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6 FORMULATION OF A MODEL TO PREDICT SECOND DESTINATION TRANSPORTATION TONNAGE ESTIMATES FOR FUTURE BUDGET REQUIREMENTS

10 Christopher J. Lamb, Captain, USAF  
Joseph B. Sarnacki, Captain, USAF

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The purpose of the research was to develop a better method for computing SDT tonnage estimates which are used to derive future budget requirements. The objectives were to determine whether flying hours, manpower, or both were significantly reliable predictors of tonnage estimates and to develop a computerized model for computation of SDT tonnage and budget estimates. Obtaining both actual and programmed data with MAC as a data source, discontinuous linear regression was used to derive twelve equations for the five overseas geographic areas serviced by MAC. The equations were synthesized into four models which were tested by various statistical methods to determine their overall validity. The optimal model chosen verified that programmed flying hours and manpower were significantly reliable predictors of tonnage estimates. A comparison between the optimal model and the method currently used to estimate tonnage revealed that the model provided a significantly more accurate estimation of tonnage to be moved. Computerization of the model was developed utilizing FORTRAN and the Statistical Package for the Social Sciences. After reviewing the results, the authors concluded that tonnage can be estimated using programmed flying hours and manpower as variables to derive future SDT budget requirements.

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FORMULATION OF A MODEL TO PREDICT SECOND DESTINATION  
TRANSPORTATION TONNAGE ESTIMATES  
FOR FUTURE BUDGET REQUIREMENTS

A Thesis

Presented to the Faculty of the School of Systems and Logistics  
of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the  
Degree of Master of Science in Logistics Management

By

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Captain, USAF

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September 1978

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This thesis, written by

Captain Christopher J. Lamb

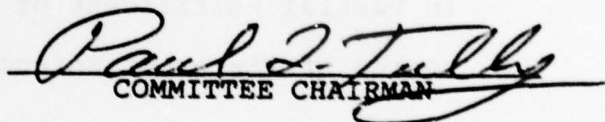
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has been accepted by the undersigned on behalf of the  
faculty of the School of Systems and Logistics in partial  
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MASTER OF SCIENCE IN LOGISTICS MANAGEMENT

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## CHAPTER I

### INTRODUCTION

Currently, determination of future Second Destination Transportation (SDT) general cargo tonnage requirements for the Military Airlift Command are being computed manually, utilizing historical and programmed flying hours and previous tonnage transported as predictors. The intent of this study is to develop a method for computing tonnage estimates to derive future SDT budget forecasts.

#### Statement of the Problem

A validated method does not exist for computation of tonnage estimates to derive future SDT budget requirements.

#### Background

"Second Destination Transportation is frequently referred to as all transportation which is not first destination [14:3]." Each is defined as:

First Destination Transportation: (1) the movement of property from f.o.b.<sup>1</sup> point of origin to the point at which the material in the form required for use, is

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<sup>1</sup>"f.o.b., free on board: delivered on board and into a carrier without charge [13:525]."

first received for subsequent distribution in the military supply system; (2) the cost of such movement.

Second Destination Transportation: (1) the subsequent movement of property for intradepartment or interdepartment distribution from the point of storage at which originally received from f.o.b. point of origin; (2) the costs of such movement [22:124].

Second Destination Transportation funds support the cost of cargo movements from continental U.S. (CONUS) depots to field activities worldwide, of intertheatre and intratheatre shipments overseas, of Army Post (APO) mail, of some civilians on permanent change of station overseas, and of materials between CONUS installations and major stock points. In addition, SDT covers CONUS port handling charges and overseas port operating costs. Costs involved in special assignment airlift for movement of cargo which requires special consideration due to security, weight, size of cargo, and/or mission requirements are supported by SDT (14:3; 19:pp.10-18 to 10-19).

The Military Services are responsible for the planning, programming, and expending of SDT funds, which comprise a separate line item under Major Force Program (MFP) VII: Central Supply and Maintenance, in the Operations and Maintenance budget of each Service (12; 14:3-4). Within the Air Force, the Air Force Logistics Command (AFLC) is the largest user of SDT funds. Approximately 75 to 80 percent of the total Air Force SDT funding each year is allotted to AFLC, almost 15 percent is allotted to the Directorate of

Administration, Office of the Chief of Staff, and the remainder is provided to the other Air Force Commands (14:32).

The SDT budgeting and funding responsibilities within AFLC are divided into six major categories, or modes of transportation: Military Airlift Command (MAC), Military Sealift Command (MSC), Commercial Air, Commercial Surface, Logistics Airlift (LOGAIR), and Port Handling Operations. Excluding LOGAIR, the Air Force flying hour program by overseas geographic area is the basis for the development of tonnage and budget requirements for the five modes (9:12; 14:34). Each of the five modes support five geographic areas: European, Pacific, Alaskan, Southern, and Northeastern. The areas correspond to the four major Air Force overseas commands, U.S. Air Forces in Europe (USAFE), Pacific Air Forces (PACAF), Alaskan Air Command (AAC), and U.S. Air Forces Southern Command (USAFSO), and to the consolidation of the northern radar sites which comprise the Northeastern area (9; 12).

MAC and MSC are the primary modes which support the movement of general cargo shipments from and between aerial and water ports in the CONUS and the overseas areas (9; 12; 19:p.10-19). The budget required to cover the SDT costs of MAC and MSC is flying hour related and encompasses approximately \$150 million, which is 50 percent of all SDT

within MFP VII, and is 70 percent of the total provided to AFLC (11; 12).

#### Justification

Since the early 1960s, budget forecasts have been based upon the Air Force flying hour programs by overseas geographic area. The present tonnage estimating method depends on a tonnage transported per flying hour ratio being applied to the flying hour programs of future budget years (12; 14:34). The tonnage, and hence the budget estimates, are projected for five future years to coincide with the Five Year Defense Program (FYDP) (12).

The ton/flying hour ratio, also referred to as the delta factor, and the future budget are recomputed manually for each mode of transportation three times a year for the FYDP, and also each time the flying hour program changes (12). To obtain the final budget estimate for MAC and MSC, a tonnage estimation computation is accomplished for each geographic area based on programmed flying hours within the areas. Tonnage and budget estimates for each geographic area are computed separately for two reasons:

1. The costs of cargo movements differ and are related to:

- a. Flying distance
- b. Tonnage moved
- c. Weather

2. Flying hours are programmed by, and are changed for, major commands.

The task is time-consuming considering other budget computations must be accomplished manually for the other modes of transportation by geographic area, excluding LOGAIR, for the total SDT program within AFLC. When flying hour programs change, or when speculative questions are asked by HQ USAF, short lead times are experienced for recomputations, which only increases the probability of human error in manual estimation of tonnage requirements and in final budget forecast submission (9; 11; 12).

Previous tonnage estimates, as predicted by programmed flying hours, have usually been directly related mathematically, such that an increase in flying hours yielded a positive delta factor and an increase in tonnage estimates. Yet, at times, an inverse relationship occurs which is presumed to have been caused by previous miscalculations (12). These occurrences resulted in the necessity for periodic rejustification of the method to higher echelons to avoid possible reductions in the SDT budget submissions. Therefore, to eliminate the probability of an inverse relationship, deviations from and juggling of the base period<sup>2</sup> for each geographic area within each mode of transportation

---

<sup>2</sup>"Base period: that period of time for which factors were determined for use in current planning and programming [22:20]."

became necessary each time the budget estimates were computed. For example, the base period for the Pacific area for MAC might be nine months one year and sixteen months the next year; while for the same area for MSC, the base period might be fifteen and twenty-four months. After the manipulation of the historical data, a positive delta factor would be reflected and would provide a direct relationship to the programmed flying hours (12). The additional computations and adjustments contributed to wasted manhours, miscalculations, inconsistencies, and potential future errors (9; 11; 12).

Consequently, although the method is relatively simple, apprehension exists at various Air Force levels as to the method's validity and reliability (9; 11; 12). For FY77, only 95 percent of the programmed flying hours were flown which should have equated to approximately the same percentage of the estimated budget being spent, leaving approximately \$7 million in excess. However, only \$2.5 million remained. The expenditure of the other \$4.5 million, and the movement of subsequent tonnage, cannot be explained utilizing the delta factor technique (12).

All too often, furnishing valid justification to preclude a budget reduction, without an accompanying reduction in flying hours, has been difficult because of previous budget overestimations (1:7; 9; 12). The Office of the Secretary of Defense examiners do not consider the present

method of tonnage estimation as an acceptable and understandable decision-making tool for budget estimations (3:1; 5; 11; 12). Because a validated method is not being utilized, higher echelons hesitate to accept or approve budget submissions without a myriad of justification (9; 11; 12).

### Scope

In limiting the scope of this research, numerous variables and data sources were considered. The final selections were predicated on the availability of sufficient, reliable information for resolution of the problem.

### Variables

The Management Sciences Division, HQ AFLC/XRS, recently conducted a study which was to provide support for the use of flying hours as a predictor of tonnage estimates for MAC and MSC (3:1). Twenty-one variables<sup>3</sup> were identified as being directly or indirectly related to the SDT program for MAC and MSC. The study revealed that both the number of flying hours and the number of manpower authorizations per geographic area had high overall correlation to tonnage estimations, but not in all geographic areas. The flying hour variable was not considered "a totally valid predictor of tonnage requirements. . . . However, it is the most logical factor to use . . . given the data

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<sup>3</sup>A listing of the variables is provided in Appendix A (3:3).

available [3:]." Manpower was not mentioned in the study as being a valid predictor. However, during a personal interview with the study's author, he stated that manpower appeared as good as, if not better than, flying hours as a tonnage predictor (4).

