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# BuPers PCS Expenditure Estimating Final Report

KFR 167-78

31 March 1978



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Contract Number N00014-77-0681



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A preliminary investigation was made to ascertain whether the Naval Manpower pay account for Permament Change of Station expenditures could be statistically modelled. The report includes: a description of the PCS planning and execution process, analysis of nine months of data concerning reservations, obligations and expenditures, an explanation why time series analysis is not practicable, a theoretical statistical model for the prediction

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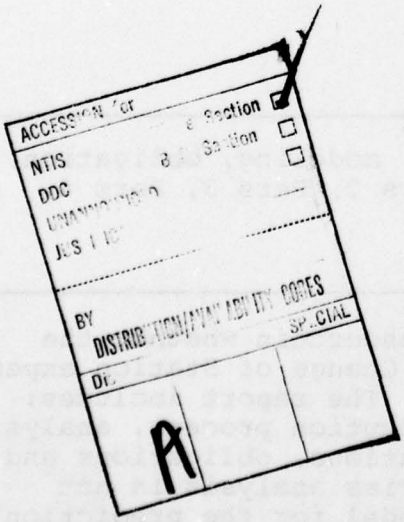
20. ABSTRACT (Cont.)

of expenditure and a recommendation for further research. The conclusion of the study was that PCS expenditure could be successfully modelled when enough data was on hand to be sure of statistically valid results.



# EXECUTIVE SUMMARY

The ultimate objective of this study effort is to provide the Bureau of Naval Personnel with improved means of forecasting PCS expenditures. This analysis constitutes a preliminary examination of the PCS account designed to document the management procedures currently in effect and to explore the potential for modelling it statistically.

Forecasts of expenditures in this account are currently generated within BuPers. These forecasts are, however, point estimates. There is currently no mechanism for estimating the size or form of the random fluctuations which occur in expenditures. This is of vital concern to management since unplanned fluctuations can cause inadvertent overexpenditure.

One method of coping with such a situation is to develop a time series model. Ketron, Inc. developed such a tool to assist BuPers in forecasting future expenditures in pay and allowances as a function of prior expenditures and obligations. This model provides not only a point forecast but also the residual error distribution, thus enabling management to tailor a reserve fund to a desired probability of not overexpending.

Essential to this type of modelling and estimation is access to data which allows comparison of bureau estimates (forecasts) and actual outcomes (expenditures) over time. Such data were available for pay and allowances but is not available in adequate quantity or quality for PCS.

The major difficulty presented by PCS data is that expenditures occur over an extended time frame. Thus, to compare forecasts with outcomes, expenditure data which are identified both to time of expenditure and to time of obligation are needed. Such data are currently available only for nine months and are largely incomplete even for that time frame. Even if this data were complete, at least a three year record would be required for time series forecasting. A time series model of the form used for pay and allowances is based

on the assumption that forecasts predict expenditures except for some residual unpredictable randomness. It is, therefore, essential that a specific expenditure be related only to the obligation which forecast it, otherwise the model makes no sense. Since such data do not exist for PCS, a time series model is not possible at this time.

It would seem desirable to have a means of forecasting the time distribution of expenditures. It should be emphasized that this is not necessary for purposes of financial control, since the issue there is control of the total expenditure over the life of the authorization. Its primary value would be in providing a means for introducing inflation effects in a more realistic way by apportioning then appropriately over time. A model is developed for this purpose in the report. There are again insufficient data to completely validate it. It is recommended that validation be undertaken as the data become available.

When sufficient data have been generated, time series modelling should be undertaken. There is reason to conjecture, however, that PCS data can be modelled and forecast much more simply than was the case with pay and allowances. Serial correlation was natural in month to month obligations and expenditures in BA1 and BA2 given the stable size of the military payroll. This is probably not the case with PCS, since obligations and expenditures relate solely to periodic transfer decisions which may in fact be statistically independent. Secondly, it should be kept in mind that the variable of interest for financial control is not the month to month expenditure stream, which is quite complex, but the total over 36 months of expenditures generated by one month's obligation. Thus, simple linear regression of total expenditures generated by a given month obligation on obligations would seem to be a sensible first cut approach. Analysis of residuals will then indicate whether a more sophisticated approach is warranted. We recommend that Pers 3 initiate such regression calculations on the partial expenditure data for preliminary analysis pending the assembly of a complete data set.

In addition, a statistical evaluation of existing bureau estimators would be extremely valuable and should be undertaken. These estimators are Bureau estimates of wage costs generated when orders are written and Travel Information Cards prepared by the service member which detail his moving plans. We recommend that a random sample of actual, realized move costs be drawn for comparison with both of these estimates to determine their statistical reliability.

## PREFACE

We are sincerely grateful for the assistance of the following BuPers personnel: Mr. Dan Corcoran, LCDR William Henry, LCDR Martin Mayer, Mr. Eulis Pratt, LCDR J.E. O'Neil, and Mr. Edward Timko.

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# INTRODUCTION

The ultimate objective of this study effort is to provide BuPers with improved means of forecasting PCS expenditures. This analysis constitutes a preliminary examination of the PCS account designed to document the management procedures currently in effect and explore the potential for statistical modelling.

Forecasts of expenditures in this account are currently generated within the bureau. These forecasts are, however, point estimates. There is currently no mechanism for estimating the size or form of the random fluctuations which occur in expenditures. This is of vital concern to management since unplanned fluctuations can cause inadvertent overexpenditure.

This study proceeds along the following lines. First the PCS planning and expenditure process is described in qualitative terms. The available data on PCS reservations, obligations and expenditure are then analyzed. Finally, four separate attempts at modelling are outlined. The first, using time series analysis, failed because of inadequate data; the reasons for failure are analyzed. The second, a tentative graphical model, provides insight into expenditure patterns. Refinement potential is discussed. The third and fourth are theoretical statistical models which successfully describe the the data, although validation awaits compilation of an adequate data base.

## PRESENT PCS PROCEDURES

### THE PCS ACCOUNT

The Bureau of Naval Personnel's Permanent Change of Station Program (PCS), also known as Budget Activity (5), has for years been a difficult account to administer, requiring a far greater proportion of managerial effort than its percentage share of the Navy's manpower budget would suggest. The PCS account is used to pay the travel and transportation expenses of active Navy personnel and their dependents when they move from one permanent duty station to another. It ranges in size from approximately $320 million per year.

Management of the PCS account is difficult because of the lags which occur between the time money is "reserved" for expenditure and when the expenditure is finally incurred. That is, varying periods of time can pass from the point at which the cost of a PCS move is first estimated and that sum of money is set aside, and the point at which the actual cost of the move is reported. The actual costs can vary considerably from those which were estimated, so that BuPers personnel charged with monitoring expenditure cannot be sure if the account is being depleted too rapidly, if funds are moving according to plan, or if money is being spent too slowly.

These lags result from a number of causes. First, orders are issued long before they are executed. Second, when a member executes his orders, he does not necessarily claim all his moving rights immediately. Thus, certain expenditures attached to his move may occur at a much later date. Finally, there are lags inherent in the expenditure processing cycle of the system, such as carriers not submitting bills promptly for services rendered. These lags can result in a delay in reporting the expenditures back to BuPers.

PCS differs from other budget activities in the Navy manpower pay system in that it has historically been designated a "Congressional Interest Item". This means that no money can be programmed into or out of BA(5) without Congressional approval. Thus, if some unforeseen event takes place which requires a large number of additional PCS moves, BuPers must either request permission from the Congress to shift

funds into PCS from another budget activity, or else cut back on certain "discretionary" moves which it had planned. This designation increases the importance of correct expenditure prediction, since correction of errors becomes more difficult under the circumstances it imposes.

The PCS account is comprised of six categories, each of which is described below.

1. Accession moves: These refer to all movement undertaken by a military member from entering the Navy, through training, to his first permanent duty station.

2. Separation moves: These refer to the movement from departure of last official duty station to the member's determined place of residence.

3. Organized unit moves: When a ship or aircraft squadron is switched permanently from one base to another, the expenses incurred in moving dependents and members who cannot be accommodated aboard the unit's organic transport are paid from PCS.

4. Operational moves (OPS): Operational moves are moves of members from one duty station to another within CONUS or from one geographical location to another when no transoceanic travel is involved.

5. Rotational moves (ROTS): These moves involve the transfer of members to and from overseas stations. These can be either from or to CONUS, or from one overseas post to another, as long as transoceanic travel is involved.

6. Training moves (TRA): PCS funds pay for all travel and transportation costs to training courses when the instruction will last for more than twenty weeks.

When undertaking a PCS move, a military member has the legal right to exercise a number of different entitlements, dependent upon the member's pay grade and length of active duty service. They include such things as movement of dependents, household goods, and privately owned vehicles and a dislocation allowance. Members do not necessarily

use all the entitlements to which they have a right, which introduces an element of uncertainty when the cost of a move is estimated. Generally, members most often exercise their entitlements during the summer months, causing a definite trend in the outlay of expenditures. That is, when the fiscal year began on 1 July, a large amount of expenditures occurred at the beginning and end of the fiscal year. However, with the new start date of 1 October of each year, the highest number of expenditures now occurs during the last quarter of the year.

