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USER DELAY COST MODEL AND FACILITIES MAINTENANCE COST MODEL FOR A TERMINAL CONTROL AREA

Volume III: User's Manual and Program Documentation for the Facilities Maintenance Cost Model

L. B. Greene
J. Witt
M. Sternberg-Powidzki

ARINC RESEARCH CORPORATION
2551 RIVA ROAD
ANNAPOLIS MD 21401

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NOTICE

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16. Abstract

The Facilities Maintenance Cost Model (FMCM) is an analytic model designed to calculate expected annual labor costs of maintenance within a given FAA maintenance sector. The model is programmed in FORTRAN IV and has been demonstrated on the CDC Kronos time-sharing system.

Model inputs are facility identification data, maintenance support scenarios, and facility reliability and maintainability data.

The principal model outputs include the expected annual direct labor and salary costs of maintaining a specific facility type within a sector, the required number of personnel by skill level for that facility type, the costs of preventive maintenance and corrective maintenance, and the costs of call-backs. The model also provides total cost and labor data on all of the facilities within the sector.

This is the third of three volumes. Volume I documents the model formulation and demonstration. Volume II is a user's manual and contains the program documentation for the user delay cost model.

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PREFACE

The Federal Aviation Administration is responsible for operating and maintaining the airway facilities of the National Aviation System. The magnitude of annual operating and maintenance costs is such that means for reducing these costs are being sought.

This report documents the results of a study to model the relationship between airway facility maintenance practices and (1) aircraft delays in terminal areas, and (2) maintenance costs.

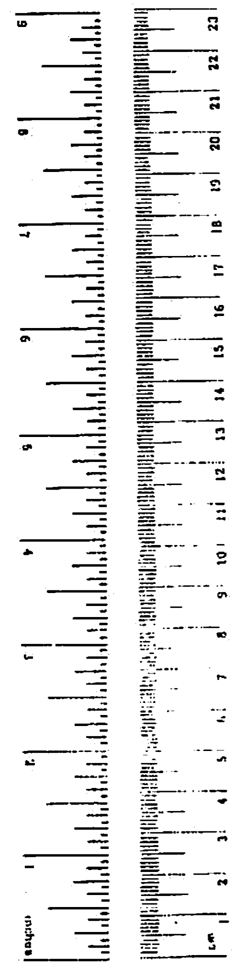
These models are intended to serve as tools for estimating the impact on system users and system operators of proposed maintenance cost reduction initiatives.

The models were formulated, demonstrated, and documented by ARINC Research Corporation under contract to the Transportation Systems Center. Mr. F. Frankel of the Transportation Systems Center provided the technical guidance. The dedication and expertise of Mr. L. B. Greene, Dr. J. Witt, and Mr. M. Sternberg-Powidzki of ARINC Research is acknowledged to be the major contribution to this work.

METRIC CONVERSION FACTORS

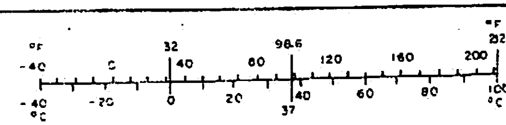
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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CHAPTER ONE

INTRODUCTION

This program, Facilities Maintenance Cost Model (FMCM), is one of two programs prepared by ARINC Research Corporation for the DOT/Transportation Systems Center (TSC) under project number TSC/420-0137-WD. The purpose of the two programs, or models, is to provide the FAA with management tools to estimate the effect of variation in airway facilities maintenance scenarios on:

Costs to the user community caused by facility outage

Costs of corrective and preventive maintenance.

The Facilities Maintenance Cost Model has been designed to address the second issue, while the companion model, the User Delay Cost Model (UDCM), addresses the first.

This report provides the documentation of the FMCM, including a description of the model, a program description, and an example application of the model. It is the third of three reports prepared under contract to TSC. The first report, entitled "User Delay Cost Model and Facilities Maintenance Cost Model for a Terminal Control Area", provides documentation of the entire model development efforts. The second report, entitled "Users' Manual and Program Documentation for the User Delay Cost Model", provides data on the UDCM, comparable to that contained in this report.

CHAPTER TWO

FACILITIES MAINTENANCE COST MODEL

2.1 DESCRIPTION OF THE COST DETERMINATION PROCESS

The Facilities Maintenance Cost Model was formulated to evaluate labor costs associated with maintaining FAA facilities within a maintenance sector. The model determines these costs by computing the number of maintenance and supervisory personnel required to perform all corrective maintenance (CM) and preventive maintenance (PM), with proper allowance for personnel productivity. The basic cost-determination process that is modeled is depicted in Figure 2-1. For corrective maintenance, mean time between corrective maintenance actions (MTBCMA) and mean time to restore (MTTR) are used to determine the expected number of corrective maintenance actions and expected repair times per action. For each action, man-hour demands, by skill level, are incurred for direct maintenance action, as well as travel time on level B facilities.* Man-hour demands are similarly determined for preventive maintenance. Total man-hour requirements are summed over all facility types for the sector. These are then converted to numbers of personnel required for each skill level, and the numbers are then used to determine support personnel. These total manpower requirements are then combined with wage rates and salaries to determine the annual sector labor costs.

2.2 OVERVIEW OF THE MODEL AND ITS CAPABILITIES

It is recognized that personnel costs represent 80 percent of the FAA maintenance costs. Consequently, TSC encouraged the development of a model that would focus on this single key maintenance-cost factor. Therefore, the FMCM has been designed to predict required maintenance staff levels and associated costs on the basis of the expected annual requirements for corrective and preventive maintenance, the desired facility-restoration levels, and personnel productivity factors. The FMCM evaluates the expected direct labor and salary costs for a one-year interval. The model has been formulated to evaluate both the preventive maintenance and corrective maintenance

*There are three facility-restoration levels. Level A facilities are not repaired outside normal working hours. Level B facilities that fail outside normal working hours are repaired, if possible, by calling maintenance personnel back. Facilities subject to level C restoration are attended by three shifts of maintenance personnel on a 24-hour basis.