Therefore, based on the XRS study and on an analysis of the identified variables, nineteen of the variables were not considered applicable or feasible for one or more of the following reasons. First, the time constraint imposed during this research effort precluded reconstruction of data bases from data systems which had undergone recent modification, and had thereby altered the data content. Second, many variables did not have a historical data base which would provide sufficient information for analysis of the research problem. Third, none of the nineteen variables had programmed information for future projections, which is considered useful in predicting future tonnage estimates (3:3; 4; 6; 9; 12).

Flying hours and manpower were selected as the independent variables most likely to predict tonnage requirements in this research effort. An *a priori* relationship appears to exist between these variables in that tonnage transported supports the flying hours and manpower in each geographic area (9; 11). "Historical data shows a fairly constant relationship over the years between personnel assigned from year to year, and the material required to

support a man for one year [1:9]." Further, flying hours and manpower data are programmed for future projections and are available from USAF program documents (8; 11; 20; 21). Also, the historical data bases for the variables have not undergone modification in the last few years (8; 12). Thus, although both variables were not considered as valid predictors of tonnage estimates by the XRS study, sufficient justification exists for utilization of these variables (9; 11; 12).

#### Data Source

In limiting the scope of this study, MAC was chosen as a data source. As was previously stated, MAC and MSC SDT programs are allotted approximately 50 percent of the total MFP VII funds, of which MAC alone utilizes 33 percent of this total funding. The remaining five modes of transportation each account for 18 percent or less (12). Although the other modes are flying hour related, except for LOGAIR, they do not have the well established data system that MAC has (9; 12). MAC is the only data source which has not modified or changed its method for compiling data in the last ten years. Further, with each mode having five geographic areas from which to gather sufficient data, the time constraint imposed a formidable hinderance to efficiently formulate and test a new tonnage estimation model (12). Hence, this study was directed towards determining

if the variables chosen do predict tonnage estimates, and if a model can be developed for MAC's five geographic areas.

#### Research Objectives

The objectives for derivation of future SDT tonnage estimates and budget requirements are to:

1. Determine whether flying hours, manpower, or both are significantly reliable predictors of tonnage estimates.

2. Develop a computerized model for computation of SDT tonnage and budget estimates, if the variable(s) chosen are significantly reliable predictors.

#### Research Hypothesis

A computerized model can be developed to forecast tonnage and budget estimates, utilizing flying hours and/or manpower as predictors.

## CHAPTER II

### METHODOLOGY

The problem, as previously stated, is that a validated method does not exist for computation of tonnage estimates to derive future SDT budget requirements. The prime objective of this research was to determine whether flying hours, manpower, or both are significantly reliable predictors of tonnage estimates. If one or both of the variables were a reliable predictor, the second objective would be achieved through computerization of the optimal regression model chosen.

#### Data Acquisition

##### Variables Defined

Flying Hours: The independent variable, flying hours, is the total number of hours flown by the various Air Force aircraft which are (1) assigned to each overseas geographic area, or (2) transient in each overseas geographic area in excess of thirty days. The flying hours are not the hours flown by MAC cargo aircraft.

Manpower: The independent variable, manpower, is the total number of Air Force military personnel in each overseas geographic area.

Short Tons: The dependent variable, short tons, is the total number of tons of general military cargo transported by MAC to each overseas geographic area for support of Air Force programs and personnel. A short ton is measured as 2000 pounds. The terms tonnage and short tons are used interchangeably throughout this thesis.

#### Sample Plan

For the purpose of this research, the population is defined as all tonnage that has been and would be moved by MAC for all five overseas geographic areas. The sample consists of all tonnage transported by MAC during the time period 1 October 1973 to 31 March 1978, by quarter. Both actual and programmed data for this period were utilized. The decision was made to limit the sample in this manner because the influences of the Vietnam War were not considered representative of peacetime tonnage movements and because the data for the selected period were readily available.

#### Data Sources, Description and Validity

The actual and programmed data used to describe the variables were obtained from HQ AFLC/LORET. The data were accumulated from various sources within the Air Force<sup>4</sup> and were assumed to be valid as documented in accordance

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<sup>4</sup>See Appendix B for a list of data sources for the variables (12; 20; 21).

with Air Force directives (8; 12). It was further assumed that errors, if any, in data documentation at the working level and in the transmission to the computer systems were random in nature and did not affect the overall validity of the data.

#### Data Modification

The data received were for the period 1 October 1973 to 31 March 1978, by quarter, except for actual manpower data. Actual manpower data could only be obtained for the period 1 October 1974 to 30 September 1977, for all five geographic areas. Further, these data were *year-end* figures, that is, the end of the fourth quarter for fiscal year (FY) 1975, 1976, and 1977. Therefore, modification of the actual manpower data was necessary to:

1. Homologize this data with all other data for ease of manipulation and computation.
2. Provide a sufficient quantity of data points from which to mathematically develop tests and a model.
3. Avoid the loss of any explanatory power in development of a model if the data were not utilized.

To modify the data such that quarterly rather than year-end data were available, programmed manpower data were utilized to estimate quarterly actual manpower. First, programmed manpower data for fourth quarter FY73 (April-June 1973) was assumed to be a sufficient estimate of actual

manpower for the same period. Second, a linear relationship was assumed to exist between the fourth quarter of FY73 and the fourth quarter of FY75. Hence, quarterly estimates of actual manpower were obtained for FY74 and FY75. To obtain actual quarterly manpower data for FY76 and FY77, including fiscal quarter 7T, a linear relationship was assumed to exist from fourth quarter FY75 to fourth quarter FY76, and from fourth quarter FY76 to fourth quarter FY77.

Apprehension regarding the effects of the data modification is expected. However, to fully utilize available data, the procedure was the most logical. Since the actual manpower variable does not appear in the final model, the validity of the model has not been diminished.

#### Model Development

The differences between this research effort and the XRS study were twofold. First, XRS used a mixture of both actual and programmed data within one model in an attempt to provide support for flying hours as a predictor of tonnage estimates (4; 9). This research effort considered both actual and programmed data as separate entities to determine whether flying hours, manpower, or both were reliable predictors of tonnage estimates. Second, the previous study used sample data from the period FY73 to FY76 without consideration of the events associated with the Vietnam War (3:3; 4; 6). The current effort utilized data from the

period 1 October 1974 to 31 March 1978, thereby eliminating the effects of the Vietnam War.

The first step in any model development is to plot the data to determine what type of relationship exists, whether linear or curvilinear (10). As illustrated in Figures 1 and 2,<sup>5</sup> a linear relationship appears to exist between flying hours and tonnage, and manpower and tonnage. However, a gap, or discontinuity, between data points of the apparently linear relationship is evident in both figures. Whenever a linear regression function changes slope, and also jumps, the technique utilized to deal with the function is called discontinuous linear regression (10; 15:316). Linear regression analysis is a technique whereby one or more quantitative variables are used to predict the value of another quantitative variable (7:9; 10; 18:391).

#### Discontinuous Linear Regression

On occasion, a regression of "Z" on "X" and/or "Y" may not follow a uniform linear relation. The regression function may change slope at some point and/or may shift some constant value up or down with regards to the Z-axis. To account for the occurrences, discontinuous linear regression (DLR) must be used (15:313-316).

Upon examination of the scattergrams of the data, DLR seemed appropriate for discontinuities appeared to

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<sup>5</sup>See Appendix C for a listing of data utilized for the figures.