As with the other budget activities in the Navy manpower pay system, BA(5) remains "active" for three years. During the first fiscal year expenses incurred on PCS moves must be paid out of the money which Congress has specifically set in BA(5). After the first fiscal year closes, the liability is expanded to the entire Navy pay (MPN) account and is not limited to any specific budget activity. Following the end of the third fiscal year, the balance remaining in the account, representing unliquidated obligations*/ less reimbursements to be collected, is transferred to the "M" account. For example, if a PCS order is issued in Fiscal Year 1976, and a bill incurred because of it comes in during FY 76, it must be paid out of PCS funds allocated for that year; if it comes in during either FY 77 or FY 78, it must be paid out of the funds remaining in the entire FY 76 MPN account; and if it comes in after FY 78, it comes from the general 76 pool held in the "M" account.

Although almost all of the other obligations incurred during the fiscal year in the MPN account are also liquidated during that same year, PCS differs from the norm. In many cases, a PCS obligation is not liquidated until the second or third fiscal year after an order for a move was issued. For instance, a member might be entitled to move a dependent but not choose to do so until some time after he has moved to his new duty station. The dependent's moving expenses will be paid from funds obligated during the month of his detachment. In fact, the member can elect to use any of his entitlements at any time during his stay at the assigned duty station. One example of a case occurs when a child is left behind to finish schooling.

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*/ An obligation is an estimated dollar amount set aside at one point in the PCS process prior to the actual receipt and payment of bills. The section entitled "The Movement Ordering Process" will discuss obligations in greater detail.

The PCS fund controls two types of monies. Those given to BuPers by Congress are known as "direct availability" funds: they form the vast majority of funds in the budget activity, and are held according to the rules described immediately above. A small portion of the total "gross availability" in PCS is composed of "reimbursable availability". These are funds given BuPers by the Comptroller of the Navy to provide services to other government agencies on a reimbursable basis, as when a member of the Navy is assigned to duty with another agency. BuPers pays the member's pay and entitlements during the assignment, included in which are the cost of moving the member, his dependents and his property. During the assignment, BuPers requests reimbursement from the other agency; reimbursements are calculated at a certain "composite rate" for each month the member spends at the agency. Office of the Secretary of Defense regulations set the composite rate for each military service.

PCS ACTORS IN BUPERS

Several different portions of the Bureau of Navy Personnel cooperate in the planning, execution and monitoring of the Permanent Change of Station Account. Pers 223 is the Program Manager who oversees the determination of move requirements for the six move categories, allocates funds once they are appropriated by Congress, and monitors the account as it is executed. Pers 3 is responsible for the financial management of BA(5); among the groups under his control is the PCS Variance Analysis Division (PCS VAD) which develops and stores the statistical files used to cost the PCS requirements generated by Pers 223. Detailers under the command of Pers 4 or Pers 5 are the last members of BuPers who are directly concerned with PCS; they set aside the reservations (see below) intended to pay for OPS, ROTS, and TRA moves. One of Pers 223's duties is making the reservations for the other three categories. Only Pers 3 and his staff are directly concerned with expenditures; the others' duties center on the movement of personnel.

The amount of control which BuPers can exert over the number of moves in each category varies. Accession, separation and organized unit moves are all termed "mandatory"; that is, the Bureau is obligated by plans made by higher authority in these categories to make

these moves. The other three categories are called "discretionary" because BuPers can increase or decrease activity in each to varying degrees according to the dictates of necessity. For instance, should PCS expenditures be running well ahead of what was planned for a given fiscal year, the Bureau can cut back moves in any or all of the last three categories as necessary to keep within the limits of the budget. It could not readily alter any of the first three.

PCS BUDGET PLANNING

The PCS budget planning process begins with Pers 223. Using a variety of models, and OPNAV directives for organized unit moves, he creates an initial set of "requirements" for PCS moves which are expressed in the number of personnel who are to change their station permanently. The requirements for each of the six move categories are determined in the following manner:

- For accessions and separations (Categories 1 and 2) the requirements for enlisted personnel are obtained from a series of projection models called the ADSTAP (Advancement, Strength and Training Plan) models. These models predict the number of losses to the force that are expected for a given budget year, conversely determining the number of accessions that are necessary to meet end strength authorization. For officers, the requirements for these two categories are projected by a computer model known as NOPPS-2, (Naval Officer Personnel Planning System). It does not give as extensive a projection as ADSTAP does for enlisted personnel.

- The requirements for organized unit moves are developed by Mission Sponsors in OPNAV. These requirements are for the number of changes of home port that are necessary for fleet realignment or a ship overhaul.

- The PRD model is used to determine the requirements for the remaining three categories of operational moves, rotational moves and training moves. This simulation model projects the total number of vacancies that will occur and then, using historical factors, it determines a breakdown into these three categories. The historical information is based primarily on data from the previous fiscal year.

The PRD model also has factors which relate to cost/no cost moves. Pers 3 budget analysts use this information from the model for costing purposes.

In the past few years, little use has been made of the PRD model to estimate requirements for the non-fenced category moves. This has resulted because of constraints placed on the total PCS program. It has been decided by OSD authority that a 3% cut per year should occur in the PCS budget up to a 10% decrease by 1980. Therefore, the program for a given year has recently been determined by taking the previous year's program, adding in price increases and deducting 3% of the total.

Once Pers 223 has developed the requirements, they are sent for costing in Pers 311. Pers 311 costs the PCS requirements by means of a price "base". The base establishes ratios of the number of military members who will exercise an entitlement to the number of all members with those same characteristics who will be making PCS moves during the fiscal year for which plans are being made. These ratios are determined by PCS VAD from data contained on Travel Information Cards (TICs) received from the previous period. Military members use TIC's to inform PCS VAD of their intentions on exercising -- or not exercising -- entitlements during a PCS move. Since return of a TIC is voluntary, PCS VAD receives them for 75-80 percent of all PCS moves; this average figure varies from that which is obtained in the individual move categories. For instance, a considerably lower percentage of TICs come in for separation moves. In establishing the ratios, it is assumed that the group which does not submit TICs exercises its entitlements in the same proportions as does the group which does send in the cards. Data from the TICs supplies the percentages of moves in each category according to pay grade, number of dependents and entitlement claims. With these percentages Pers 31 budget analysts can compute expected costs for the requirements in each move category.

Because the present means of determining a base depends on an accurate representation of all the obligations for a given year by the sample of TIC cards received, Pers 3 and PCS VAD personnel

have begun to depend on past expenditure data and past actual obligations. This has become a feasible alternative because expenditures are now being reported with the social security number of the member for which the expenditure was made. It is also planned that a twelve to fifteen month moving average will be used so that the base will always be developed from the most recent complete data.

The base is frequently updated by personnel under Pers 3, including those in PCS VAD. Updating occurs for each step in the annual cycle in which the manpower budget moves up the Navy, DOD and the Executive Branch hierarchy to the Congress.

Once the total cost for the PCS program is developed, it must then be compared to dollar limitations imposed by higher authority. These constraints come from OP-90 (Navy Program Planning Office), OP-92 (Navy Fiscal Management Division and Navy Comptroller) and the Office of the Secretary of Defense. The program requirements must be reduced by the Program Manager if the costs are too high.

The Program Manager is restricted somewhat in how he can adjust the program when the costs exceed dollar constraints. The first three categories are "fenced" items, meaning that the requirements are mandatory moves and therefore cannot be changed. The last three categories are not "fenced", so that the requirements may be reduced in these categories when the dollars cannot support the total program. Even within the non-fenced items, most of the reductions in requirements take place in the operational move category. This is because the program manager can really only solicit personnel to extend their stay at a given assignment past their projected rotation date (PRD). Most people will not elect to do this and the requirements then can not be cut back in the rotational move category. Also little reduction in requirements occurs in the training move category. Once the requirements meet dollar constraints, the budget is submitted for its first review. The above cycle is repeated for each additional budget submit.

PCS BUDGET EXECUTION

Pers 223

Once funds have been appropriated by Congress, Pers 223 removes the CNP contingency fund and then removes monies for and monitors the fenced

categories - accessions, separations, and organized unit moves. He suballocates the rest of the funding to Pers 4 and Pers 5 for officer and enlisted moves for the three remaining categories. Pers 4 and Pers 5 receive a percentage of the funds appropriated as determined by the percentage which their requirements formed of the total submitted in the budget. Pers 223 will also monitor Pers 4 and Pers 5 to see that their projected costs per move are as expected and that they are using their money as planned.

The amount held out for the contingency fund is usually determined by the CNP. If he prefers to withhold a large amount, then many programs can be enhanced during the final quarter of the year. Additionally, in this case the contingency fund normally would be used to cover unexpected cost increases rather than relying on cutbacks in the program to bring costs in line. On the other hand, if the CNP wishes to maximize program requirements with respect to the total availability, only a small contingency fund will be withheld as a safeguard against overspending. If program costs then begin to exceed cost estimates, the program will be cut back rather than be sustained by the contingency fund. A contingency fund of approximately two million dollars usually will be held in reserve until the last quarter as a minimum precautionary measure. Generally speaking, the contingency fund is less than 1% of the total appropriation.