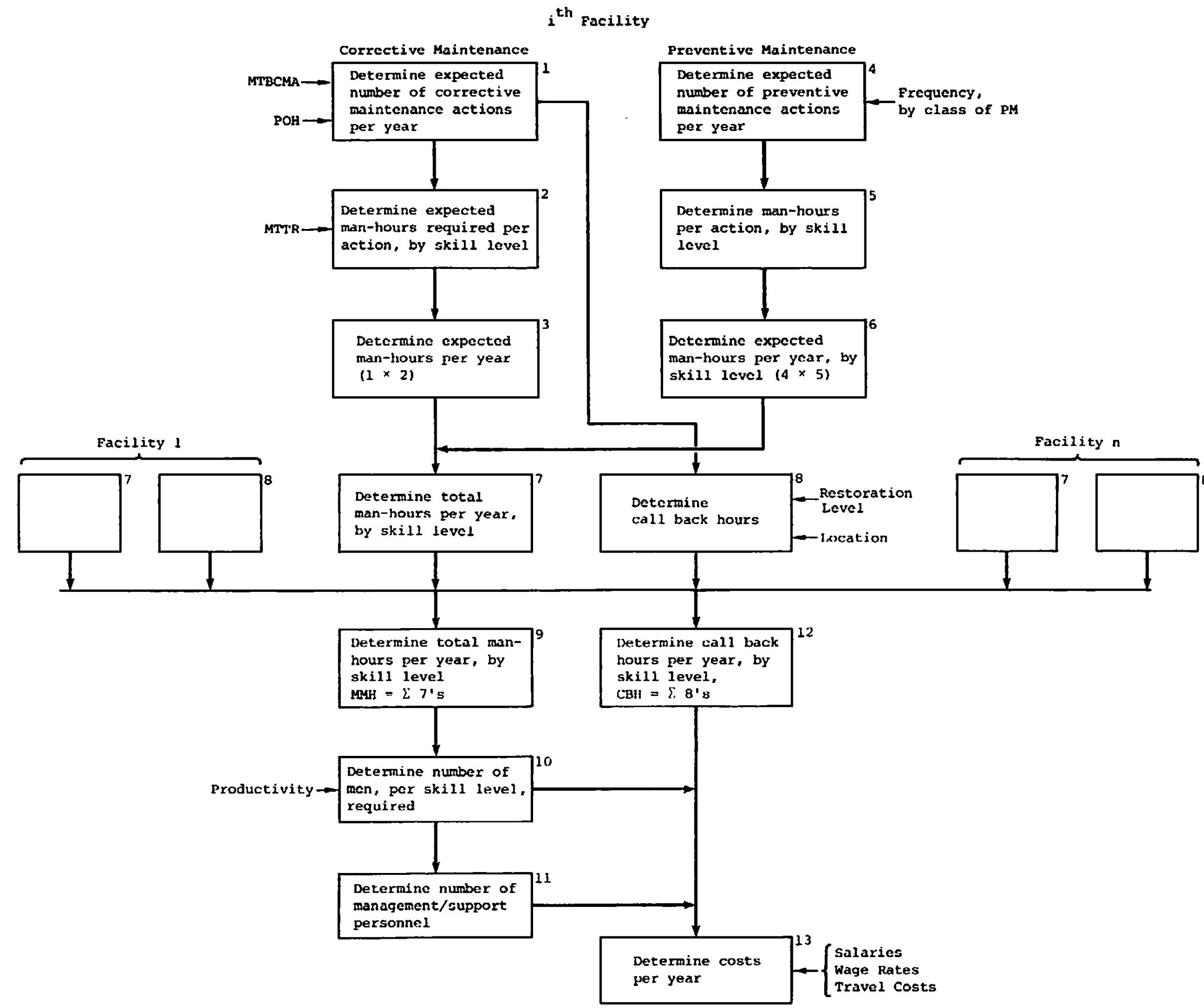


Figure 2-1. COST OF MAINTENANCE LABOR ANALYSIS

required by any single facility type, accumulate staffing and cost data for the facility type within the specified maintenance sector, evaluate all other designated types of facilities within the sector, and accumulate total sector maintenance costs.

The principal model outputs include the expected annual cost of maintaining a specific facility type within a sector, the required number of personnel by skill level for that facility type, the cost of preventive maintenance and corrective maintenance, and the cost of call-backs. The model also provides similar cost and labor data on the total of all facilities within the sector, including management/support personnel requirements and costs.