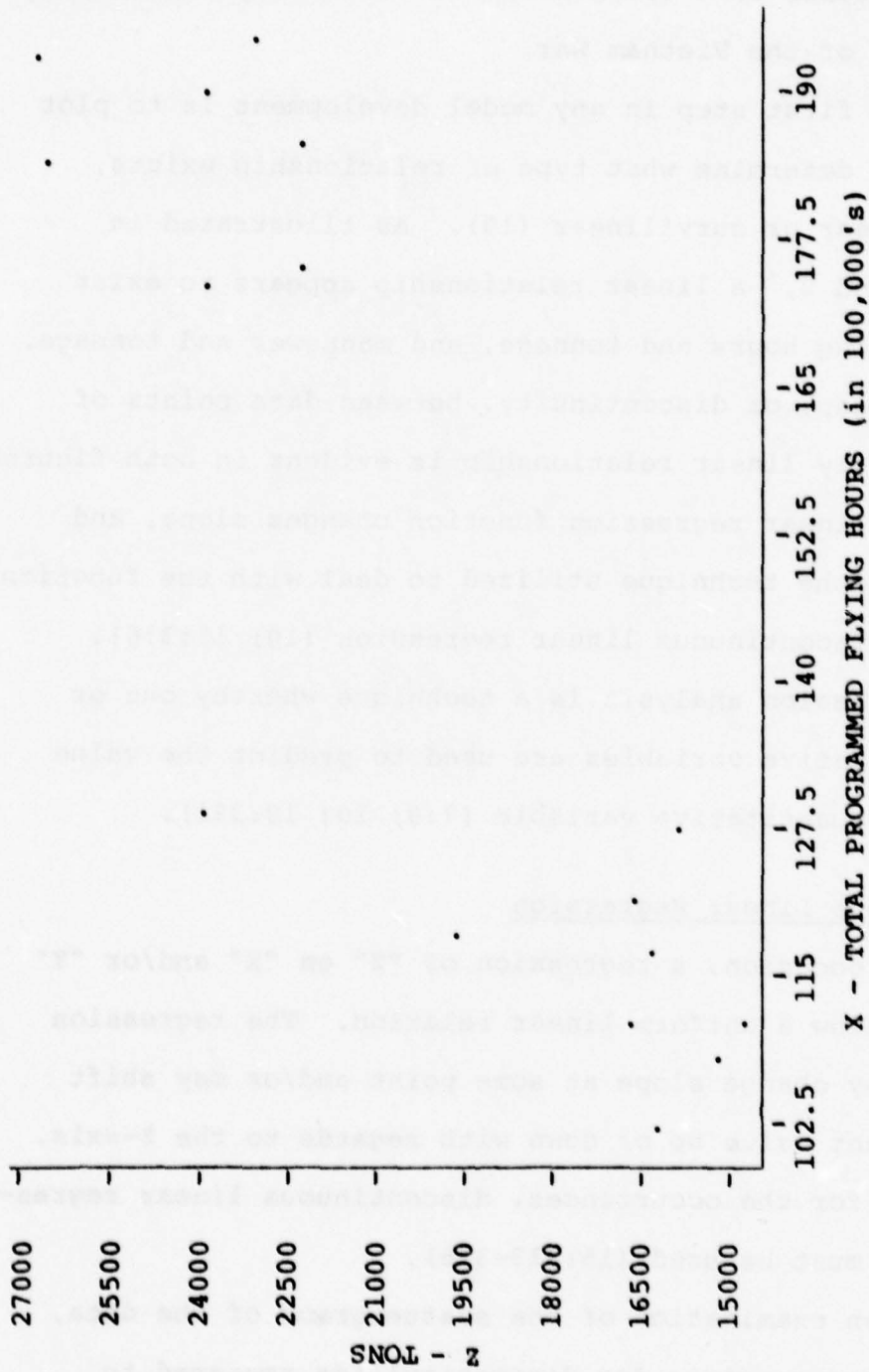


Fig. 1. Actual Tonnage Versus Total Programmed Flying Hours

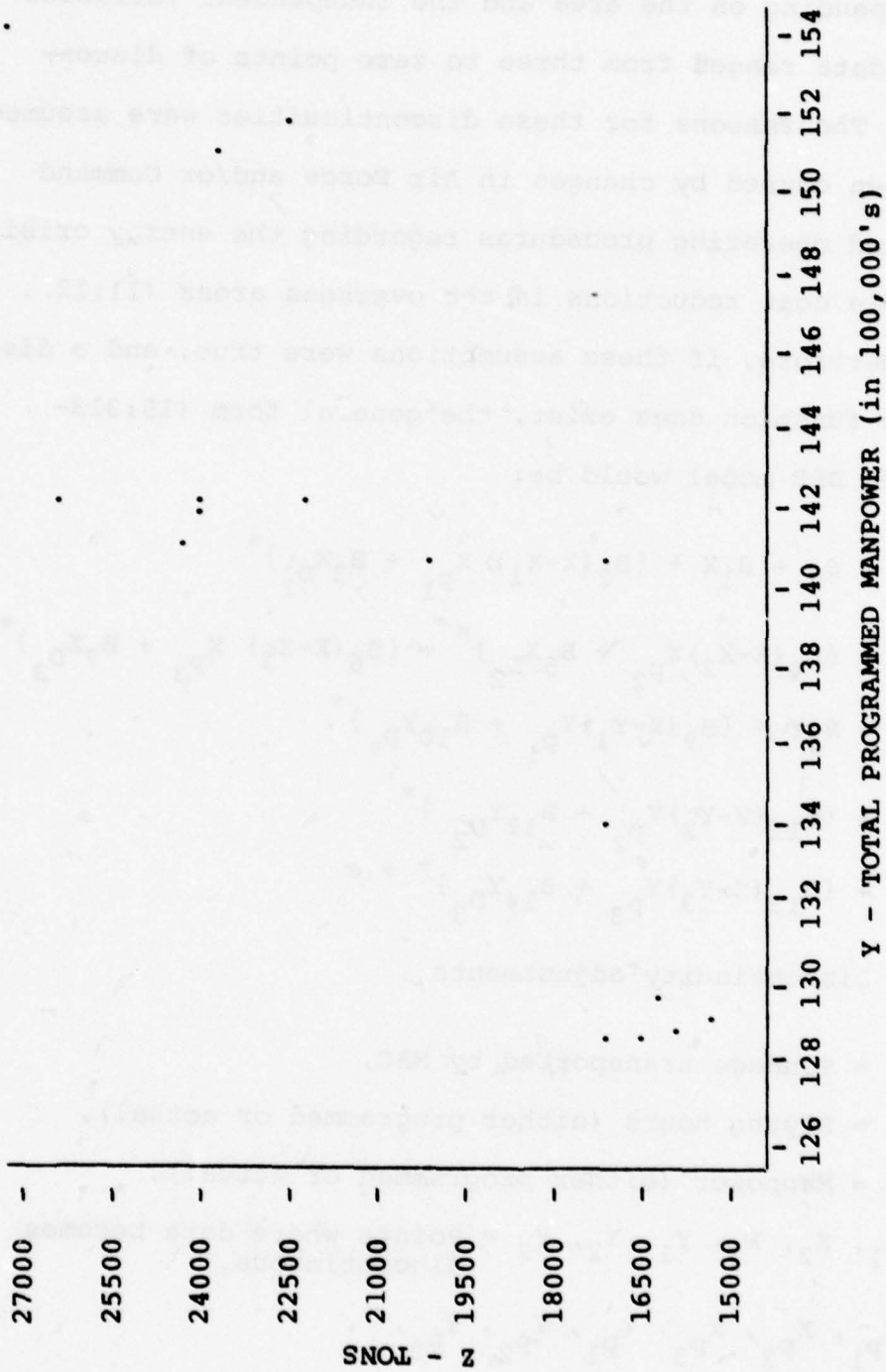


Fig. 2. Actual Tonnage Versus Total Programmed Manpower Authorizations

exist. Depending on the area and the independent variables used, the data ranged from three to zero points of discontinuity. The reasons for these discontinuities were assumed to have been caused by changes in Air Force and/or Command policies and operating procedures regarding the energy crisis, and possible cost reductions in the overseas areas (11:12).

Therefore, if these assumptions were true, and a discontinuous function does exist, the general form (15:313-316) of the DLR model would be:

$$\begin{aligned}
 Z = & B_0 + B_1X + \{B_2(X-X_1) X_{P_1} + B_3X_{D_1}\}^* \\
 & + \{B_4(X-X_2)X_{P_2} + B_5X_{D_2}\}^* + \{B_6(X-X_3) X_{P_3} + B_7X_{D_3}\}^* \\
 & + B_8Y + \{B_9(Y-Y_1)Y_{P_1} + B_{10}Y_{D_1}\}^* \\
 & + \{B_{11}(Y-Y_2)Y_{P_2} + B_{12}Y_{D_2}\}^* \\
 & + \{B_{13}(Y-Y_3)Y_{P_3} + B_{14}Y_{D_3}\}^* + e
 \end{aligned}$$

\* Discontinuity adjustments

where: Z = Tonnage transported by MAC,

X = Flying hours (either programmed or actual),

Y = Manpower (either programmed or actual),

$X_1, X_2, X_3, Y_1, Y_2, Y_3$  = Points where data becomes discontinuous,

$X_{P_1}, X_{P_2}, X_{P_3}, Y_{P_1}, Y_{P_2}, Y_{P_3}$ ,

$X_{D_1}, X_{D_2}, X_{D_3}, Y_{D_1}, Y_{D_2}, Y_{D_3}$  = Indicator (dummy variables) defined as:

$$X_{P_1} = X_{D_1} = \begin{cases} 1, & \text{if } X > X_1 \\ 0, & \text{otherwise} \end{cases}$$

$$X_{P_2} = X_{D_2} = \begin{cases} 1, & \text{if } X > X_2 \\ 0, & \text{otherwise} \end{cases}$$

$$X_{P_3} = X_{D_3} = \begin{cases} 1, & \text{if } X > X_3 \\ 0, & \text{otherwise} \end{cases}$$

$$Y_{P_1} = Y_{D_1} = \begin{cases} 1, & \text{if } Y > Y_1 \\ 0, & \text{otherwise} \end{cases}$$

$$Y_{P_2} = Y_{D_2} = \begin{cases} 1, & \text{if } Y > Y_2 \\ 0, & \text{otherwise} \end{cases}$$

$$Y_{P_3} = Y_{D_3} = \begin{cases} 1, & \text{if } Y > Y_3 \\ 0, & \text{otherwise} \end{cases}$$

$B_0, \dots, B_{14}$  = Coefficients of regression, and

$e$  = The explained component in each value that is not explained by the independent variables.

To illustrate how an equation was formulated, the following example is provided. In examining the scattergrams in Figures 1 and 2, discontinuities not only appeared to exist at 130,000 and 140,000 flying hours, but also at 130,000, 140,000 and 150,000 manpower authorizations. The general form of this example DLR equation now becomes:

$$\begin{aligned} Z = & B_0 + B_1X + \{B_2(X-130000)X_{P_1} + B_3X_{D_1}\} \\ & + \{B_4(X-140000)X_{P_2} + B_5X_{D_2}\} + B_8Y \\ & + \{B_9(Y-130000)Y_{P_1} + B_{10}Y_{D_1}\} \end{aligned}$$

$$\{B_{11}(Y-140000)Y_{P_2} + B_{12}Y_{D_2}\} \\ + \{B_{13}(Y-150000)Y_{P_3} + B_{14}Y_{D_3}\} + e$$

where:  $X_1 = 130,000,$   
 $X_2 = 140,000,$   
 $Y_1 = 130,000,$   
 $Y_2 = 140,000,$   
 $Y_3 = 150,000,$  and  
 $X_3 = X_{P_3} = X_{D_3} = B_6 = B_7 = 0.$

#### Basic Assumptions

The following assumptions were required to justify use of DLR and to fit the curve (regression line) to the independent data points.