The program manager monitors the non-fenced categories through Pers 4 and 5. He issues an OPTAR (Operational Target Amount or Authorization Amount) which tells Pers 4 and 5 how much funding they have available to manage. This authorization is divided into four quarters by the program manager who determines these quarterly amounts based on the percentage of the total authorization each quarter's funding was in the previous year. These quarterly amounts, however, may be increased or decreased to adjust for known program fluctuations affecting cost totals. The program manager then monitors the account by comparing the monthly cost estimates that make up his operating plan with monthly reports received from PCS VAD on total dollars obligated or reserved in each of the move categories for both enlisted and officer personnel. The operating plan for these non-fenced categories

is determined primarily from estimates made by Pers 4 and 5 personnel of total monthly costs for their portion of the program. Should one of the non-fenced categories exceed cost estimates three lines of action are open. Funds may be moved from Pers 4 to Pers 5, or vice versa, depending on where the money is deficient; that portion of the program that is in trouble may be cut back, or part of the contingency fund can be used to maintain the program as planned. If the requirements must be reduced, the Program Manager usually attempts to make an equitable cut between officer and enlisted personnel moves.

In the case where program cost estimates are considerably higher than the monthly totals received from PCS VAD, the program manager must determine what is wrong. If he finds that the monthly obligation and reservation costs are lagging because of deficiencies within the system then he will not alter his program. He also will not change the program if he cannot immediately determine what the problem may be. However, if it appears that the tables used to estimate moving costs are inaccurately high, the program manager can increase the allocation to Pers 4 and Pers 5 to supplement and enhance their portion of the program for the non-fenced move categories.

A similar method of control is used by the Program Manager to monitor the fenced categories which are his concern in their entirety. Authorization funds for these categories are divided up by quarter according to the plans given Pers 223 by higher authority. Accessions and separations are given by the Navy strength plan; organized unit moves are based on overhaul plans and scheduled home port changes. During the fiscal year the accounts are monitored by comparing an operating plan with monthly reports from PCS VAD; should it appear that actual costs are exceeding estimated costs, additional funds would be obtained from the contingency fund or, possibly, from Pers 4 or Pers 5. Normally the fenced category moves cannot be reduced, although if accessions or separations are lower than planned, money allocated to these categories is freed to be spent elsewhere.

Pers 3

Pers 3 is charged with monitoring PCS expenditure and ensuring that it will not exceed the appropriated amount. To do this, Pers 311 develops an expenditure plan once the budget has been funded by Congress. Actual expenditures from the previous year are plotted and monthly adjustments are made to allow for known circumstances that may affect expenditure transactions in the coming year. Expenditure data from other years may also be used if for some reason the past year's expenditure flow rate was unusual. Generally the expenditure plan is based on a 68-75% liquidation of funds during the first year, leaving around 100 million dollars in the account for the delayed expenditures. Pers 311 computes the variance on a monthly basis and instantly investigates any major divergence from the plan. Often these divergencies are temporary, as in the case of a computer breakdown or system change causing a backlog in reporting expenditure information. If this is found to be the case, Pers 311 will not alter the expenditure plan. However, all large variances which are the result of temporary problems will be noted and explained in full. Should major disagreements between the planned and actual expenditures appear to be permanent, then the plan will be changed to reflect the actual data. If these changes threaten the budget for the whole year, program adjustments may also be necessary, although this has not happened in recent years.

The Movement Ordering Process

Before discussing the activities of the staffs of Pers 4 and Pers 5, it is necessary to give a general description of how a military member makes a PCS move. Such a person changes his duty station on the order of a detailer or assignment officer. When the detailer or assignment officer issues the order, he makes an estimate of its cost using what is known as a STEP 1 table. This preliminary estimate, or reservation, is sent to PCS VAD, which functions as the bookkeeper for the entire process. At some point, three days or more before the member is detached to go to his new station, he will send in his TIC to VAD. When it is received, it is used to determine the costs of the member's move more accurately by pricing the move using

STEP 2 tables. This new estimate, or actual obligation, then replaces the reservation. If no TIC is received, the reservation then becomes the actual obligation. When the bills for the move are submitted to the Navy these expenditures are reported back to Pers 3 for comparison against the expenditure plan and then are sent to VAD.

Clearly, the STEP 1 and STEP 2 tables play a central role in PCS execution. The STEP 2 tables are average costs by pay grade for such things as the shipment of household goods and automobiles, and storage costs for household goods during all or part of the duty assignment over certain ranges of miles. These costs are developed from the information on the TICs. Other tables of costs, such as airfares or mileage rates as set by the government are used along with the STEP 2 tables in calculating the actual obligation for a PCS move. These costs are combined to form the STEP 1 tables. These display in matrix form a lump sum average cost of a PCS move by pay grade, number of dependents and mileage range travelled. Thus, in making a reservation, a detailer has only to turn to the proper page and find the proper box in a matrix to ascertain a single figure. He or she obtains the data needed to do this from the MAPMIS personnel file.

Inflation factors covering rises in cost are built into the STEP 1 tables, since the reservations which the tables establish are for moves which will be executed several months after they are made. The inflation factors are calculated from historical data from the previous 6 to 12 month period, and are on the order of four to six percent. They are now applied only against the cost of moving household goods, although until recently they were used to raise the entire estimate.

The STEP 1 and STEP 2 tables are updated constantly, as various costs are increased or decreased. A major updating is done every fiscal year, after all the TICs for the previous year have been collected and analyzed.

Pers 4

Pers 4 and the personnel subordinate to him are responsible for issuing orders for officers' accessions, separations, and OPS, ROTS, and TRA moves. Since Pers 4 is responsible for monitoring the cost expenditure for the last three categories of moves, Pers 4 is closely involved in the PCS process. Pers 4c acts as PCS manager; the orders issued by Pers 4 are cut by officers who are known as "assignment" officers" or tertiary managers. Each assignment officer is responsible for a single group within the total officer population of the Navy; for instance, he or she might keep track of all naval aviators of a certain grade. Supervisory personnel under Pers 4 play a major role in planning and in monitoring the execution of the budget, assuring both the efficient expenditure of funds and that monies will not be overspent. Altogether, Pers 4 is responsible for ordering approximately 28,000 OPS, ROTS and TRA moves annually.

The personnel in Pers 4 develop plans for executing the PCS budget by determining the Navy's requirements for assigning officers to new duty stations, and then modify these in the light of fiscal constraints. They find it difficult to be completely accurate because of a number of factors.

Planning for OPS and ROTS moves centers on Projected Rotation Dates, or PRD's. Whenever a member makes a move to a new station, his tour theoretically will last for a specified length of time set by policy. The exact length depends on a number of considerations, e.g. location, type of assignment, rank, promotional status, availability of replacements and whether the individual is in the regular or the reserve branches of the Navy. When this specified length of time is added to the date when an officer assumes his new duties, a PRD is obtained.

Because very few training courses in the Navy last for as long as a year, PRD's cannot be used meaningfully to plan TRA moves. Assignment officers must rely on the number of billets in the various training facilities open to their category of officer to estimate how many moves the members for whom they are responsible will make.

The PCS planning process follows the pattern described below. Tertiary managers calculate their requirements for moves by counting the PRD's which will fall in the current fiscal year and the training billets which they must fill. These are then submitted to Pers 4c who sums them and applies a number of factors which will influence the number of moves which are actually made. These factors are discussed below. Finally, these requirements are compared against the OPTAR which Pers 4c has been issued, and are adjusted accordingly. Although funding is a constraint, the moving program is created with goals other than saving money taking priority.

A number of considerations makes the prediction of requirements difficult, even though an attempt is made by Pers 4c through the factors he applies to correct for them. PRD's, for instance, do not equate exactly to moves. That is, each PRD does not mean that one move will have to be made for it. For OPS moves 1 PRD $\approx$.88 moves, since many officers stationed in the United States are willing to extend their tour in their present station, or they separate from the service at a tour's end. For ROTS moves, on the other hand, 1 PRD $\approx$1.6 moves, since moving an officer in an overseas station frequently means that other officers have to be shifted to fill in behind him, even though they have not yet reached their PRD. The number of these "chain reaction moves", where four or five officers must move to fill a gap originally created by one PRD is unpredictable, but it can impact significantly on the PCS budget for Pers 4.

Mandatory moves also make difficult the projection of OPS and ROTS moves. Officers can be accessed into the Navy directly to a duty station, or they can separate from the Navy unpredictably. In either case, their PCS move is paid out of the accession or separation funds, relieving some of the strain on the OPS and ROTS segments. This can be especially important for ROTS moves, given their great expense. Pers 4c personnel use data from the previous year to predict the number of moves which will be paid by the accession or separation accounts. The resulting predictions are about 95% accurate; nonetheless the 5% inaccuracy is still relatively large.