CHAPTER THREE

METHOD OF SOLUTION

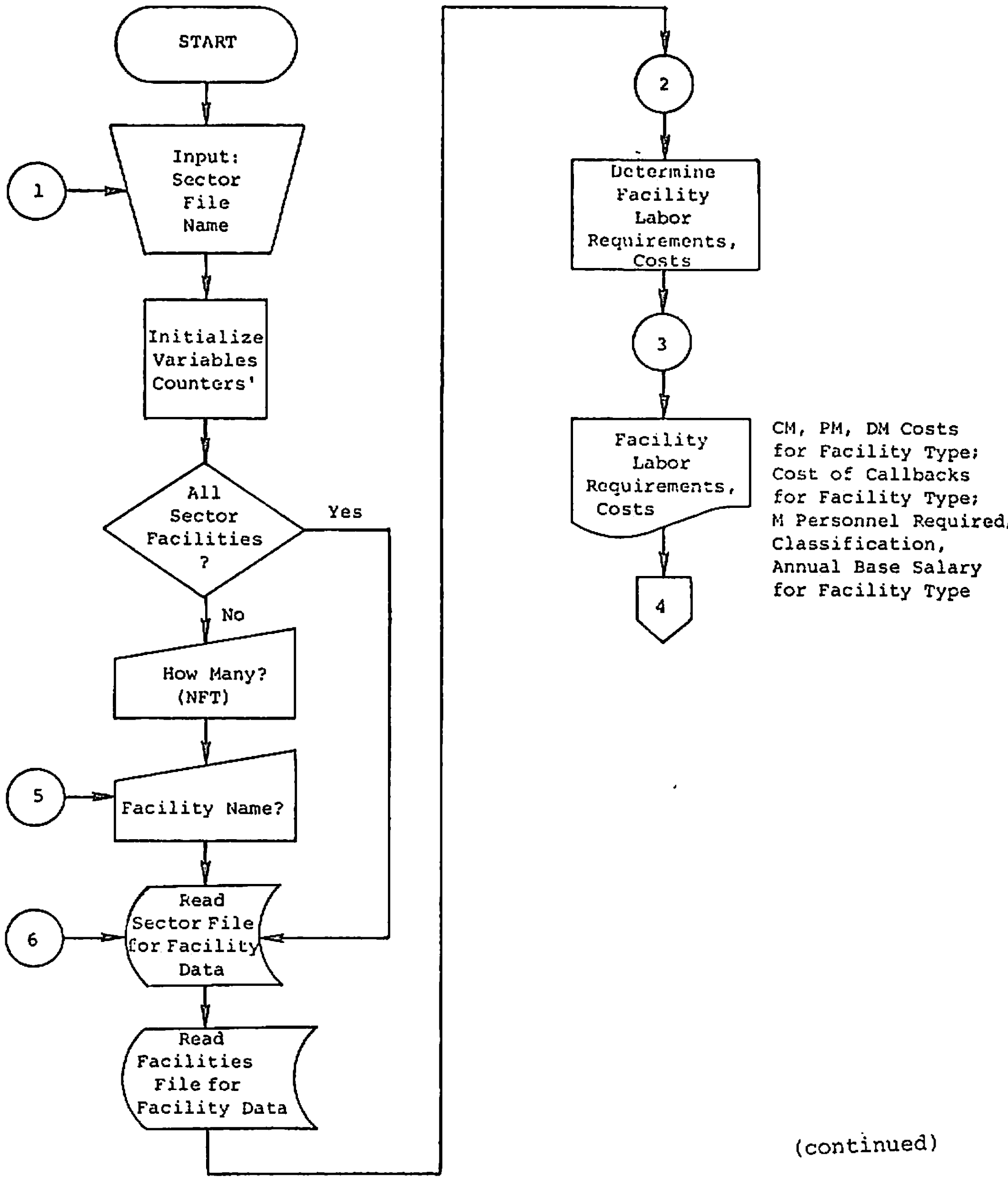
3.1 TECHNICAL APPROACH TO MODEL FORMULATION

The FMCM is an analytic model, comprising a set of equations designed to calculate the expected annual labor costs of maintenance within a given maintenance sector. The model is programmed in FORTRAN IV and has been demonstrated on the CDC Kronos time-sharing system. By running the model from a time-sharing terminal, maximum advantage can be taken of its ability to evaluate selected sectors and facilities, print the results, then run again, all in a man-machine interactive mode. A program listing is provided in Figure 4-1 of Chapter Four. Construction of the model required recognition of the predominant effect of labor on maintenance costs and the way in which this labor effect manifests itself on cost. Interviews with maintenance personnel of the New England Region and the Boston Sector were conducted so that maintenance practices common to the FAA and peculiar to the Region could be reflected in the model.

It is significant that, as currently configured, the model does not include costs of spares provisioning or other logistics support costs. These additional costs can be added to the model incrementally without requiring a restructuring of the model as it currently exists.

As shown in Figures 3-1 and 3-2, the model begins by accepting, as a terminal input, the sector file name and then reading in data from the sector file (called SECFIL) describing the overall maintenance characteristics of the sector to be evaluated and data peculiar to each of the facility types within the sector. (These data are shown in Chapter Five.) Then the analyst specifies whether or not he wants every facility type in the sector evaluated. If only selected facility types are desired, he must then input how many of the facility types within the sector will be considered in the analysis, together with their identifiers. The analysis begins by considering each facility type separately. To evaluate each facility type, an additional file (called FACFIL) containing facility data common to all facilities of that type throughout the FAA system is required. A detailed logic flow diagram is provided in Figure 4-2 of Chapter Four.

On the basis of the sector and facility file data, the corrective maintenance (CM), preventive maintenance (PM), and their sum, direct



(continued)