1. The expected value, or mean, of each error component,  $e$ , was zero as measured with respect to the regression line.
2. The variance of the error components was constant.
3. The error components were uncorrelated, or statistically independent.
4. The error components were normally distributed about the regression line.
5. The number of sample observations was greater than the number of estimated population parameters.
6. Sample observations were linearly independent.

7. Measurement errors were associated with the dependent variable, not with the independent variables (10; 15:316; 18:545; 23:265).

Since multiple observations were not available for each data point, the assumptions could not be tested to verify justification. However, they were assumed to hold for the data being utilized.

#### Model Manipulation

A computer program, the Statistical Package for the Social Sciences (SPSS), was utilized for construction of the models through linear regression analysis. The Regression Subprogram was used to derive the DLR equations necessary for determination of the optimal regression model (16: 320-367).

First, a set of twelve equations was obtained utilizing SPSS: six equations utilizing programmed data and six equations utilizing actual data. Consider first the six equations obtained from the programmed data. The programmed data for each geographic area was used to derive an equation which could be used to predict the tonnage moved to that area. Thus, five equations were derived, one for each area. The last of the six equations was derived utilizing the total of all programmed data for all areas to predict total tonnage moved. The six equations utilizing actual data were similarly developed.

Second, from these twelve equations, four models were developed. Consider first the programmed data equations. The five area equations were summed, without loss of integrity to the individual equations, to form one model. In other words, each equation represented the tonnage moved to that area, and the total sum of these five areas was the total summed tonnage shipped. The last equation formed another model. The six equations utilizing actual data were similarly used to form two additional models.

Before comparing the models, an explanation of the equations' value inputs to be used is necessary. In using these models as predictive tools, actual value inputs could not be utilized because they would not exist. For example, in forecasting for FY82 in FY78, actual value inputs would not be available for that future period. Therefore, programmed value inputs would have to be used.

Finally, in determining which model was optimal, the mean average deviation (MAD) per quarter was used. Programmed data available for the period 1 October 1974 to 31 March 1978 was utilized to determine whether the tonnage estimated by each model was the same as the actual tonnage transported during the same period. The model which yielded the lowest MAD was considered the optimal model. The formula (17:663) used was:

$$MAD = \frac{t \sum_{i=1}^n |Z - \hat{Z}|}{n}, \quad n=1, \dots, 14$$

The optimal model was subjected to statistical and criteria tests to determine its validity, as specified in the next section. If the model failed to be valid, the second best model was to be tested, and so on until all models were exhausted. If any one of the models was statistically validated, external tests were applied to determine whether the ultimate model or the present delta factor method was most accurate.

Once the most accurate method was determined, a FORTRAN program was developed for computations of the tonnage and budget estimates (17:1-293).

#### Model Validation

##### Statistical Tests

The classical, or sampling-theory, hypothesis test was conducted to determine if a relationship existed between the dependent and independent variables (2:372).

For the final DLR model:

$$H_0: B_i = B_{i+1} = \dots = 0, i=1, \dots, p-1$$

$$H_1: \text{At least one } B \neq 0$$

where:  $p$  = The degrees of freedom lost due to  $b_0, b_1, \dots, b_{p-1}$  estimated simultaneously (10).

The F test, which was used in the DLR model, compared the  $F_0$  value, which was found using:

$$F_0 = \frac{\text{variation explained by regression}}{\text{unexplained variation}}$$

with the F critical,  $F_c$ , found in any statistics textbook. The  $F_0$  value must be greater than  $F_c$  to reject the null hypothesis,  $H_0$ , and to conclude a statistically significant relationship existed between the dependent and independent variables (2:395-397; 10; 18:549-550; 23:340).

An F test was also used to test for the problem of multicollinearity<sup>6</sup> in the DLR model (10). The test hypothesis (10) for the model was:

$$H_0: B_i = 0, \text{ for each } i; \text{ where } i=1, \dots, p-1$$

$$H_1: B_i \neq 0$$

The test statistic was:

$$F_0 = \frac{(\Delta EV) \text{ due to } X_i}{UV/n-p}$$

where:  $(\Delta EV)$  due to  $X_i$  = The change in explained variation attributable to the presence of a particular independent variable,  $X_i$ . Also referred to as the net or marginal contribution to EV,

$X_i$  = Independent variable, flying hours or manpower, where  $i=1, \dots, p-1$ ,

UV = Unexplained variation, and

n = The number of sample observations.

---

<sup>6</sup>Multicollinearity is the effect and existence of an inter-correlation between independent variables which reduces the ability to explicate the explanatory power as owing to the presence of a particular independent variable (10; 23: 292-295).

If the  $F_0$  value was greater than the  $F_c$  value, the null hypothesis,  $H_0$ , was rejected, thereby concluding that there was statistical significance to the regression of  $X_i$  at the designed equivalent- $\alpha$  level of significance, which was:

$$\text{equivalent-}\alpha = \frac{\alpha}{p-1}$$

All independent variables were tested simultaneously.

Although multicollinearity may cause statistical significance tests to fail, the predictive ability of the final model would not be necessarily impaired (10).

#### Criteria Tests

A subjectively chosen level of confidence of 90 percent was used to determine the statistical significance of the results of the DLR model. This confidence level was chosen because it is a generally accepted criteria test for new research (10).

A criterion used to evaluate the predictive power of the model was a subjective test on the coefficient of determination ( $R^2$ ). This coefficient, referred to as the measure of efficiency of the regression line, was computed as part of the SPSS output, but could be found (18:412) using:

$$R^2 = \frac{\text{variation explained by regression}}{\text{total variation}}$$

An  $R^2$  approximately equal to 0.80 is normally considered sufficient to conclude that a model is effective in predicting the dependent variable (10; 18:408-413,548; 23:341-342). The model with the highest predictive power was preferred.

#### External Test

To test the final model in real world terms, programmed data available for the period 1 October 1974 to 31 March 1978, was utilized to determine whether the tonnage estimated by the model was the same as the actual tonnage transported during the same period. The model's predictions were compared with the predictions obtained from the present delta method, utilizing the mean average deviation (MAD) per quarter. The following formula (18:663) was used:

$$MAD = \frac{\sum_{t=1}^n Z - \hat{Z}}{n}, n=1, \dots, 14$$

An improvement in overall estimation was expected from the final research model. However, if the model was not more accurate, the second objective could not be met.

#### Limitations

The model developed from this research will be valid only for predicting estimates of tonnage programmed to be transported by MAC for the total of the overseas areas.

Any inferences to other modes of transportation must be based on a subjective evaluation of the respective situation.

## CHAPTER III

### MODEL DETERMINATION

This chapter includes a summary of results from the SPSS Regression Subprogram. The data utilized to compute the twelve equations are listed in Appendix D. The DLR equations and the residuals by area by quarter, are listed in Appendices E and F, respectively. Interpretation of the results provides the reasons for selection of the final model, which was considered most applicable in determining tonnage estimates.

#### Presentation of Results

Tables 1 and 2 illustrate the results of the statistical tests for each of the twelve equations. The mean average deviation (MAD) for each equation was computed utilizing the residuals listed in Appendix F.

#### Interpretation of Results

Before discussing the four models which were developed, an explanation of why the Southern area showed such a low  $R^2$  and why the data was not statistically significant seems appropriate. A review of the data revealed that only 322 short tons per quarter on the average were shipped to that area. Deviations in tonnage from the

TABLE 1  
OUTPUT WITH PROGRAMMED DATA

Area \ Statistics	$R^2$	$F_o^*$	$F_c$	df**	MAD***
European	0.595	5.881	2.61	3, 12	49
Pacific	0.949	27.935	2.55	6, 9	-315
Alaskan	0.467	5.699	2.76	2, 13	- 36
Southern	0.088	0.625	2.76	2, 13	- 3
Northeastern	0.902	36.637	2.61	3, 12	- 27
Total Data	0.886	31.212	2.61	3, 12	- 8

\*If  $F_o > F_c$ , the results are statistically significant.

\*\*With an  $\alpha$  level of 0.10, the df (degrees of freedom) are indicated with the upper and lower values.

\*\*\*MAD is the mean average deviation from actual tonnage per quarter of the equation's forecast.

TABLE 2  
OUTPUT WITH ACTUAL DATA

Area \ Statistics	$R^2$	$F_o^*$	$F_c$	df**	MAD***
European	0.577	5.445	2.61	3, 12	-2358
Pacific	0.991	164.170	2.55	6, 9	292
Alaskan	0.671	8.161	2.61	3, 12	- 215
Southern	0.059	0.407	2.76	2, 13	- 37
Northeastern	0.921	31.914	2.54	4, 11	- 214
Total Data	0.902	36.705	2.61	3, 12	1120

\*If  $F_o > F_c$ , the results are statistically significant.

\*\*With an  $\alpha$  level of 0.10, the df (degrees of freedom) are indicated with the upper and lower values.

\*\*\*MAD is the mean average deviation from actual tonnage per quarter of the equation's forecast.

average without proportional-like deviations in flying hours and manpower drastically reduced the predictive power of the equation. As shown in Appendix F, the actual tonnage moved fluctuated without corresponding changes in flying hours and manpower. Thus, the results showed a low correlation and an equation which was not statistically significant. However, because less than 2 percent of the total tonnage moved was shipped to the Southern area, the absence of a high correlation would not have a significant impact on the overall model.

The four models were developed from the twelve equations as previously stated. The models, two utilizing programmed data and two utilizing actual data, were compared to determine which was the most optimal as indicated by the lowest MAD value.