Training moves are also subject to unpredictable fluctuations, despite the fact that the number of training billets filled annually is known quite accurately. This is because coursework at Navy schools tends to expand; curricula which at one time took less than twenty weeks to complete may expand to the point that longer than that period is necessary to finish. When this occurs, a move to a school to take that set of courses becomes a PCS move, and Pers 4 must foot the bill out of its accounts. The number of these additional TRA moves required annually is unpredictable.

Training requirements also make it difficult to predict OPS and ROTS moves, because much training is conducted enroute between duty stations, slipping the time between when an officer's rotation date arrives and when his relief appears. Because the number of occurrences and the length of time involved is not predictable, this makes PRD's less reliable as a planning factor.

Yet another factor affecting PCS planning for Pers 4c personnel is that changes of duty station usually cost nothing, if the new station is in the same area as the old one. Such moves are known as "no-cost moves", and, although Pers 4 attempts to maximize their number, its success in doing so fluctuates from year to year. Very few ROTS moves are no cost; in FY 77 about 37% of OPS moves cost the Navy nothing, as did about 10% of TRA moves. The fact that these percentages vary somewhat from year to year can affect the availability of funds to Pers 4c considerably.

When BuPers receives PCS funds, Pers 4 gets its share of the funds based on its share of the budget submitted to Congress. Using information on the individual assignment officer's requirements for funds, Pers 4c personnel create quarterly OPLANS for each tertiary manager. Each assignment officer writes orders for those officers for whose moves he is responsible and reserves a sum for each PCS move using the STEP 1 tables. The assignment officer reports his actions to Pers 4c who monitors the execution of the budget.

Pers 4c, as the PCS manager, has several management tools available to him. If an assignment officer needs more funds, he can shift them out of categories that do not need as much money as had been allocated them; Pers 4c can also speed or slow reservations. If necessary, the number of moves in any of the categories can be cut back.

Pers 4c also monitors the difference between STEP 1 reservations and STEP 2 obligations. STEP 1 tables have consistently reserved less money than obligated, giving a "negative rollback" which drains funds faster than the reservations indicate. This problem can be sizable; Pers 4c retains a small contingency fund to cover these additional costs, rather than having assignment officers keep them. His management task is made more difficult by the fact that almost 40% of officers' moves take place in June and July, too late in the fiscal year to be able to take any action.

Pers 5

Pers 5 is responsible for the planning and execution of OPS, ROTS, and training moves for enlisted personnel in the Navy. Ten secondary managers, each with responsibility for personnel with skills in a particular area, oversee the writing of about 120,000 orders a year at an annual cost of around $146 million. Pers 542 is the PCS account manager for Pers 5.

Enlisted personnel PCS cost moves are divided into two categories, planned-programmed and planned-unprogrammed. OPS and ROTS moves fall under the first type, since they can be predicted with high accuracy by a computer model. The remaining moves come under the second category, since they are relatively less predictable.

Pers 5 plans OPS and ROTS moves by using PRD's of enlisted sailors. The large population of enlisted personnel enables the Pers 2 PRD model to project accurately the number of PRD's expected to be vacant in a given Fiscal Year. The model provides estimates for the number of PRD's that Pers 5 may make up to five years in the future. It also can provide breakouts of numbers of PRD's by month for the first two years its' projections cover, as well as by type of move (OPS/ROTS only), such as from CONUS to an overseas billet. It is usually accurate to within one percent of the number of assignments Pers 5 will issue. However, since the estimated assignments never match available dollars, management action is necessary to reduce projected moves to fit the dollars. Factors such as re-enlistment rates, known ship or aircraft squadron decommissionings, or assign-

ment policy alteration, and other management alterations are inserted into the analysis of a given PCS model run based largely on historical assignment trends.

The moves which cannot be predicted by PRD for the most part do not fluctuate sharply from year to year. For that reason planners can account for them rather easily. Two categories cause trouble however, because they do vary widely from year to year; these are moves for humanitarian purposes and decommissionings. Since the Navy will decommission few ships in the next few years, and is due to begin commissioning considerable numbers of them, PCS moves resulting from decommissionings will cease to be troublesome, while those stemming from commissionings will begin to demand special attention because of the lengthy and costly training pipelines. In FY 77 humanitarian moves comprised 3.7% of all PCS moves for enlisted personnel; decommissionings formed another 5%.

Pers 223 allocates a portion of the overall PCS budget to Pers 542 for use in constructing a PCS OPLAN. Pers 542 must then use historical experience and other management information such as projected changes in force levels or overhauls to break the projections down for the proper allocation of moves and funds to each OPTAR manager. Changes in force levels are important because the commissioning or decommissioning of a ship can drastically alter the number of moves which must be made, especially when an aircraft carrier is involved. Pers 542 discusses the estimated quarterly allocation with the secondary managers, so that, if he has overlooked some event which will affect the number of moves, the oversight can be corrected before the OPLAN is submitted. Finally, the quarterly allocations are broken down into monthly move totals. Pers 542 accomplishes this using historical experience as a guide. Again, secondary managers may offer their comments on these totals so that if Pers 542 has been unaware of a potential perturbation in the number of moves in a given month, the OPLAN can be adjusted to account for it.

Since the budget chain always reduces the number of PCS assignments requested by the Bureau, Pers 5 always receives less money than his staff had predicted for the cost of the year's PCS program. Although, some funds are usually released from the mandatory move categories and the CNP's contingency during the fiscal year, these dollars are never enough to make up the full difference.* A number of options are available to surmount the difficulties imposed by the shortage of money, as noted on page 8.

The number of moves in each quarter is generally close to the number in any other quarter. As with officers, summer is the high point and winter is the nadir, but the fluctuation between quarters ranges only between 22% and 28%.

Execution of the Enlisted PCS budget follows the process described below. A detailer receives a requisition for an enlisted person with a certain skill and grade level and matches it with a list of available personnel with these characteristics, writing an order for the person who best fills the requisition. When the order is written, a "Blue Top Card" (NAVPERS7041/3 PCS Cost Control Card) is sent to PCS VAD in Cleveland, Ohio to reserve the cost of the move. TICs for non-rated entitled personnel are sent in directly by Pers 533/EPMAC. When the TIC is sent in by the entitled member, Pers 542 is eventually informed of the STEP 2 obligations in the aggregate by PCS VAD, Cleveland through a monthly reporting system. The STEP 1 tables by which the reservations are made, are generally higher than STEP 2 obligations by design. Obligations thus tend to be lower than reservations, so that Pers 5 actually spends less on a move than it reserves, and thus it can buy more moves and come closer to the move plan. Eventually, financial tracking will be officially done by the Military Personnel, Navy Financial System (MFS), but tracking methods currently used within Pers 5 give a slightly more accurate picture of the account. When MFS is fully operational and certified, it will be the one and only method of PCS tracking.

*Monies are freed from the mandatory move categories for reasons such as there being fewer accessions into the Navy than predicted, or obligations being cheaper than planned.

In writing orders for a specific move, a number of factors must be considered in priority. First of these is the needs of the Navy; second is availability of personnel; and third is cost. Although manning priorities are set by higher authority (the Manning Control Authorities), they are actually somewhat flexible. If the squeeze on funds is especially tight towards the end of a fiscal period, then cost becomes more important. As the current nationwide inflation rate reduces the real value of the PCS budget faster than actual costs can be predicted, cost appears to be moving towards first priority.

One constraint on the execution of the PCS plan is that, unlike officers, enlisted personnel are quite reluctant to extend their tour past their PRD. Thus, a device open to Pers 4 when funds are running low, extension of a member's time in a billet, is usually closed to Pers 5. Pers 5 therefore makes a strong effort to keep PCS moves within an "assignment window" of one month prior to and one month after a PRD. If funds do begin to run low, necessitating that moves be delayed, those members whose moves fall into one of the many "must move" categories are moved first. This is because members due to make a sea-going OPS or ROTS move must be replaced, or else operational readiness in a particular fleet unit may be degraded; thus meeting a PRD means that two moves must be made.

This problem is especially acute at the end of the fiscal year, because the short period of time before the account is closed means that Pers 542 cannot take advantage of all the "positive rollback" from the design difference between the STEP 1 and STEP 2 tables. As a result, Pers 5 must "bow-wave" moves, pushing the more expensive ones into the beginning of the new fiscal year. Pers 4 also uses bow-waving as a management method. With MFS implementation, the need to use the bow-wave technique disappears.

## DATA ANALYSIS

In analyzing a set of data which we suspect has both deterministic and random components, as in the case of the PCS account, if possible we would like to isolate the two components for separate analysis. We do this for two major reasons: (1) It is usually necessary to assume certain behavior of the deterministic component, and then subtract that from the whole before we can study the random component. And (2), it is usually easier to construct two smaller models, one for each component, and merge them, than it is to construct one all-inclusive model from the outset.

Due to limitations in data availability, this report focuses primarily on the deterministic component. Although we believe one or more of the methods we propose can be refined with more data to model both components, data limitations at this point do not yet allow a statistical universe large enough to even complete our assumptions and descriptions of the deterministic component, much less either confirm or reject them with mathematical rigor. Without this confidence in the deterministic component, it would be sheer guesswork to analyze the random component beyond simple inspection techniques.