Figure 3-1. FMCM LOGIC

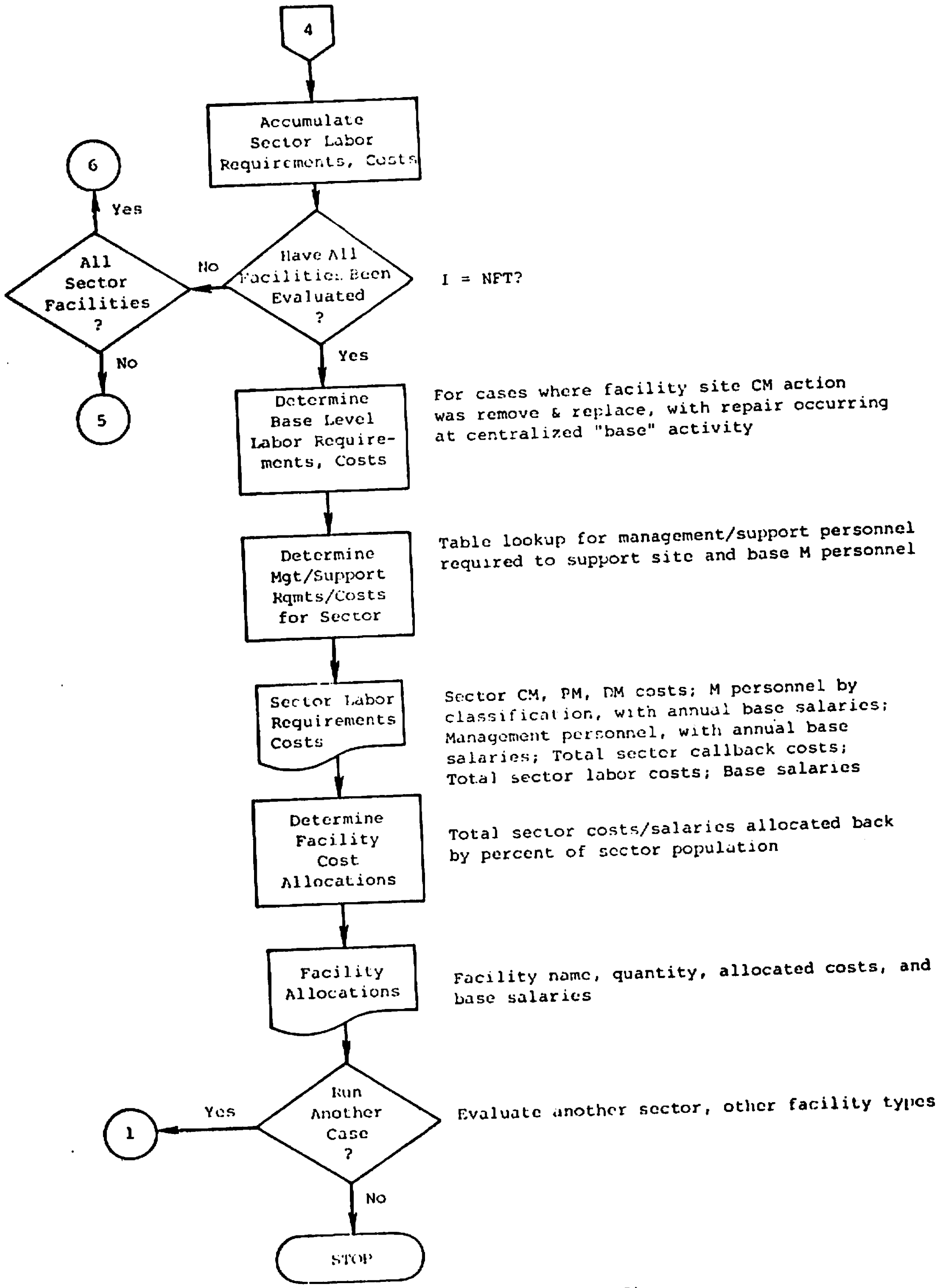


Figure 3-1. (continued)

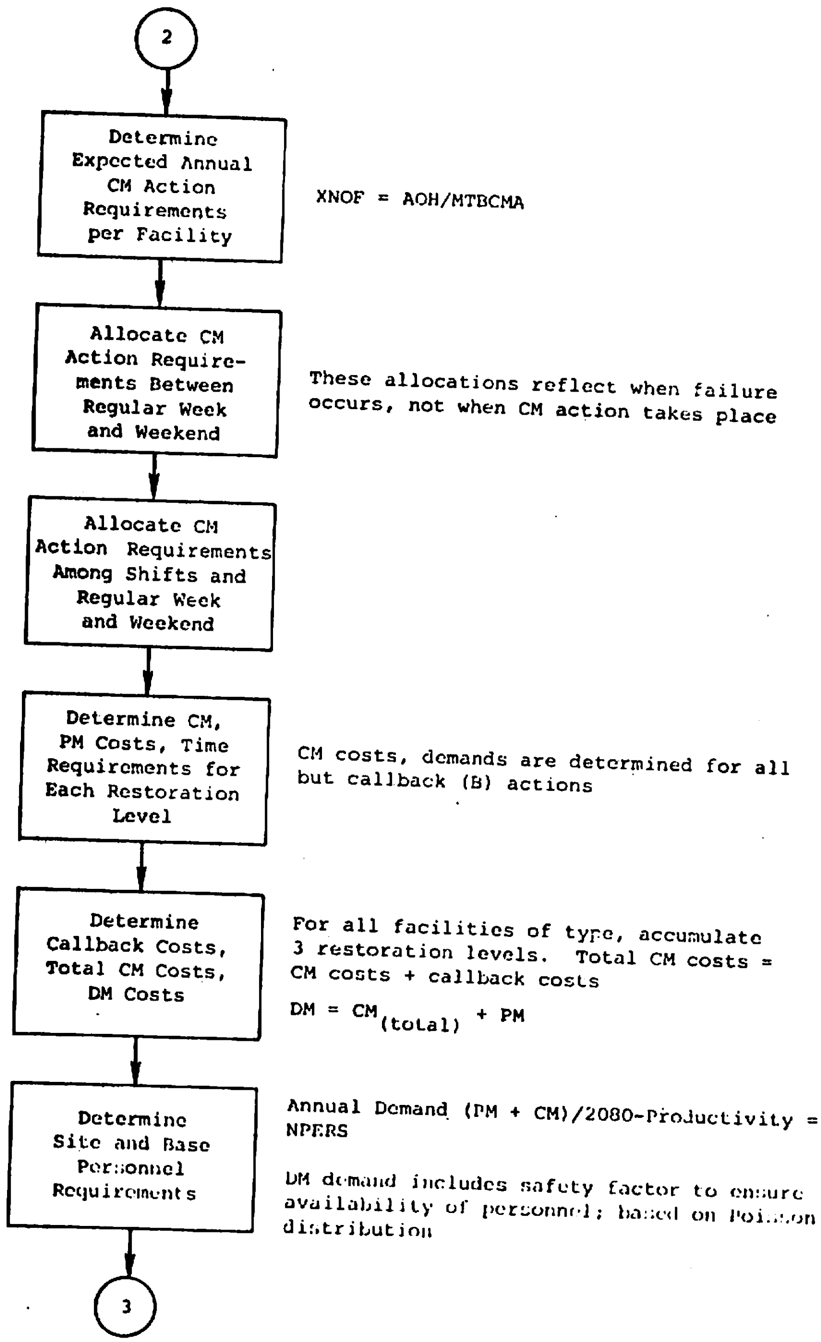


Figure 3-2. FMCM LOGIC (EXPANSION BETWEEN PARTS 2 AND 3)