The first model, developed from the five area equations summed using programmed data, had a MAD of -332 short tons per quarter. The second model, which was the total of all programmed data, had a MAD of -8 short tons per quarter. The third model, developed from the five area equations summed using actual data had a MAD of -2531 short tons per quarter. The fourth model, which was the total of all actual data, had a MAD of 1120 short tons per quarter. The negative short tons indicated that the model overestimated tonnage requirements for the period 1 October 1974 to 31 March 1978.

Clearly, the second model yielded the most optimal result. This model was tested to determine its validity. If the model failed to be valid, the first model would be tested, as indicated in Chapter II.

#### Final Model Validation

Based on the results of the analysis in Table 1 and the tests established in Chapter II, the Total Data equation was statistically significant. In other words, a significant relationship existed between the independent variables and the dependent variable (2:395-397; 10; 18:549-550; 23:340). Also, the  $R^2$  of 0.886 was greater than the previously established criterion of 0.80. This indicated that the model was effective in predicting the dependent variable (10; 18:408-413,458; 23:341-342). Therefore, the model was considered to be statistically valid.

The final model was practical because of its pervasiveness. Fluctuations in the individual areas were counteracted by each other, thereby balancing the overall effects of the separate areas. In addition, the final model, which utilized programmed data, produced more accurate results, according to the MADs, than did the two models using actual data. This was because the latter two models yielded results which were predicated on programmed inputs into equations derived from actual data. Logically, the

final model was the most valid because programmed inputs were used to forecast programmed tonnage.

### Final Model Validation

Based on the results of the analysis in Table 1 and the tests established in Chapter II, the final regression equation was statistically significant. In other words, a significant relationship existed between the independent variable and the dependent variable (2.155-197; 10.18-249-250, 21-240). Also, the  $r^2$  of 0.886 was greater than the previously established criterion of 0.80. This indicated that the model was effective in predicting the dependent variable (10.18-249-250; 21-240). Therefore, the model was considered to be statistically valid.

The final model was practical because of its parsimony. Predictions in the individual cases were compared by each other, thereby balancing the overall effects of the separate cases. In addition, the final model which utilized programmed data, produced more accurate results, according to the NBS, than did the two models using actual data. This was because the latter two models yielded results which were produced on programmed inputs. These operations derived from actual data. Logically, the

## CHAPTER IV

### MODEL VALIDATION

The data for the estimates computed from the present Delta ( $\Delta$ ) Method used by AFLC/LORET and for the actual tonnage shipped overseas were obtained from LORET (12) (see Table 3). The estimates for the final model were part of the SPSS output.

#### Presentation and Interpretation of Results

Ordinarily, an overestimation of tonnage is better than an underestimation for various reasons (12). First, an overestimation of tonnage would provide a sufficient budget to meet unforeseen surges in tonnage requirements. Second, with a reasonable excess of funds, the increased costs of inflation could be met. Finally, an overestimation would preclude the necessity to request and await additional funds to move needed tonnage overseas.

However, continuous overestimation can cause problems. One is that the creditability of office submitting the budget may be questioned. Another problem is that substantial justification may become necessary to obtain funds. Finally, funds that may be needed elsewhere are not being utilized to the full extent possible.

TABLE 3  
COMPARISON OF METHODS

FY QTR	Actual Tonnage (Z)	Δ Method		Final Model	
		$\hat{Z}$	Z- $\hat{Z}$	$\hat{Z}$	Z- $\hat{Z}$
75-2	23895	25898	-2003	23762	133
-3	22233	26083	-3850	23774	-1541
-4	23905	27286	-3381	23813	92
76-1	24102	21984	2118	23512	590
-2	19748	20224	- 476	17703	2045
-3	16778	19224	-2446	17683	- 905
-4	17123	20180	-3057	17004	119
77-T	16315	20228	-3913	16642	- 327
-1	16569	18008	-1449	16473	96
-2	15899	18913	-3024	16491	- 592
-3	17109	19046	-1937	16478	631
-4	15452	19212	-3760	16519	-1067
78-1	16904	18786	-1882	15955	949
-2	15634	19662	-4028	15970	- 336

The Delta Method has caused such problems for AFLC/LORET. As shown in Table 3, the method excessively overestimated tonnage to be moved for thirteen of the fourteen quarters. The MAD value was -2363 short tons per quarter. Since tonnage for each area was computed separately, the summed total did not consider fluctuations. The average overestimation of tonnage to be moved per quarter was 12.64 percent of what was actually moved.

The final model overestimated tonnage in six of the fourteen quarters, producing a MAD value of -8 short tons per quarter. The tonnage overestimation was 0.04 percent per quarter. The model provided a closer estimate of tonnage moved in every quarter except for FY76-2. This exception resulted from the fact that more tonnage was shipped than was expected although actual flying hours and manpower decreased significantly (see Appendix D, Total Data). Yet overall, the model developed provided a more accurate estimation of tonnage to be moved.

#### Computerization of the Final Model

The SPSS program required to derive the variables and their coefficients used in the final model is listed in Appendix G. The FORTRAN program necessary to compute the budget estimate per area per quarter is listed in Appendix H. The cost per ton per area is an input to the FORTRAN program and is not a concern in this research effort.

## CHAPTER V

### CONCLUSIONS AND RECOMMENDATIONS

#### Conclusions

The purpose of this research was to develop a better method for computing tonnage estimates which are used to derive future budget requirements. Discontinuous Linear Regression provided a more accurate estimation of tonnage to be moved than did the current Delta Method.

In development of the final model, several areas required consideration. First, of the many independent variables affecting tonnage, only two, flying hours and manpower, were known to be predictive in nature and programmed for future years. Second, although the SDT is divided into six major categories, only one, MAC, has an information system capable of providing necessary data of tonnage actually moved. Finally, the data sample had to be representative of the current situation so as to provide a more realistic comparison.

Once these judgements were made, the determination of the final model depended on the reliability and validity of the variables and data, and whether actual or programmed data would provide the optimal solution. As was shown, the final model was developed utilizing both programmed

flying hours and manpower. The comparison between the Delta Method and the final model illustrated that the latter provided a more accurate estimate of tonnage to be moved.

With the development of the computer programs, several advantages of the final model over the Delta Method are evident. First, the base period need not be arbitrarily chosen for each area since the final estimates will directly relate to changes in the independent variables. Next, manual computations will not be necessary, and results can be obtained faster. Third, the model has been shown to be a valid technique which provides a closer, quarterly estimation of tonnage. Finally, and probably the most important, justification for over or underestimations can be understandably and clearly explained to higher echelons. A more accurate picture of tonnage to be moved and of the funds necessary to support these shipments should insure future budget allocations are not in excess of those required.

Finally, the model and the programs developed in this research effort are adaptive. Their value will increase as more data are accumulated. The discontinuity should be absent within two years, providing the present circumstances are not drastically altered as was the case in 1973 and 1975. With the elimination of any discontinuity through substitution of FY78 and FY79 data for FY74 and FY75 data, a simpler multiple linear regression can be used

to compute tonnage estimates. The use of hand calculators should suffice, and would be as fast as the larger computers.

#### Recommendations

Regarding future research in the area of SDT tonnage and/or budget estimates, consideration should be given to these additional subjects:

1. The use of MAC as a data source should be expanded to include the other SDT categories, when and if adequate information systems are developed.
2. Determine which variables affect the short tons moved by LOGAIR and how tonnage estimates can be developed.
3. The inclusion of other independent variables should be considered, if they can be programmed for future years.
4. A better method for determination of the cost per ton per geographic area per mode is one subject which should provide a more accurate estimate of budget requirements.

#### Summary

The two objectives of this research effort were accomplished. First, the final model revealed that both programmed flying hours and manpower were reliable predictors of tonnage estimates. Second, a computerized model was

developed for determination of tonnage and budget estimates with programmed flying hours, manpower, and cost per ton as inputs.

Recommendations

1. The use of a data source should be expanded to include the other DOT categories, when it is possible to do so.

2. The inclusion of other independent variables should be considered, if they can be programmed for future years.

3. A better method for determination of the cost per ton should be developed, which should provide a more accurate estimate of budget requirements.

4. The use of a data source should be expanded to include the other DOT categories, when it is possible to do so.

5. The inclusion of other independent variables should be considered, if they can be programmed for future years.

References

The use of a data source should be expanded to include the other DOT categories, when it is possible to do so. The inclusion of other independent variables should be considered, if they can be programmed for future years. A better method for determination of the cost per ton should be developed, which should provide a more accurate estimate of budget requirements.