In the following sections we will describe our observations and assumptions in the isolation of critical variables, our analysis methods, and our conclusions regarding potential models, their probable capabilities and limitations.

### DATA AVAILABLE

The data with which we worked can be broken into two distinct sets, total monthly data and lagged monthly data. The first data set consists of three numbers, total availability, obligations, and expenditures occurring in each month of a fiscal year and its "out years" (the two years following the current fiscal year). The three numbers are directly related to commitments made and financed with money from the budget of that fiscal year. Thus the 36-month accounting period of one fiscal year overlaps that of four other fiscal years (the two preceeding and the two following), but the accounts themselves

are disjoint from one another, each relating solely to commitments from a single 12-month fiscal year.

This data is available for FY 75-77, and partially for the first three months of FY 78.

The second data set covers just nine months, from April 77 to December 77. The total expenditures for each of these months is broken down along four dimensions: (1) type of move (OPS, ROTS, etc.), (2) personnel category (officer or enlisted), (3) expense category (MT, DT, DLA, HHE, NTS, TA, and POV), and (4) time lag from month of obligation to month of expenditure. This last ranges from 0 to 35 months for the 36-month accounting periods.

Only expenditures, not obligations, are given in this detail. Also lacking in this data set is exact breakdown of the FY's from which each expenditure dollar derives. For example, an expenditure in month 3 of FY 77 with lag = 1 month will be primarily derived from the obligation in month 2 of FY 77. But some smaller portion will also probably be derived from an obligation in month 14 (12+2) of FY 76. For our analyses we have assumed that the expenditure patterns of both of these obligations are the same, but without a breakdown of expenditures by FY of obligation we cannot be sure that our assumption is correct.

To our advantage, though, is the fact that out-year obligations are usually less than 5% of initial obligations, so any deviation from our assumption will have a relatively small effect.

The largest problem with data uncertainty stems from missing data, that is, a known total amount of expenditures which cannot be categorized in the four dimensions previously mentioned due to keypunch or other errors, or slow-downs in the BuPers administrative process. The proportion of missing data to the total data can range as high as 50% and is regularly around 20%.

If it was known that the missing data were not based in any of the expenditure dimensions, each datum could be adjusted by a single factor. Unfortunately not enough is known of the characteristics of the missing data to make that determination. However, for demonstration purposes, it has been assumed that there is no bias and the data have been adjusted accordingly. Although there is some evidence in the results that the assumption is justified further investigation is necessary as additional data become available. This topic is further discussed later in the report.

CRITICAL VARIABLES

The only form of obligation data now available is the total montly data set, one number per month. Expenditures, on the other hand, come in both the total and lagged forms. In the following sections various attempts are made to relate obligations to the total or lagged forms of expenditures. In doing so we have observed several variables of importance besides obligations. The two most important are seasonality and lags.

Since it is impossible to isolate and verify yearly seasonality using the available nine months of lagged data. We have only described the probable effects of seasonality and how this might be verified in the future.

The lag, that is, the amount of time passing from themonth of obligation until the month of expenditure, has a significant effect on the amount of edpenditure over a wide range of lags. Our graphical model described later will illustrate this clearly. The range of significant lags coupled with seasonality effects is in fact so great that there is no hope of producing a statistically valid time series analysis projecting expenditures from lagged data. This will be described in the next section.

We have investigated obligation trend in the time series analysis. This trend over the past 36 months is relatively small and of little importance compared to the major critical variables obligations, seasonality, and lags.

When we describe the graphical model we will mention other variables critical to that model's refinement. These basically include the dimensionalities of the lagged data, such as type of move, personnel category, and expense category.

## PRELIMINARY MODELS

### TIME SERIES ANALYSIS

Table 1 gives total monthly obligations and expenditures for the PCS account from the beginning of FY 75 through July, 1977. We applied the Box-Jenkins time series analysis procedure to the PCS obligations and expenditures, but, as will be explained below, we obtained no satisfactory model.

Box-Jenkins operates on streams of numbers whose average size and variability are the same along the entire length of the streams. Looking at Table 1, it is apparent that the levels of obligations and expenditures in the out years are significantly different from the levels during the year in which the money was appropriated. We decided to limit our attention at first to the obligations and expenditures in the year of appropriation and then, if possible, to expand the analysis to include the out years. The data we used are presented in Table 2.

The Box-Jenkins procedure could not produce a model relating monthly expenditures to monthly obligations. More technically, the expenditure data had a standard deviation of 6.91 (million dollars), and the residual series left after applying the best model had a standard deviation of 6.54. This is a reduction of 5.4%, and in a series this short is most likely due to random chance.

There are two apparent reasons why Box-Jenkins fared so poorly. First, in the PCS account the time lag between obligation and expenditure is often long. This means that the resulting model would have a large number of terms, more than can be estimated with only three years of data. This problem can be overcome by collecting data for a number of additional years. Second, the long delays between obligation and expenditure mean that a significant amount of the expenditure for a given month can occur in the out years. Since we were forced to ignore the out years, we miss those expenditures.

### GRAPHICAL MODEL

The so-called Graphical Model is less a model than simply a graphical display of data. The benefit of the display is that it yields intuitive insights into the relationships between obligation

TABLE 1
(in 1000's of dollars)

| Calendar Year | Month | Obligations FY75 | Obligations FY76 | Obligations FYTQ | Obligations FY77 | Expenditures FY75 | Expenditures FY76 | Expenditures FYTQ | Expenditures FY77 |
|---|---|---|---|---|---|---|---|---|---|
| 1974 | July | 38,796 | | | | 12,415 | | | |
| | August | 35,795 | | | | 5,258 | | | |
| | September | 25,369 | | | | 9,636 | | | |
| | October | 22,449 | | | | 11,067 | | | |
| | November | 17,422 | | | | 19,709 | | | |
| | December | 25,904 | | | | 24,393 | | | |
| 1975 | January | 22,403 | | | | 28,152 | | | |
| | February | 21,141 | | | | 21,647 | | | |
| | March | 23,484 | | | | 20,211 | | | |
| | April | 21,153 | | | | 22,908 | | | |
| | May | 24,338 | | | | 29,895 | | | |
| | June | 36,369 | | | | 21,529 | | | |
| | July | -1,479 | 47,879 | | | -6,555 | 19,208 | | |
| | August | 292 | 30,129 | | | 19,082 | 8,306 | | |
| | September | -561 | 26,191 | | | 16,228 | 24,344 | | |
| | October | 1,202 | 24,571 | | | 11,894 | 21,268 | | |
| | November | -238 | 18,935 | | | 10,282 | 21,009 | | |
| | December | -354 | 24,956 | | | 6,114 | 19,572 | | |
| 1976 | January | -1,173 | 24,223 | | | 5,139 | 20,254 | | |
| | February | -241 | 24,112 | | | 4,078 | 23,507 | | |
| | March | -146 | 20,015 | | | 4,160 | 21,011 | | |
| | April | -71 | 24,397 | | | 747 | 11,263 | | |
| | May | -71 | 22,325 | | | 2,263 | 30,797 | | |
| | June | -14 | 36,046 | | | 3,086 | 25,799 | | |
| | July | 0 | 0 | 40,285 | | 362 | -8,856 | 18,466 | |
| | August | 0 | 1,845 | 33,648 | | 853 | 19,928 | 7,236 | |
| | September | 0 | -1,155 | 24,817 | | 136 | 6,644 | 24,051 | |
| | October | 0 | 1,175 | 1,102 | 27,520 | 574 | 17,127 | -21,473 | 18,697 |
| | November | 0 | -528 | 1,184 | 20,720 | 134 | 8,008 | 10,146 | 18,391 |
| | December | 0 | 482 | 1,070 | 24,864 | 226 | 6,317 | -1,416 | 5,582 |
| 1977 | January | 0 | -194 | 1,383 | 25,737 | 34 | 11,577 | 17,485 | 11,842 |
| | February | 0 | 354 | -83 | 24,303 | 78 | 4,286 | 6,626 | 2,011 |
| | March | 0 | -422 | 113 | 25,127 | 219 | 4,652 | 6,519 | 21,185 |
| | April | 0 | 35 | -61 | 27,699 | 148 | 589 | 4,488 | 20,591 |
| | May | 0 | 6 | -237 | 31,046 | 25 | -1,546 | 3,623 | 23,337 |
| | June | 0 | 21 | -57 | 40,729 | 24 | 281 | 446 | 17,602 |
| | July | 0 | | 0 | 40,340 | 456 | | 4,268 | 17,361 |