maintenance (DM), are computed and presented as intermediate output data. After these manpower requirements have been computed separately for each facility type, they are combined to determine the total personnel requirements for the maintenance sector.

The combined man-hour requirements are translated into specific staffing levels for each of the maintenance skill levels defined in the input data. Through this procedure realistic staffing levels are developed wherein personnel of the same skill category may work on several facility types. Having determined the number of maintenance personnel, the model uses a table lookup to determine the number of management/support personnel. Total personnel costs are calculated in the model by summing the product of personnel requirements, in man-hours, and the wage rate over the labor classes required.

At the end of the analysis, total sector maintenance requirements and costs and facility cost allocations are printed. At the option of the analyst, the program can then either terminate or return to the beginning for another program execution.

3.2 KEY COST CATEGORIES

The key cost categories that the model considers are defined in the following subsections.

3.2.1. Preventive Maintenance

Preventive maintenance (PM) cost is determined by the maintenance man-hour expenditures required (in accordance with preventive maintenance schedules published in DOT orders applicable to the facilities under evaluation) and travel time. Daily preventive maintenance actions are assumed to require travel times different from those for the longer PM actions, which are assumed to be the same as for a CM action. This is done to reflect facility-to-facility travel for daily PM, rather than travel from the central maintenance location to the facility assumed for the other actions.

Preventive maintenance is assumed to be performed during normal work hours only. It does, however, affect the overall staffing requirements for the facility type and maintenance sector.

3.2.2 Corrective Maintenance

Corrective maintenance (CM) actions are those initiated by failure within a facility. The failure may be catastrophic, caused by a component failure; or it may be one caused by performance degradation below the tolerances specified in DOT orders for facility operations. Either type of failure will normally require replacement of components, modules, or entire systems, depending on the severity of the failure.

The model assumes that all failures are scheduled for immediate repair during normal duty hours and that they preempt preventive maintenance requirements. Corrective action considers the manpower required to restore a facility and includes the transportation time from normal duty station to the failed facility, test and diagnostic setup time, fault-isolation time, time to repair, operational test time, and transportation time to return to normal duty station.

Failures occurring during off-duty hours are scheduled for repair during normal duty hours if the failed system has a restoration level A, or scheduled for repair by call-back personnel if the system has a restoration level B. Call-back repairs are subject to premium overtime rates for labor and include the additional time authorized for transportation between the technician's home and his normal duty station. Level B system failures are repaired the next normal working day if contact with call-back personnel is not established.

Facilities categorized as restoration level C are normally manned 24 hours per day. Therefore, failures of systems in these facilities are treated the same as normal duty system failures except that the labor rates are increased to reflect a shift differential.

3.2.3 Direct Maintenance

The direct maintenance (DM) is the sum of the preventive maintenance and the corrective maintenance. This quantity represents the total maintenance labor demand for the facility and/or maintenance sector.

3.2.4 Personnel Requirements

The model computes the minimum number of personnel of a given skill category required to perform all expected preventive and corrective maintenance for each facility type. Personnel requirements are determined through the application of productivity factors, which include corrective maintenance and preventive maintenance times (both of which include transportation time) as the baseline (direct labor) and all other labor categories such as training, watch-standing, leave, vacation, etc., as nonproductive activities. The model includes as an output the actual productivity of each labor class, which takes into account the foregoing factors plus any minimum manning constraints (e.g., level C manning requires at least 3 maintenance personnel per day).

The model will permit consideration of an alternative scenario in which some failed items are repaired at an intermediate repair facility, with the site repair activity then becoming simply a remove and replace action. The extent of this option is established within the sector file by the variable RTS (fraction of failures repaired directly at the site). The model automatically determines the number of required intermediate-level personnel and their associated costs based on the input values of RTS for each facility type ($0 \leqslant RTS < 1$). The model also determines the number of management/support personnel required for the established maintenance personnel based on FAA standards; it determines their costs and includes these costs in the total costs (direct labor and salary) for the sector.

CHAPTER FOUR

PROGRAM DESCRIPTION

4.1 OPERATING ENVIRONMENT

The Facilities Maintenance Cost Model (FMCM) program has been developed to run on a time-sharing computer system -- the CDC Kronos system. However, the program is written in FORTRAN and could be utilized on other time-sharing systems but, due to the interactive nature of the program execution, it could not be run in a batch computer environment without some reprogramming.

The program instructions and the input data files should be entered into the time-sharing computer system prior to running the FMCM. Once these files have been set up, the program can be executed after going through the normal log-in procedure for the time-sharing system. The log-in procedure will result in the main program being called into the computer, and the execution of the program will cause the required data files to be accessed.

4.2 PROGRAM SPECIFICATION

The program is written in standard FORTRAN IV. There is no calling sequence or overlay structure.

4.3 SUBPROGRAMS

There are no subprograms.