APPENDICES

APPENDIX A  
LIST OF XRS VARIABLES

<u>Variable</u>	<u>Data Source</u>
Requisitions Filled	AFLC/ACM
Requisitions	AFLC/ACM
Aircraft	AFLC/ACM
Engines	AFLC/ACM
Receipts GSD*	AFLC/LORF
Gross Sales GSD	AFLC/LORF
Gross Sales SSD**	AFLC/LORF
DPEM*** - Aircraft	AFLC/LORER
DPEM - Missiles	AFLC/LORER
DPEM - Engines	AFLC/LORER
DPEM - Other Major End Items	AFLC/LORER
DPEM - Exchangeables	AFLC/LORER
DPEM - Area Base Maintenance	AFLC/LORER
DPEM - Total	AFLC/LORER
Overseas Flying Hours	G022B System
Worldwide Flying Hours	G033B System
Receipts Off Base - Line Items	LOG-XR(Q) 7507
Receipts Off Base - Tons	LOG-XR(Q) 7507
Issues Off Base - Line Items	LOG-XR(Q) 7507
Issues Off Base - Tons	LOG-XR(Q) 7507
Manpower	USAF/PMR

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\*GSD: General Support Division  
 \*\*SSD: System Support Division  
 \*\*\*DPEM: Depot Purchased Equipment Maintenance

APPENDIX B  
DATA SOURCES FOR RESEARCH VARIABLES

Variables

Data Sources

I. Actual

1. Flying Hours, Overseas
2. Manpower, Overseas
3. Short Tons

G033B System  
HQ USAF/PRMP  
0027A MAC TONS/  
COST SYSTEM

II. Programmed

1. Flying Hours, Overseas
2. Manpower, Overseas

PA 75-2 to PA 79-2  
PM 75-2 to PM 79-2

APPENDIX C  
DATA FOR FIGURES 1 AND 2

<u>Fiscal Year</u>	<u>Quarter</u>	<u>Programmed Flying Hours</u>	<u>Programmed Manpower</u>	<u>Actual Tonnage</u>
1974	2	190709	154200	26843
	3	183069	152050	22239
	4	188616	151310	23512
1975	1	184068	142431	26399
	2	174914	142250	23895
	3	176267	142319	22233
	4	185665	142369	23905
1976	1	130414	141358	24102
	2	119099	140879	19748
	3	114029	140873	16778
	4	121080	133697	17123
1977	T	124631	129889	16315
1977	1	103265	128958	16569
	2	108466	128949	15899
	3	109735	128765	17109
	4	110248	129169	15452

APPENDIX D  
DATA FOR SPSS COMPUTATION BY AREA

EUROPEAN AREA

<u>FY-QTR</u>	<u>Z</u>	<u>X1</u>	<u>Y1</u>	<u>X2</u>	<u>Y2</u>
74-2	9847	65165	71519	44928	68444
-3	7499	66872	71518	48297	68460
-4	8434	72811	71581	57189	68475
75-1	9868	66167	69226	56187	68491
-2	8877	63382	69323	53200	68506
-3	7701	64172	69364	50402	68522
-4	7479	72830	69368	59430	68537*
76-1	7876	67113	67713	64171	68934
-2	7522	58950	67768	51821	69331
-3	6576	59072	67790	51897	69728
-4	5650	67007	67761	42781	70125*
77-T	6469	70991	67009	49861	70345
-1	8003	55223	67038	50499	70565
-2	7652	56272	67029	53576	70784
-3	8122	60384	66922	61441	71004
-4	7940	59550	66913	64078	71224*
78-1	8680	65292	66455		
-2	7563	66519	66455		

Where: Z = Actual Short Tons Moved  
X1 = Programmed Flying Hours  
Y1 = Programmed Manpower  
X2 = Actual Flying Hours  
Y2 = Actual Manpower

Suspected Points of Discontinuity:

X1 = 66500  
Y1 = 67600, 69000, 70500  
X2 = 46000, 58000  
Y2 = 68800, 7000

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\*Actual year-end data which was used to determine remaining data. See Chapter II, Data Modification.

PACIFIC AREA

<u>FY-QTR</u>	<u>Z</u>	<u>X1</u>	<u>Y1</u>	<u>X2</u>	<u>Y2</u>
74-2	12712	107324	63011	74282	74634
-3	11122	97578	60865	80409	72406
-4	11471	96453	60124	81864	70178
75-1	12362	99594	56229	73204	67949
-2	10872	93874	55959	68050	65721
-3	10529	94123	55958	67530	63493
-4	12250	94136	55982	58156	61265*
76-1	12437	48156	57284	51712	57093
-2	9185	45757	56734	36387	52921
-3	7114	40378	56702	31821	48750
-4	8007	38808	49692	27445	44578*
77-T	6593	41044	47118	30691	43679
-1	5670	37037	46168	33625	42780
-2	5629	39359	46168	34231	41880
-3	5977	37492	46095	34327	40981
-4	4829	38647	46508	34405	40082*
78-1	5350	38970	41530		
-2	5632	41150	41530		

Where: Z = Actual Short Tons Moved  
X1 = Programmed Flying Hours  
Y1 = Programmed Manpower  
X2 = Actual Flying Hours  
Y2 = Actual Manpower

Suspected Points of Discontinuity:

X1 = 70000  
Y1 = 49000, 53000, 60000  
X2 = 36000, 51000, 70000  
Y2 = 48000, 62000

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\*Actual year-end data which was used to determine remaining data. See Chapter II, Data Modification.

ALASKAN AREA

<u>FY-QTR</u>	<u>Z</u>	<u>X1</u>	<u>Y1</u>	<u>X2</u>	<u>Y2</u>
74-2	2016	10684	13237	9430	12553
-3	1716	10963	13234	10412	12411
-4	1877	11696	13235	11507	12269
75-1	2276	13319	12760	11652	12127
-2	2155	12155	12752	7401	11985
-3	2131	12469	12781	8081	11843
-4	2160	13176	12803	9085	11701*
76-1	2310	10128	12095	8124	11603
-2	1973	9485	12139	7825	11506
-3	1716	9697	12138	8022	11408
-4	1794	10128	12056	7550	11310*
77-T	2023	9718	11622	8973	11109
-1	1792	8217	11616	7707	10907
-2	1652	9514	11616	9954	10706
-3	1676	8981	11612	8722	10504
-4	1713	9155	11612	8629	10303*
78-1	1972	8477	11211		
-2	1351	7860	11211		

Where: Z = Actual Short Tons Moved  
X1 = Programmed Flying Hours  
Y1 = Programmed Manpower  
X2 = Actual Flying Hours  
Y2 = Actual Manpower

Suspected Points of Discontinuity:

X1 = None  
Y1 = 12000, 12500, 13000  
X2 = None  
Y2 = 12200

---

\*Actual year-end data which was used to determine remaining data. See Chapter II, Data Modification.

SOUTHERN AREA

<u>FY-QTR</u>	<u>Z</u>	<u>X1</u>	<u>Y1</u>	<u>X2</u>	<u>Y2</u>
74-2	548	5736	2346	2636	2437
-3	330	5856	2346	3148	2536
-4	276	5856	2346	2923	2636
75-1	364	3004	2251	3363	2735
-2	286	3164	2251	2552	2834
-3	335	3164	2251	2277	2934
-4	343	3164	2251	2410	3033*
76-1	295	2743	2168	1850	2851
-2	294	2743	2168	1289	2670
-3	370	2743	2168	2100	2488
-4	333	2863	2164	1652	2306*
77-T	340	1440	2057	1548	2306
-1	388	1440	2053	1733	2307
-2	304	2109	2053	1705	2307
-3	370	1440	2053	2626	2308
-4	207	1440	2152	2280	2308*
78-1	330	1440	1979		
-2	320	1440	1979		

Where: Z = Actual Short Tons Moved  
X1 = Programmed Flying Hours  
Y1 = Programmed Manpower  
X2 = Actual Flying Hours  
Y2 = Actual Manpower

Suspected Points of Discontinuity:

X1 = 1500, 4500  
Y1 = 2100, 2200, 2300  
X2 = None  
Y2 = 2400, 2700

---

\*Actual year-end data which was used to determine remaining data. See Chapter II, Data Modification.

NORTHEASTERN AREA

<u>FY-QTR</u>	<u>Z</u>	<u>X1</u>	<u>Y1</u>	<u>X2</u>	<u>Y2</u>
74-2	1720	1800	4087	1697	3399
-3	1572	1800	4087	1701	3231
-4	1454	1800	4087	2028	3062
75-1	1529	1984	1965	2089	2894
-2	1705	2339	1965	1708	2725
-3	1537	2339	1965	1843	2557
-4	1673	2359	1965	2008	2388*
76-1	1184	2274	2050	1349	2229
-2	774	2164	2050	1336	2070
-3	1002	2139	2075	1363	1910
-4	1339	2274	2024	1088	1751*
77-T	890	1438	2083	1006	1699
-1	716	1348	2083	1221	1647
-2	662	1212	2083	1218	1596
-3	964	1438	2083	1416	1544
-4	763	1456	2083	1257	1492*
78-1	772	1420	2064		
-2	768	1420	2038		

Where: Z = Actual Short Tons Moved  
X1 = Programmed Flying Hours  
Y1 = Programmed Manpower  
X2 = Actual Flying Hours  
Y2 = Actual Manpower

Suspected Points of Discontinuity:

X1 = 1700, 2000  
Y1 = 4000  
X2 = 1000, 1600  
Y2 = 2000, 2800

---

\*Actual year-end data which was used to determine remaining data. See Chapter II, Data Modification.

TOTAL DATA

<u>FY-QTR</u>	<u>Z</u>	<u>X1</u>	<u>Y1</u>	<u>X2</u>	<u>Y2</u>
74-2	26843	190709	154200	132973	161467
-3	22239	183069	152050	143967	159044
-4	23512	188616	151310	155511	156620
75-1	26399	184068	142431	146495	154196
-2	23895	174914	142250	134911	151771
-3	22233	176267	142319	130133	149349
-4	23905	185665	142369	131089	146924*
76-1	24102	130414	141358	127206	142710
-2	19748	119099	140879	98658	138498
-3	16778	114029	140873	95203	134284
-4	17123	121080	133697	80516	130070*
77-T	121080	124631	129889	92079	129138
-1	16569	103265	128958	94785	128206
-2	15899	108466	128949	100684	127273
-3	17109	109735	128765	108532	126341
-4	15452	110248	129169	110659	125409*
78-1	16904	115599	123239		
-2	15634	120387	123213		

Where: Z = Actual Short Tons Moved  
X1 = Programmed Flying Hours  
Y1 = Programmed Manpower  
X2 = Actual Flying Hours  
Y2 = Actual Manpower

Suspected Points of Discontinuity:  
X1 = 130000, 140000  
Y1 = 130000, 140000, 150000  
X2 = 127000  
Y2 = 140000

---

\*Actual year-end data which was used to determine remaining data. See Chapter II, Data Modification.