TABLE 2

(in 1,000's of dollars)

| YEAR | MONTH | OBLIGATION | EXPENDITURE |
|---|---|---|---|
| 1974 | July | 38,796 | 12,415 |
| | August | 35,975 | 5,258 |
| | September | 25,369 | 9,636 |
| | October | 22,449 | 11,067 |
| | November | 17,422 | 19,709 |
| | December | 25,904 | 24,393 |
| 1975 | January | 22,403 | 28,152 |
| | February | 21,141 | 21,647 |
| | March | 23,484 | 20,211 |
| | April | 21,153 | 22,908 |
| | May | 24,338 | 29,895 |
| | June | 36,339 | 21,529 |
| | July | 47,879 | 19,208 |
| | August | 30,129 | 8,306 |
| | September | 26,191 | 24,344 |
| | October | 24,571 | 21,268 |
| | November | 18,935 | 21,009 |
| | December | 24,956 | 19,572 |
| 1976 | January | 24,223 | 20,254 |
| | February | 24,112 | 23,507 |
| | March | 20,015 | 21,101 |
| | April | 24,397 | 11,263 |
| | May | 22,325 | 30,797 |
| | June | 36,046 | 25,799 |
| | July | 40,285 | 18,466 |
| | August | 33,648 | 7,236 |
| | September | 24,817 | 24,051 |
| | October | 27,520 | 18,697 |
| | November | 20,720 | 18,391 |
| | December | 24,864 | 5,582 |
| 1977 | January | 25,737 | 11,842 |
| | February | 24,303 | 2,011 |
| | March | 25,127 | 21,185 |
| | April | 27,699 | 20,591 |
| | May | 31,046 | 23,337 |
| | June | 40,729 | 17,602 |
| | July | 40,340 | 17,361 |

and expenditure patterns. We call the display a model because the patterns illustrated, even with minimal data, are sufficiently regular to warrant speculation and recommendations regarding future data collection. More data could lead to quantification of the graphical display into a useful model. For the present, however, we must be content with those insights the display gives us into the patterns which underlie our proposed Exponential Model, which will be discussed in the next section.

Given a planned sequence of obligations, we would ideally like to be able to predict the ensuing sequence of expenditures. The graphical model we will describe shows promise of being able to do this without resort to complex computer-based analytical means.

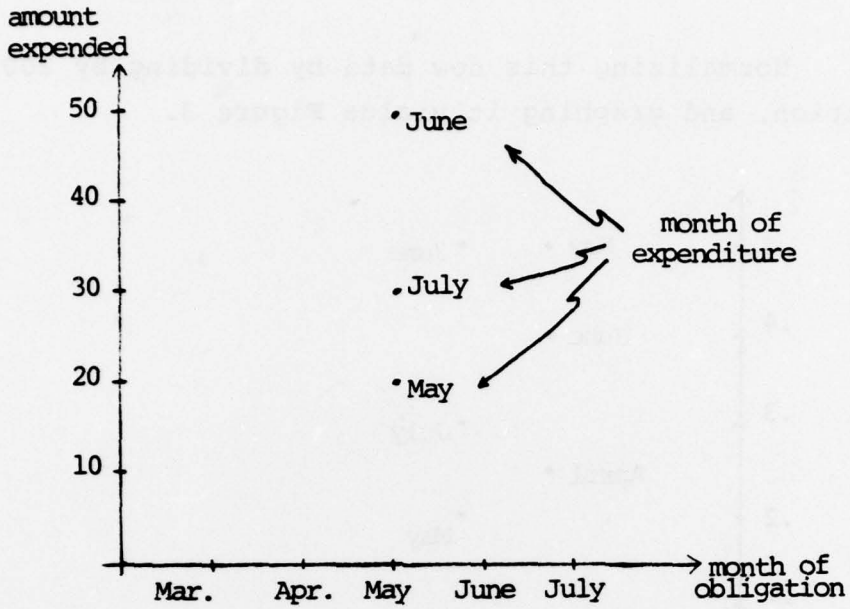
Both data sets are required by this model. The initial version of the model requires only the lag dimension of the lagged data set, which may simplify data collection procedures. However, as is explained later, we envision refined versions of this model using several of the dimensions available.

The graphical model is constructed as follows:

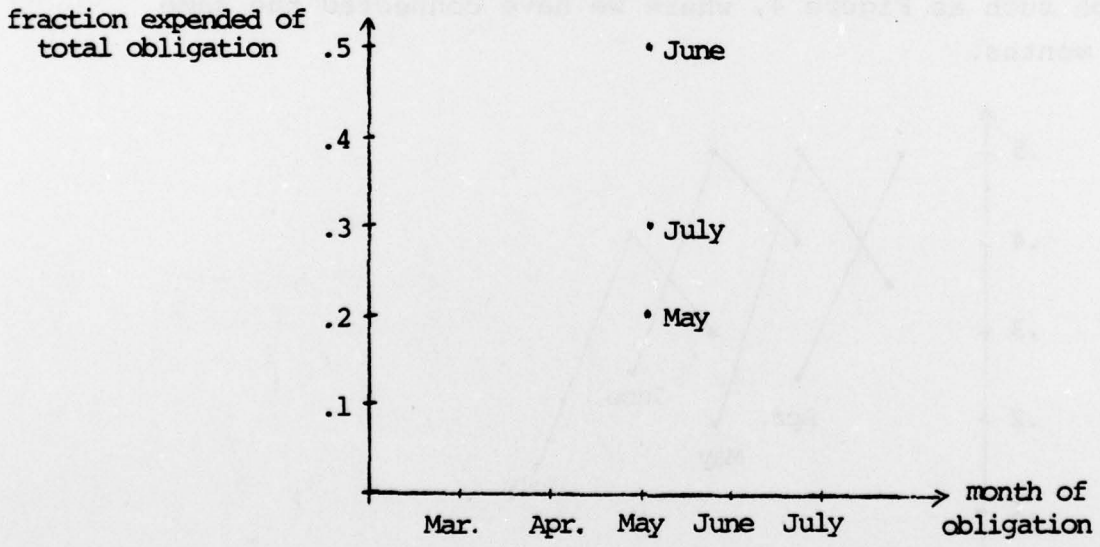
(1) Suppose the total obligation was 100 dollars in May of some year. (We would obtain this datum from the total monthly data set).

From the lagged data set it might be that in May, 20 dollars were expended with obligation lag zero, that is, 20 of the 100 dollars obligated in May were also expended in May. In addition, the data might say that 50 dollars were expended in June with lag 1 and 30 dollars expended in July with lag 2. Note that the lags are such that all of the expenditures relate to obligations made in May.

(2) This information is graphed as in Figure 1.

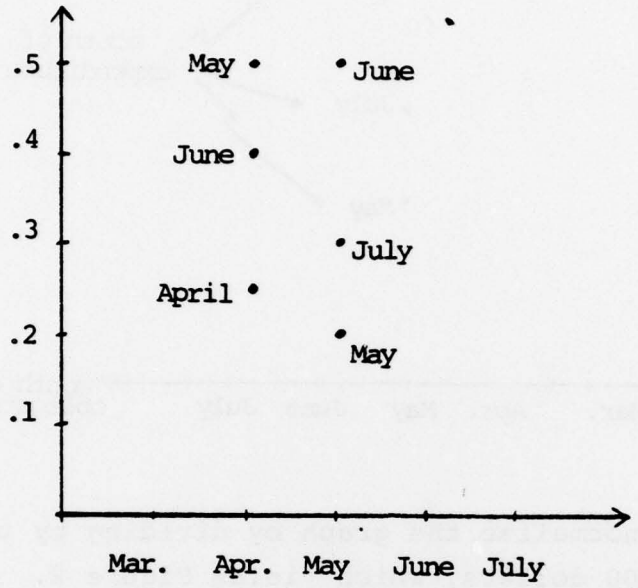



(3) We normalize the graph by dividing by the total obligation in May, 100 dollars, which yields Figure 2. Only the vertical scale has changed from Figure 1.

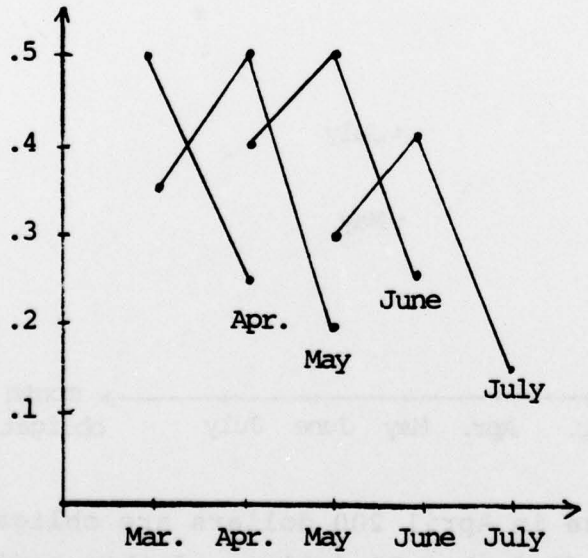



(4) Suppose in April 200 dollars are obligated. From the lagged data we might find that 50 dollars of this April obligation were expended in April (lag zero), 100 in May (lag 1), and 80 in June. Note that the total expenditure is 230 dollars in this case, greater than the obligation.

Normalizing this new data by dividing by 200, the total obligation, and graphing it yields Figure 3.




(5) Following this procedure for several months may yield a graph such as Figure 4, where we have connected the same expenditure months.




(6) Upon graphing all the data, patterns begin to form.

The final result, with all the data to date normalized and graphed, is shown in Figure 5.

The vertical sum of the curves at any given month of obligation is equal to the total proportion of that obligation eventually expended.