4.4 SOURCE LISTING

The complete source listing for the Facilities Maintenance Cost Model Program is presented in Figure 4-1. The listing is in FORTRAN coding with the associated line numbers for time-share application. To facilitate understanding of the coding flow, the specific functions performed by the lines or groups of lines of code are summarized in Table 4-1.

4.5 DETAILED FLOW CHARTS

A detailed flow chart of the program is presented in Figure 4-2.

```
PROGRAM SECMCM(INPUT,OUTPUT,TAPE1,TAPE2)
PRINT,◆             AIRWAYS & FACILITIES MAINTENANCE SECTOR COSTS◆
DIMENSION NAMFAC(100),LABOR(6),SLR(6),PSLR(6),SDIF(10),MPER(40),
+NSKL(6),PCON(3),NDS(3),NWS(3),NRL(3),PMMH(10),PSF(3),RLF(3)
+,PE(3),PD(3),MS(3),MES(3),IF(10),NOF(100)
+,NMINS(6),DLHRS(6)
REAL MTBCMA,MLR,MTTR,MTRR
1 PRINT,///◆ INPUT SECTOR FILE NAME◆,
READ, SECFIL
CALL GET (5HTAPE1,SECFIL,0,0)
CALL GET (5HTAPE2,6HFACFIL,0,0)
READ (1,) LN,L,L,L,L
READ (1,) LN,L,NFT,L,NSL,L,MLR,L,BLR,L,PRODB
DO 2 I=1,NSL $ NSKL(I)=0
NMINS(I)=0 $ DLHRS(I)=0.
2 READ (1,)LN,LABOR(I),L,SLR(I),L,PSLR(I),L,SDIF(I)
READ (2,) LN,L,L,L
READ (1,) LN,L,(MPER(I),I=1,22)
PRINT,◆ DO YOU WANT TO CONSIDER ALL FACILITY TYPES◆,
READ,AA
IF(AA.EQ.3HYES)GOTO 3
PRINT,◆ HOW MANY TYPES◆,
READ,NFT
3 NPER=NOFT=0 $ TMCOST = PCON(1) = 0. $ PCON(3)=1.
COSCT=COSPT=COSTT=TPOTP=DEMBT=0.
DO 4 I=1,NFT
IF(AA.EQ.3HYES)GOTO 5
PRINT,◆ FACILITY◆,
READ,NAMF
5 READ (1,)LN,NAMFAC(I)
IF(AA.NE.3HYES) GOTO 15
PRINT 100,NAMFAC(I)
100 FORMAT(//◆ FACILITY ? ◆A10)
15 CONTINUE
READ (1,)LN,L,AOH,L,DOH,L,PCON(2),L,PTS,L,PROD,L,NSCAT
READ (1,)LN,(L,NRL(J),L,NDS(J),L,NWS(J),J=1,3)
READ (1,)LN,L,TRTP,L,TRT,L,TRTD
IF((AA.NE.3HYES).AND.(NAMFAC(I).NE.NAMF))GOTO 5
7 READ (2,)LN,LDUM
READ (2,)LN,L,MTBCMA,L,SUF,L,FITT,L,MTTR,L,MTRR,L,BMMH
READ (2,) LN,L,(PMMH(J),J=1,10)
IF(LDUM.NE.NAMFAC(I))GOTO 7
REWIND 2
READ (2,)LN,L,L,L
XNOF=AOH/MTBCMA $ NOF(I)=0
XNOFD=260◆DOH/MTBCMA $ XNOFW=XNOF-XNOFD
DO 9 J=1,3 $ MS(J)=MES(J)=1
NOF(I)=NOF(I)+NRL(J)
9 PD(J)=PE(J)=0.
NOFT=NOFT+NOF(I)
EOH=AOH/104-2.5◆DOH
IF(DOH.GT.16.)PD(1)=PD(2)=PD(3)=.333
IF(DOH.LE.8.)PD(1)=1.
```

(continued)