APPENDIX E  
DERIVED EQUATIONS BY AREA

PROGRAMMED

European:

$$Z = -16845.49010 + 0.09428X + 0.28292Y - 2050.76151X_{D_1}$$

Where: Z = Short Tons  
X = Flying Hours  
Y = Manpower  
 $X_{D_1} = \begin{cases} 1, & \text{if } X > 66500 \\ 0, & \text{otherwise} \end{cases}$

All remaining variables = 0

Pacific:

$$Z = -4391.18216 + 0.55141X - 0.24170Y + 541.44135Y_{D_3} \\ - 17285.71810X_{D_1} - 0.35122(X-70000)X_{P_1} + 3033.02733Y_{D_1}$$

Where: Z = Short Tons  
X = Flying Hours  
Y = Manpower  
 $X_{D_1} = X_{P_1} = \begin{cases} 1, & \text{if } X > 70000 \\ 0, & \text{otherwise} \end{cases}$   
 $Y_{D_1} = \begin{cases} 1, & \text{if } Y > 49000 \\ 0, & \text{otherwise} \end{cases}$   
 $Y_{D_3} = \begin{cases} 1, & \text{if } Y > 60000 \\ 0, & \text{otherwise} \end{cases}$

All remaining variables = 0

Alaskan:

$$Z = 1774.46948 + 0.12407X - 0.09345Y$$

Where: Z = Short Tons  
X = Flying Hours  
Y = Manpower

All remaining variables = 0

Southern:

$$Z = 303.97209 + 0.01443X - 0.00532Y$$

Where: Z = Short Tons  
X = Flying Hours  
Y = Manpower

All remaining variables = 0

Northeastern:

$$Z = 12777.38987 + 0.14928X - 5.85725Y + 143.38485(Y-4000)Y_{P_1}$$

Where: Z = Short Tons  
X = Flying Hours  
Y = Manpower  
 $Y_{P_1} = \begin{cases} 1, & \text{if } Y > 4000 \\ 0, & \text{otherwise} \end{cases}$

All remaining variables = 0

Total Data:

$$Z = 3420.16333 + 0.00365X + 0.09829Y + 5721.21114X_{D_1}$$

Where: Z = Short Tons  
X = Flying Hours  
Y = Manpower  
 $X_{D_1} = \begin{cases} 1, & \text{if } X > 130000 \\ 0, & \text{otherwise} \end{cases}$

All remaining variables = 0

ACTUAL

European:

$$Z = 126468.43720 - 0.00941X - 1.71398Y + 3.74566(Y-70000)Y_{P_2}$$

Where: Z = Short Tons  
X = Flying Hours  
Y = Manpower  
 $Y_{P_2} = \begin{cases} 1, & \text{if } Y > 70000 \\ 0, & \text{otherwise} \end{cases}$

All remaining variables = 0

Pacific:

$$Z = 11980.50391 - 0.31119X + 0.10060Y + 7648.24262X_{D_2} \\ + 3204.03004X_{D_1} + 2034.87252X_{D_3} + 0.15037(X-51000)X_{P_2}$$

Where: Z = Short Tons  
X = Flying Hours  
Y = Manpower  
 $X_{D_1} = \begin{cases} 1, & \text{if } X > 36000 \\ 0, & \text{otherwise} \end{cases}$   
 $X_{D_2} = X_{P_2} = \begin{cases} 1, & \text{if } X > 51000 \\ 0, & \text{otherwise} \end{cases}$   
 $X_{D_3} = \begin{cases} 1, & \text{if } X > 70000 \\ 0, & \text{otherwise} \end{cases}$

All remaining variables = 0

Alaskan:

$$Z = -2051.00354 + 0.01744X + 0.34045Y - 486.92236Y_{D_1}$$

Where: Z = Short Tons  
X = Flying Hours  
Y = Manpower  
 $Y_{D_1} = \begin{cases} 1, & \text{if } Y > 12200 \\ 0, & \text{otherwise} \end{cases}$

All remaining variables = 0

Southern:

$$Z = 417.60027 + 0.02530X - 0.05395Y$$

Where: Z = Short Tons  
X = Flying Hours  
Y = Manpower

All remaining variables = 0

Northeastern:

$$Z = -1509.42140 + 2.38735X + 0.07210Y \\ - 870.50057X_{D_1} - 2.59719(X-1600)X_{P_2}$$

Where: Z = Short Tons  
X = Flying Hours  
Y = Manpower  
 $X_{D_1} = \begin{cases} 1, & \text{if } X > 1100 \\ 0, & \text{otherwise} \end{cases}$   
 $X_{P_2} = \begin{cases} 1, & \text{if } X > 1600 \\ 0, & \text{otherwise} \end{cases}$

All remaining variables = 0

Total Data:

$$Z = 1325.18607 - 0.02762X + 0.14046Y + 5165.17698X_{D_1}$$

Where: Z = Short Tons  
X = Flying Hours  
Y = Manpower  
 $X_{D_1} = \begin{cases} 1, & \text{if } X > 127000 \\ 0, & \text{otherwise} \end{cases}$

All remaining variables = 0

APPENDIX F  
RESIDUALS BY AREA BY QUARTER

EUROPEAN

<u>FY-QTR</u>	<u>Z</u>	<u>Actual</u>		<u>Programmed</u>	
		<u>Ẑ</u>	<u>Z-Ẑ</u>	<u>Ẑ</u>	<u>Z-Ẑ</u>
75-2	8877	7054	1823	8743	134
-3	7701	6976	725	8829	-1128
-4	7479	6888	591	7596	- 117
76-1	7876	9696	-1820	6620	1274
-2	7522	9726	-2204	7891	- 369
-3	6576	9722	-3146	7903	-1327
-4	5650	9697	-4047	6592	- 942
77-T	6469	10948	-4479	6755	- 286
-1	8003	11047	-3044	7327	676
-2	7652	11053	-3401	7424	228
-3	8122	11197	-3075	7781	341
-4	7940	11221	-3281	7700	240
78-1	8680	11951	-3260	8112	568
<u>-2</u>	7563	11940	<u>-4377</u>	6176	<u>1387</u>
14			-32995		679

<u>PACIFIC</u>					
<u>FY-QTR</u>	<u>Z</u>	<u>Actual</u>		<u>Programmed</u>	
		<u>Ẑ</u>	<u>Z-Ẑ</u>	<u>Ẑ</u>	<u>Z-Ẑ</u>
75-2	10872	7731	3141	11209	- 337
-3	10529	7691	2838	11259	- 730
-4	12250	7692	4558	11256	994
76-1	12437	5962	5475	11350	1087
-2	9185	6653	2532	10160	- 975
-3	7114	8324	-1210	7202	- 88
-4	8007	8107	- 100	8031	- 24
77-T	6593	7152	- 559	6853	- 260
-1	5670	8303	-2633	4873	797
-2	5629	7581	-1952	6153	- 524
-3	5977	8155	-2178	5141	836
-4	4829	7837	-3008	5678	- 849
78-1	5350	7235	-1885	7059	-1709
<u>-2</u>	5632	6557	<u>- 925</u>	8262	<u>-2630</u>
14			4094		-4412

ALASKAN

<u>FY-QTR</u>	<u>z</u>	<u>Actual</u>		<u>Programmed</u>	
		<u><math>\hat{z}</math></u>	<u><math>z-\hat{z}</math></u>	<u><math>\hat{z}</math></u>	<u><math>z-\hat{z}</math></u>
75-2	2155	2015	140	2091	64
-3	2131	2031	100	2127	4
-4	2160	2051	109	2213	- 53
76-1	2310	2243	67	1901	409
-2	1973	2247	-274	1817	156
-3	1716	2250	-534	1843	-127
-4	1794	2230	-436	1904	-110
77-T	2023	2075	- 52	1894	129
-1	1792	2047	-255	1708	84
-2	1652	2070	-418	1869	-217
-3	1676	2059	-383	1804	-128
-4	1713	2062	-349	1825	-122
78-1	1772	1914	-142	1779	- 7
<u>-2</u>	1351	1938	<u>-578</u>	1950	<u>-599</u>
14			-3014		-507

SOUTHERN

<u>FY-QTR</u>	<u>Z</u>	<u>Actual</u>		<u>Programmed</u>	
		<u><math>\hat{Z}</math></u>	<u><math>Z - \hat{Z}</math></u>	<u><math>\hat{Z}</math></u>	<u><math>Z - \hat{Z}</math></u>
75-2	286	376	-90	338	-52
-3	335	376	-41	338	- 3
-4	343	376	-33	338	5
76-1	295	370	-75	332	-37
-2	294	370	-76	332	-38
-3	370	370	0	332	38
-4	333	373	-40	334	- 1
77-T	340	343	- 3	314	26
-1	388	343	45	314	74
-2	304	360	-56	323	-20
-3	370	343	27	314	56
-4	207	343	-136	314	-107
78-1	330	347	-17	314	16
<u>-2</u>	320	347	<u>-27</u>	314	<u>6</u>
14			-522		-37