The area under each curve, when de-normalized, equals the total expenditure in the month of the curve label.

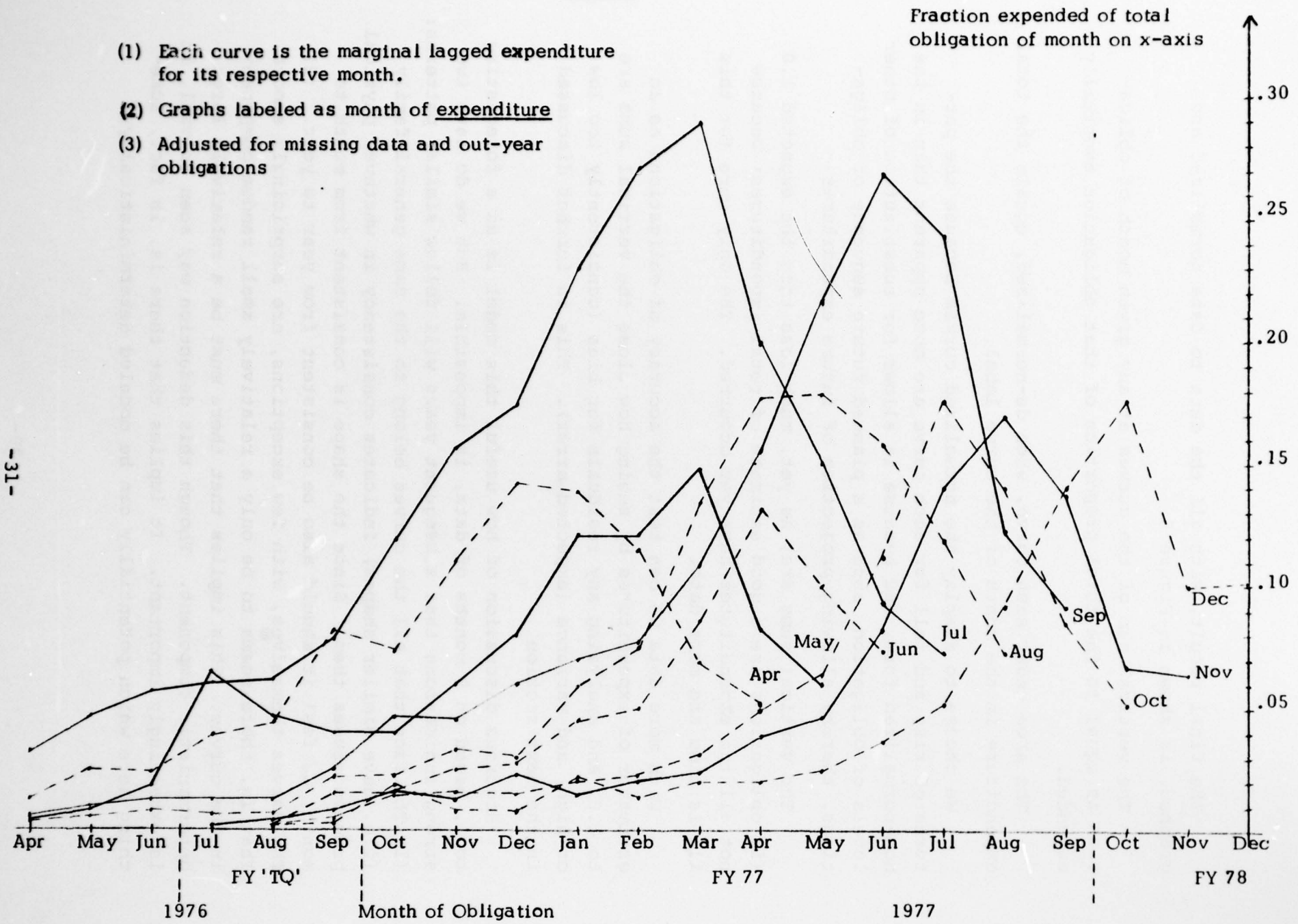
We choose to display the normalized curves because the patterns of rise and fall for each curve are more apparent than in the non-normalized form, and because it allows for substitution of other levels of obligation, such as a planned future sequence of obligations, thereby allowing projection of future expenditures.

The vertical sums are, as yet, much less than the expected 1.0 (if obligations are a good estimate of total expenditures) because not all the expenditures have yet occurred. The only cure for this ill is time and more data.

With more data we can test the accuracy of obligations as an estimator of expenditures by seeing how close the vertical sums are to 1.0, and analyzing any residuals for bias (consistently too low or high) and variance (expected error). This is further discussed in the next section.

Rigorous discussion of how useful this model is as a forecasting tool, based on 9 months of data, is impossible. But we do have two strong indications that subsequent years will follow similar patterns: (1) The fact that all the curves belong to the same general family (i.e. have similar shapes) indicates consistency in whatever physical process causes them. Since the shape is consistent from month to month, we feel it should also be consistent from year to year. (2) The curves themselves, with few exceptions, are surprisingly smooth. That is, there seems to be only a relatively small random component in the curves. This implies that there must be a relatively large deterministic component. Though this deduction may seen trivial, it is exceedingly important. It implies that there is, in fact, something here which potentially can be modeled deterministically.

Figure 5


(1) Each curve is the marginal lagged expenditure for its respective month.
(2) Graphs labeled as month of expenditure
(3) Adjusted for missing data and out-year obligations
Fraction expended of total obligation of month on x-axis
.30
.25
.20
.15
.10
.05
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Sep
Oct
Nov
Dec
Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
FY 'TQ'
FY 77
FY 78
1976
Month of Obligation
1977

The different heights and widths of the curves gives a clear illustration of what is meant by "seasonality" in the PCS context. The usual interpretation of simple seasonality would be, if applied to PCS, that a certain amount more would be expended in July than in other months. But with this model we can go into greater detail since we can clearly see what proportion of the obligations of many previous months were expended in July, and how these proportions compare to those of expenditures in other months.

Until now we have discussed only a graphical model based on variation of the lag parameter of the data. There are three other parameters available in the expenditure data for refining the model. Analysis using these parameters effectively breaks up each lagged monthly expenditure into smaller and smaller categories. The analysis of these parameters follows analogously the procedure described above with one exception: keeping in mind the original assumption that we are using obligations to estimate expenditures, we must have obligations data with the same detail as the expenditure data used.

The initial studies which we have made of the move-type category indicate that there are regular (i.e. largely deterministic) and significant differences in the expenditure patterns (curve shapes) from move category to move category. That is, for example, the shape for ROTS moves increases at lags where separation moves decrease, and vice versa for other types. Unless the total expenditures for these moves remain in exact proportion to one another for all months, which is by no means the case, these pattern differences will affect the pattern of the total curve already described. Thus, much that we may consider a random component in the current lag-only model could quite possibly be a deterministic component in a lag and move-category model. We suspect that that is probably the case, and we recommend that appropriate obligation data be gathered for a more detailed study to include the move, personnel, and expense-type categories.

REGRESSION MODEL

Our two previous models have been "lag-oriented". The time series model attempted to predict expenditures in one month as a function of obligations in previous months. The graphical model displayed the difficulty of incorporating the large number of significant lags required.

The model we propose now is effectively a regression analysis relating a given obligation to the sum total of all expenditures deriving from that particular obligation.

In contrast to the time series analysis, which attempted to predict one expenditure from many previous, partially related obligations, the Regression Model relates <u>one</u> obligation number to <u>one</u> expenditure number.

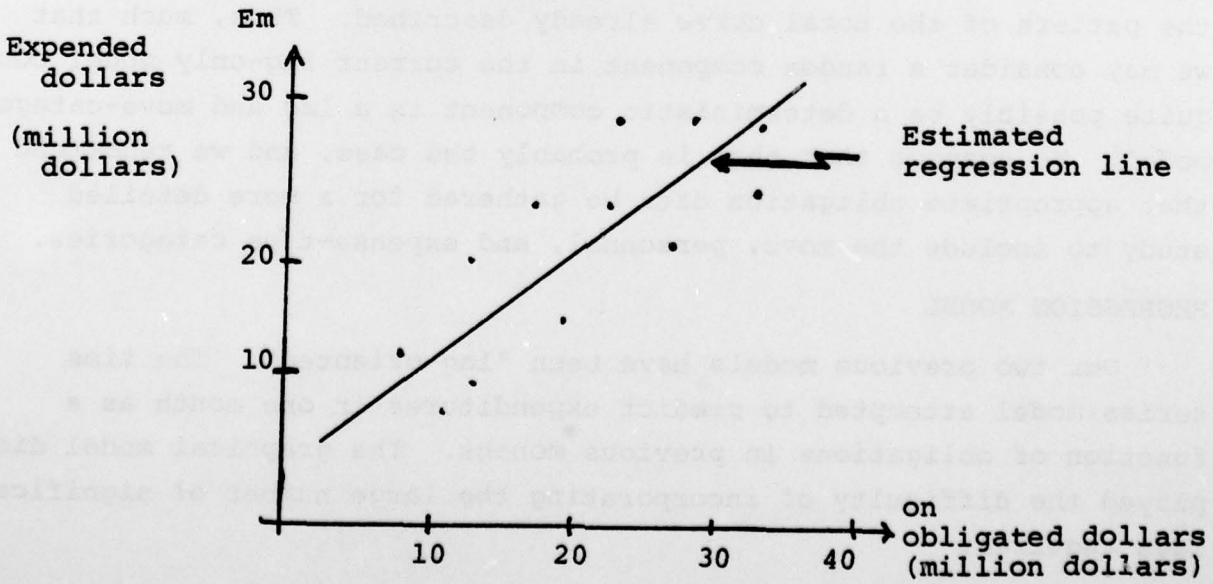
In terms of the graphical model, the Regression Model relates the obligation of each (separate) month on the horizontal axis to the vertical sum of all the expenditure curves at that point. The model is not exactly that, because we hope to break down both total obligations and lagged expenditures by fiscal year of obligation. But the basic concept of vertical summation on the graphical model is accurate.