Figure 4-1. SOURCE LISTING

```
IF((DOH.GT.8.).AND.(DOH.LE.16.))PD(1)=PD(2)=.5
IF((EOH.GT.0.).AND.(EOH.LE.8.))PE(1)=1.
IF(EOH.GT.16.)PE(1)=PE(2)=PE(3)=.333
IF((EOH.GT.8.).AND.(EOH.LE.16.))PE(1)=PE(2)=.5
DO 11 J=1,3 $ RSF(J)=0.
IF(NDS(J).LE.2)MS(3)=0
IF(NDS(J).EQ.1)MS(2)=0
IF(NWS(J).LE.2)MES(3)=0
IF(NWS(J).LE.1)MES(2)=0
IF(NWS(J).EQ.0)MES(1)=0
DO 12 K=1,3
RSF(J)=NRL(J)*(PD(K)*XNOFD*MS(K)+PE(K)*XNOFW*MES(K))+RSF(J)
12 MS(K)=MES(K)=1
11 RLF(J)=XNOF*NRL(J)-RSF(J)
SMMHP=2*TRTP+FITT+RTS*MTTR+(1-RTS)*MTRR
IF(SMMHP.LT.2.)SMMHP=2.
POTP=RLF(2)*PCON(2)*SMMHP*PSLR(NSCAT)
TPOTP=TPOTP+POTP $ DEMDC=DEMDP=0.
SMMHC=2*TRT+FITT+RTS*MTTR+(1-RTS)*MTRR $ COSC=COSP=0.
DO 14 J=1,10 $  IF(J)=0 $ IF(PMMH(J).NE.0.)IF(J)=1
14 CONTINUE $ YDUM=0.
DO 13 J=1,3 $ YY=1. $ IF(J.EQ.3)YY=SDIF(NSCAT)
DEMD=(RSF(J)+RLF(J)*(1-PCON(J)))*SMMHC
NC=0
IF(NWS(J).NE.0)NC=1
NS=5*NDS(J)+2*NWS(J)
IF(NMINS(NSCAT).LT. NS)NMINS(NSCAT)=NS
DEMP=NRL(J)*((260+104*NC)*(2*TRTD+PMMH(1))*IF(1)
++52*(2*TRT+PMMH(2))*IF(2)+12*(2*TRT+PMMH(3))*IF(3)+4*(2*TRT+PMMH(4))
+*IF(4)+2*(2*TRT+PMMH(5))*IF(5)+(2*TRT+PMMH(6))*IF(6)+
+(780+312*NC)*(2*TRTD+PMMH(7))*IF(7)+(130+52*NC)*(2*TRT
++PMMH(8))*IF(8)+104*(2*TRT+PMMH(9))*IF(9)+26*(TRT*2+PMMH(10))*IF(10))
DEMDP=DEMDP+DEMP $ DEMDC=DEMDC+DEMD
DLHRS(NSCAT)=DLHRS(NSCAT)+DEMD+DEMP
COSC=COSC+DEMD*SLR(NSCAT)*YY $ COSP=COSP+DEMP*SLR(NSCAT)*YY
IF(DEMD.EQ.0.)NS=1
XDUM=DEMD/NS+SUF*SQRT(DEMD/NS)
13 YDUM=YDUM+NS*XDUM+DEMP
NDUM=INT(YDUM/(2080*PROD)+.999)
NSKL(NSCAT)=NSKL(NSCAT)+NDUM
DEMB=(1-RTS)*BMMH*NOF(1)*XNOF
MPERB=INT(DEMB/(2080*PRODB)+.999)$ COSTL=NDUM*2080*SLR(NSCAT)
COSTB=MPERB*2080*BLR
COSC=COSC+POTP+DEMB*BLR
DEMBT=DEMBT+DEMB $ COST=COSC+COSP
COSCT=COSCT+COSC $ COSPT=COSPT+COSP
COSTT=COSTT+COST
IF(AA.EQ.3HYES)GOTO 44
REWIND 1
READ (1,)LN,L,L,L,L
READ (1,)LN,L,L,L,L,X,X,X,X,X,X
DO 22 J=1,NSL
22 READ (1,)LN,L,X,X,X,X,X,X
READ (1,)LN,L,(L,J=1,22)
44 CONTINUE
```

(continued)

Figure 4-1. (continued)

```
PRINT 101,COSC,COSP,COST
101 FORMAT(* CM COST =*F10.2,*  PM COST =*F10.2,*  DM COST =*F10.2)
PRINT 102,POTP
102 FORMAT(* COST OF CALLBACKS =*F10.2)
PRINT 103,NDUM,LABOR(NSCAT),COSTL
103 FORMAT(I4,* OF SITE LABOR CLASS  *A10,* AT ANNUAL BASE COST =*F10.2)
PRINT 104,MPERB,COSTB
104 FORMAT(I4,* OF BASE LABOR CLASS AT ANNUAL COST =*F10.2)
4 CONTINUE
MDUM=MBUM=INT(DEMBT/(2080*PRODB)+.999)
PRINT,//* SUMMARY OF SECTOR VALUES*
DO 16 I=1,NSL $ NNDD=NMINS(I)/5
IF(NSKL(I) .LT. NNDD)NSKL(I)=NNDD
XDUM=2080.*NSKL(I)
IF(XDUM .EQ. 0.)XDUM=1.
DLHRS(I)=DLHRS(I)/XDUM
16 MDUM=MDUM+NSKL(I)
IF(MDUM .LT. 14)MGT=MPER(MDUM)
DO 617 MM=1,9
MME=10*MM+4 $ MNE=10*MM+13
IF((MDUM .GE. MME).AND.(MDUM .LE. MNE))MGT=MPER(13+MM)
617 CONTINUE $ COSM=2080*MGT*MLR
TMCOST=COSTT+COSM$ BDUM=MBUM*2080*BLR
PRINT 101,COSCT,COSPT,COSTT
PRINT 102,TPOTP
TCOST=COSM+BDUM
DO 17 I=1,NSL
XDUM=NSKL(I)*2080*SLR(I)$ TCOST=TCOST+XDUM
PRINT 103,NSKL(I),LABOR(I),XDUM
17 PRINT 109,DLHRS(I)
109 FORMAT(16X,* WITH ACTUAL PRODUCTIVITY = *F6.4)
PRINT 104,MBUM,BDUM
PRINT 105,MGT,COSM
105 FORMAT(I4,* OF MGT SUPPORT AT ANNUAL COST =*F10.2)
PRINT 106,TMCOST
106 FORMAT(* TOTAL SECTOR ANNUAL LABOR DIRECT COST =*F10.2)
PRINT 107,TCOST
107 FORMAT(* TOTAL SECTOR ANNUAL LABOR BASE COST =*F10.2)
PRINT,//* ALLOCATED FACILITY TYPE LABOR COST SUMMARY*
PRINT,*  FACILITY QUANTITY   DIRECT LABOR COST     BASE LABOR COST*
DO 18 I=1,NFT
UCOSD=NOF(I)*TMCOST/NOFT
UCOSS=NOF(I)*TCOST/NOFT
18 PRINT 108,NAMFAC(I),NOF(I),UCOSD,UCOSS
PRINT,//* DO YOU WANT TO RUN ANOTHER CASE*,
READ,AB
108 FORMAT(A10,5X,I4,2F20.2)
IF(AB.NE.3HYES)STOP
REWIND 2
GOTO 1
END
```

Figure 4-1. (continued)