NORTHEASTERN

<u>FY-QTR</u>	<u>Z</u>	<u>Actual</u>		<u>Programmed</u>	
		<u>Ẑ</u>	<u>Z-Ẑ</u>	<u>Ẑ</u>	<u>Z-Ẑ</u>
75-2	1705	1426	279	1617	88
-3	1537	1426	111	1617	- 80
-4	1673	1422	251	1620	53
76-1	1184	1462	-278	1109	75
-2	774	1469	-695	1093	-319
-3	1002	1476	-474	943	59
-4	1339	1444	-105	1262	77
77-T	890	1203	-313	791	99
-1	716	988	-272	778	- 62
-2	662	664	- 2	758	- 96
-3	964	1203	-239	791	173
-4	763	1246	-483	794	- 31
78-1	772	1159	-387	900	-128
<u>-2</u>	768	1157	<u>-389</u>	1052	<u>-285</u>
14			-2996		-376

TOTAL DATA

<u>FY-QTR</u>	<u>Z</u>	<u>Actual</u>		<u>Programmed</u>	
		<u><math>\hat{Z}</math></u>	<u><math>Z-\hat{Z}</math></u>	<u><math>\hat{Z}</math></u>	<u><math>Z-\hat{Z}</math></u>
75-2	23895	19982	3913	23762	133
-3	22233	19955	2278	23774	-1541
-4	23905	19702	4203	23813	92
76-1	24102	21086	3016	23512	590
-2	19748	17824	1924	17703	2045
-3	16778	17963	-1185	17683	- 905
-4	17123	16760	363	17004	119
77-T	16315	16127	188	16642	- 327
-1	16559	16586	- 27	16473	96
-2	15899	16441	-542	16491	- 592
-3	17109	16381	728	16478	631
-4	15452	16423	-971	16519	-1067
78-1	16904	15442	1462	15955	949
<u>-2</u>	15634	15307	<u>327</u>	15970	<u>- 336</u>
14			15677		- 113

APPENDIX G  
SPSS PROGRAM

```

0010#S,R(SL) :,8,16;;,16
0020$:IDENT:WPL1149,AFIT/LSG LAMB/SARNACKI THESIS LSSR 21-78B
0030$:SELECT:SPSS/SPSS
0040RUN NAME;SDT DLR PROGRAM
0050VARIABLE LIST;Z,X,Y
0060INPUT FORMAT;FREEFIELD
0070N OF CASES;16
0080INPUT MEDIUM;CARD
0090VAR LABELS;Z,ACTUAL SHORT TONS/
0100;X,PROGRAMMED FLYING HOURS/
0110;Y,PROGRAMMED MANPOWER
0120IF;(X GT 130000) XD1=1
0130IF;(X GT 130000) XP1=X-130000
0140IF;(X GT 140000) XD2=1
0150IF;(X GT 140000) XP2=X-140000
0160IF;(Y GT 130000) YD1=1
0170IF;(Y GT 130000) YP1=Y-130000
0180IF;(Y GT 140000) YD2=1
0190IF;(Y GT 140000) YP2=Y-140000
0200IF;(Y GT 150000) YD3=1
0210IF;(Y GT 150000) YP3=Y-150000
0220REGRESSION;VARIABLES=Z,X,Y,XD1 TO YP3/
0230;REGRESSION=Z(20,2.5) WITH X(6),Y(4),XD1 TO YP(3) RESID=0
0240STATISTICS;1,2,4,5,6
0250READ INPUT DATA
0260$:SELECTA:SDTDATA
0270SCATTERGRAM:Z WITH X,Y
0280STATISTICS;ALL
0290FINISH
0300$:END JOB

```

Note: In line 0230, the F inclusion level option was used. If the dummy variable's entering F value is not greater than 2.5 ( $\alpha=0.10$ ), the dummy variable is not included in the regression equation (16:346).

APPENDIX H  
FORTRAN PROGRAM

```

00100 SECOND DESTINATION TRANSPORTATION BUDGET COMPUTATION PROGRAM
00200
00300 IMPLICIT INTEGER (A,E,F,P,S,X,Y)
00400 INTEGER Z
00500 DIMENSION M(6,5,2)
00600 PRINT, " TYPE IN THE SLOPE VALUES OF THE FOLLOWING VARIABLES: "
00700 PRINT, " NOTE: TYPE IN A 0. FOR VARIABLES NOT IN THE EQUATION!"
00800 PRINT, " CONST X Y XD1 XP1 XD2 XP2 YD1 YP1 YD2 YP2 YD3 YP3"
00900 READ,CONST,BX,BY,BXD1,BXP1,BXD2,BXP2,BYD1,BYP1,BYD2,BYP2,BYD3,BYP3
01000 PRINT, " "
01100 PRINT, " TYPE IN THE COSTS TO SHIP ONE TON IN THE FOLLOWING ORDER: "
01200 PRINT, " PACIFIC(P) ALASKA(A) NORTHEAST(N) EUROPE(E) SOUTHERN(S) "
01300 READ,PC,AC,NC,EC,SC
01400 PRINT, " "
01500 10 PRINT, " TYPE IN THE FISCAL YEAR FOR THIS FORECAST"
01600 READ,FY
01700 PRINT, " "
01800 PRINT, " TYPE IN THE PROGRAMMED FLYING HOURS (FH) AND MANPOWER (M) "
01900 PRINT, " BY QUARTER IN THE FOLLOWING ORDER: "
02000 PRINT, " PFH PM AFH AM NPH NM EFH EM SFH SM"
02100 DO 20 J=1,4
02200 WRITE (6,100) J
02300 100 FORMAT (/,1X,"TYPE IN THE DATA FOR QUARTER ",I1)
02400 READ,PFH,PM,AFH,AM,NPH,NM,EFH,EM,SFH,SM
02500 X=PFH+AFH+NPH+EFH+SFH
02600 Y=PM+AM+NM+EM+SM
02700 XD1=0
02800 XD2=0
02900 YD1=0
03000 YD2=0
03100 YD3=0
03200 IF (X.GT.130000) XD1=1
03300 XP1=XD1
03400 IF (X.GT.140000) XD2=1
03500 XP2=XD2

```

```

0360 IF (Y.GT.130000) YD1=1
0370 YP1=YD1
0380 IF (Y.GT.140000) YD2=1
0390 YP2=YD2
0400 IF (Y.GT.150000) YD3=1
0410 YP3=YD3
0420 Z1=CONST+BX*Y+BY*Y+BXD1*X+DXD1*BXP1*(X-130000)*XP1
0430 Z2=BXD2*XD2+BXP2*(X-140000)*XP2+BYD1*YD1+BYP1*(Y-130000)*YP1
0440 Z3=BYD2*YD2+BYP2*(Y-140000)*YP2+BYD3*YD3+BYP3*(Y-150000)*YP3
0450 Z=Z1+Z2+Z3+0.5
0460 M(1,J,1)=(1.0*PFH/X+1.0*PM/Y)*(Z/2.0)+0.5
0470 M(1,J,2)=M(1,J,1)*PC
0480 M(2,J,1)=(1.0*AFH/X+1.0*AM/Y)*(Z/2.0)+0.5
0490 M(2,J,2)=M(2,J,1)*AC
0500 M(3,J,1)=(1.0*NFH/X+1.0*NM/Y)*(Z/2.0)+0.5
0510 M(3,J,2)=M(3,J,1)*NC
0520 M(4,J,1)=(1.0*EFH/X+1.0*EM/Y)*(Z/2.0)+0.5
0530 M(4,J,2)=M(4,J,1)*EC
0540 M(5,J,1)=(1.0*SPH/X+1.0*SM/Y)*(Z/2.0)+0.5
0550 M(5,J,2)=M(5,J,1)*SC
0560 M(6,J,1)=Z
0570 DO 30 I=1,5
0580 M(6,J,2)=M(6,J,2)+M(I,J,2)
0590 30 CONTINUE
0600 DO 40 K=1,2
0610 DO 50 I=1,6
0620 M(I,5,K)=M(I,5,K)+M(I,J,K)
0630 50 CONTINUE
0640 40 CONTINUE
0650 20 CONTINUE
0660 WRITE (6,110) FY,((M(I,J,K),J=1,5),I=1,6),K=1,2)
0670 110 FORMAT (//////,14X,"SDT FORECAST FOR FISCAL YEAR ",I4,////,
0680&15X,"TONNAGE ESTIMATES IN SHORT TONS",///,
0690&15X,"Q U A R T E R",/,
0700&3X,"AREA",8X,"1",9X,"2",9X,"3",9X,"4",7X,"TOTAL",/,

```

```

0710&1X, "PACIFIC", 5110, //, 1X, "ALASKA", 5110, //,
0720&1X, "NORTHEAST", 18, 4110, //, 1X, "EUROPE", 5110, //,
0730&1X, "SOUTHERN", 19, 4110, //, 3X, "TOTAL", 5110, //,
0740&17X, "BUDGET ESTIMATES IN DOLLARS", //, //,
0750&15X, "Q U A R T E R", //, //,
0760&3X, "AREA", 8X, "1", 9X, "2", 9X, "3", 9X, "4", 7X, "TOTAL", //,
0770&1X, "PACIFIC", 5110, //, 1X, "ALASKA", 5110, //,
0780&1X, "NORTHEAST", 5110, //, 1X, "EUROPE", 5110, //,
0790&1X, "SOUTHERN", 5110, //, 3X, "TOTAL", 5110, //, //, //,
0800 PRINT, " IF YOU WISH TO MAKE ANOTHER FORECAST WITH THE SAME SLOPES "
0810 PRINT, "AND COSTS, TYPE IN A 1; OTHERWISE, TYPE IN A 0!"
0820 READ, L
0830 IF (L.NE.1) GO TO 70
0840 DO 60 I=1,6
0850 DO 60 J=1,5
0860 DO 60 K=1,2
0870 M(I, J, K)=0
0880 60 CONTINUE
0890 GO TO 10
0900 70 STOP
0910 END

```

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