter by DARCOM procurement. Quarterly data from fiscal year 1965 to 1979 is analyzed in the development of the time series model. Quarterly forecasts are made through fiscal year 1984. An illustration of how the model may be integrated into DARCOM's new Procurement Automated Manpower Utilization and Projection System (PAMUPS) is presented.