The algebraic expression of the vertical summation for a fiscal accouting period of expenses, $E_{m_o,}$ derived from an obligation in month $M_o$ may be shown as:

$$E_{m_o,} = \sum_{m=m_o}^{36} e_{m_o m}$$

In this formula $e_{m_o m}$ is the dollar value of expenses occuring in month in derived from the obligation in month $m_o$.

Graphing the recorded values of $O_{m_o}$ ($O_{m_o}$ equals the dollar obligations in month $m_o$ ) for different months of obligation would yield a graph similar in form to Figure 6.



To utilize $O_m$ as a predictor of $E_m$, $O_m$ is defined as the independent variable and $E_m$ as the dependent variable. The relationship between the two is approximated by calculating the "estimated regression line," which minimizes the mean square deviation of all the data points ($O_m$, $E_m$ pairs) from the line. The equation of the line is:

$$E_m = a + b\, O_m$$

where a and b are "estimated regression coefficients". The procedure for evaluating the coefficient can be found in standard statistics texts. For a given obligation $O_m$ the predicted expenditure, $E_{m_1}$, is found by solving the equation

$$E_{m_1} = a + b\, O_{m_1}.$$

The standard error of the estimate is important to calculate for this model since it enables us to calculate confidence intervals. These indicate the probability that the actual value of expenditure will lie within given accuracy limits of the predicted values. This error analysis allows calculation of the contingency fund required to reduce the probability of over-expenditure to any desired level. The formula for the standard error of the estimate can also be found in standard statistics texts.

This model will give information on the most immediately important problem: control of the total expenditure over the total life of the authorization. It does not provide a means of forecasting the time distribution of expenditures within the life cycle of the authorization, as does the graphical model, and the Exponential Model to be described in the next section.

The Regression Model will answer the following questions:

- Is the relationship a linear function of the total obligations?
- How accurate are predictions over the range of obligations?

- Given a proposed set of obligations, with what confidence can we expect the resultant total expenditures to lie within certain bounds?

- How much should be set aside in a contingency?

As with the previous models, there is not yet enough data to begin implementation of the Regression Model. A minimum of three years data (one full accounting cycle) is needed to begin accurate analysis. Less data could be analyzed if assumptions were made about how much money was not yet expended, but accuracy would be lost. We recommend that future data include breakdown of both obligations and expenditures by fiscal year of obligation for use as input to this model. The model does not require breakdown of data by type of move, personnel category, or expense category. However, if that data is available for both obligations and expenditures, it would certainly be instructive to carry out the implied detailed analyses. Such analyses could derive the accuracy of predicting expenses for each type of move, etc., and thereby provide valuable management information on where problem areas lie.

EXPONENTIAL MODEL

Assuming it is sufficient for purposes of financial control to have an accurate total-time, total-money model such as the preceeding Regression Model, the primary value of a time distribution model of expenditures would be in providing a means for introducing inflation effects more realistically by apportioning them appropriately over time. An exponential model can be developed for this purpose. Again, there are insufficient data to validate it completely, and such an effort should be undertaken as the data become available.

A mixed exponential is a natural model of the time distribution of expenditures and is consistent with the data available at this time. The model procedes from the following assumptions:

1. Expenditures in non-overlapping time intervals are independent.

2. Only one expenditure or none can occur in an instant of time.

3. The rate of expenditures over time varies randomly in accordance with the Gamma distribution.

The first two assumptions with a fixed average rate over time would yield the simple exponential:

$$f(x/\lambda) = \lambda e^{-\lambda x} \tag{1}$$

To incorporate the third assumption we integrate

$$\int_0^\infty \lambda e^{-\lambda x} \frac{\beta^\alpha \lambda^{\alpha-1} e^{-\beta\lambda}}{\Gamma(\alpha)} d\lambda = \frac{\alpha}{\beta}\left(\frac{\beta}{\beta+X}\right)^{\alpha+1} \tag{2}$$

The parameters $\alpha$ and $\beta$ may be estimated numerically. This procedure can be found in Appendix A.

To incorporate inflation we consider an obligation of y dollars to be expended over time in accordance with the density derived above with an annual inflation rate i. Then if inflation is computed on a monthly basis,

$$\text{Total inflation} = \sum_{j=1}^{36} y \cdot \frac{ji}{12}\left[\left(\frac{\beta}{\beta+X}\right)^{\alpha}_{i+1} - \left(\frac{\beta}{\beta+X}\right)^{\alpha}_{i}\right] \tag{30}$$

We recommend using the graphical model in conjunction with this time distribution model to estimate uncertainty in the parameters $X$ and $\beta$, and thereby construct confidence intervals for the inflation computations.

## CONCLUSIONS AND RECOMMENDATIONS

We have investigated four models in this report. The Time Series Model failed to predict expenditures from obligations due to the prohibitively large number of relevant variables (Lags) and insufficient data. The Graphical Model is now in a primitive stage due to lack of data; it is currently little more than a conceptually useful means of displaying the data. It shows promise of refinement into a model capable of predicting month-by-month expenditures from obligations for the entire PCS account and its sub-accounts (type of move, expense category, ect.).

The Regression Model will probably, in the end, be the most useful of all the proposed models because it predicts total expenditures from obligations, and also provide confidence levels, on the predictions. However, it does not predict the time distribution of the expenditures. To accomplish that we propose the Exponential Model with the goal of accurately incorporating inflationary effects into the prediction process. When using the Exponential Model, the Graphical Model should also be employed to allow independent predictions of expenditures.

There are a number of actions which we can recommend that BuPers undertake. These center on improving the quality of the data available on the PCS account so that the models described herein can be further deployed and validated. An additional, important, recommendation concerns present bureau estimators.

Our recommendations are as follows:

- A statistical evaluation of existing bureau estimators should be undertaken immediately. These estimators are generated when orders are written and Travel Information Cards are prepared by the service member. A random sample of actual, realized move costs can be drawn from PCS VAD files for comparrison with both of these estimates to determine their statistical reliability.

- Current data collection methods should be enriched to increase the detail of obligations data to match that of expenditure data, with the exception of lags, which are irelevant to

obligations. Data on both obligations and expenditures should also be broken down with respect to the fiscal accounting year of obligation.

With improved data in hand BuPers should take the following steps:

- With two years of data, investigate the consistency of seasonal patterns for the Graphical Model.
- In the same time frame, estimate parameter value for the Exponential Model and validate the treatment of inflation effects.
- With three years of data, implement the Regression Model in support of management decisions on fund allocations.
- With the same amount of data investigate the feasibility of making separate models for the different move types and expense categories to enhance their value in the management of the PCS account.

## APPENDIX A

## PARAMETER ESTIMATION FOR THE EXPONENTIAL MODEL

To estimate $\alpha$ and $\beta$, we form the likelihood function

$$L(\alpha,\beta) = \prod_{i=1}^{n} \frac{\alpha}{\beta} \left( \frac{\beta}{\beta + x_i} \right)^{\alpha+1}$$

and

$$\ln L(\alpha,\beta) = n \ln \alpha - n \ln \beta + (\alpha+1) \sum_{i=1}^{n} \ln (\beta+x_i)$$

$$\frac{\partial \ln L(\alpha,\beta)}{\partial \alpha} = \frac{n}{\alpha} + \ln(\beta) - \sum_{i=1}^{n} \ln (\beta + x_i) = 0$$

$$\frac{\partial \ln L(\alpha,\beta)}{\partial \beta} = \frac{n\alpha}{\beta} - (\alpha+1) \sum_{i=1}^{n} \frac{1}{\beta + x_i} = 0$$

Solving for $\alpha$

$$\alpha = \frac{n}{\sum_{i=1}^{n} \ln (\beta+x_i) - \ln(\beta)}$$

Substitution yields an equation in $\beta$ which may be solved numerically:

$$\frac{n^2}{\beta \left( \sum_{i=1}^{n} \ln (\beta+x_i) - \ln(\beta) \right)} = \frac{n + \left( \sum_{i=1}^{n} \ln (\beta+x_i) - \ln \beta \right)}{\sum_{i=1}^{n} \ln (\beta+x_i) - \ln \beta} \sum_{i=1}^{n} \frac{1}{\beta+x_i}$$