Table 4-1. SUMMARY OF PROGRAM SOURCE LISTING FUNCTIONS

Program Lines	Function
100 - 160	Program, variable type definition and dimensioning
170 - 200	Identifies and calls the sector file (SECFIL) and facilities file (FACFIL)
210 - 220	Reads SECFIL header and general sector data
230 - 240	Initializes variables
250	Reads SECFIL for skill level data
260	Reads FACFIL header
270	Reads SECFIL management data
280 - 320	Identifies number of types of facilities to be evaluated
330 - 340	Initializes variables
350	Begins facility type evaluation loop
360 - 430	Identifies type of facility to be evaluated
440 - 460	Reads SECFIL for facility type data
470 - 510	Reads FACFIL for facility type data
520 - 530	Rewinds FACFIL, reads header
540 - 550	Determines expected failures; allocates them to daily and weekends
560 - 660	Allocates daily/weekend failures to specific shifts
670 - 720	Determines daily and weekend maintenance shift factors
730 - 750	Determines regular shift maintenance action demands
760	Determines non-regular shift maintenance action demands
770 - 800	Determines call back demand and cost
810	Determines regular shift corrective maintenance time/action
820 - 830	Initializes variables
840 - 850	Determines regular shift corrective maintenance demand
860 - 890	Establishes if minimum CM coverage demands are satisfied
900 - 950	Determines PM and total maintenance demand
960	Accumulates maintenance hours for skill level required
970	Determines corrective and preventive maintenance cost
980 - 1020	Determines number of maintenance personnel required for facility type
1030 - 1050	Determines demand, cost, and number of intermediate level maintenance personnel required for facility type
1060 - 1090	Determines cost totals for facility type
1100 - 1170	Checks end of SECFIL file, rewinds SECFIL, reads header/common data
1180 - 1250	Outputs facility data
1260	Ends facility loop
1270	Accumulates intermediate level personnel
1280	Outputs summary header
1290 - 1340	Determines sector salary totals by skill level
1350 - 1390	Determines number and salary cost of management/support personnel
1400 - 1550	Outputs sector summary data
1560 - 1600	Allocates and outputs facility costs by type
1610 - 1680	Determines if additional cases are to be run or program stopped

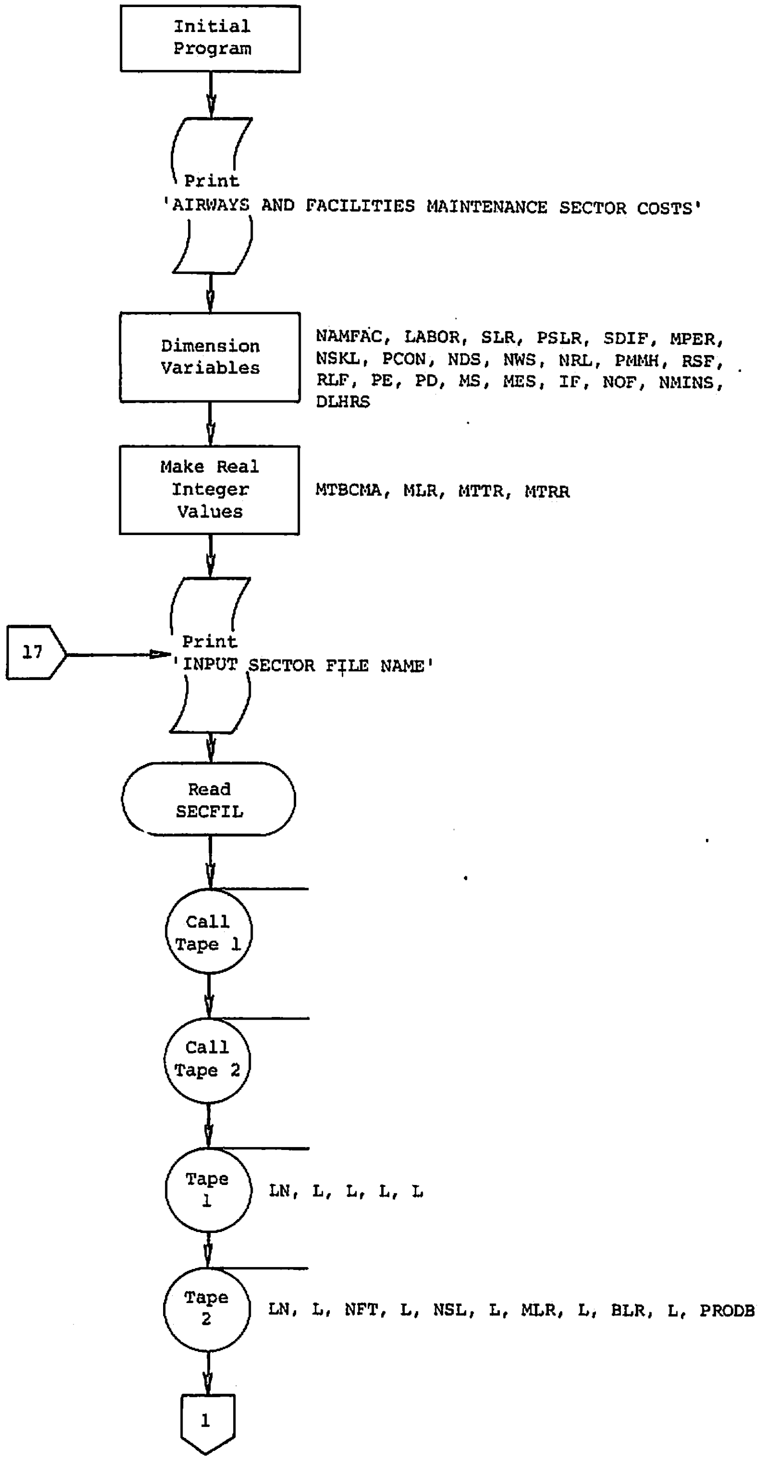


Figure 4-2. DETAILED FLOW CHART
(continued on pages 4-7 through 4-18)

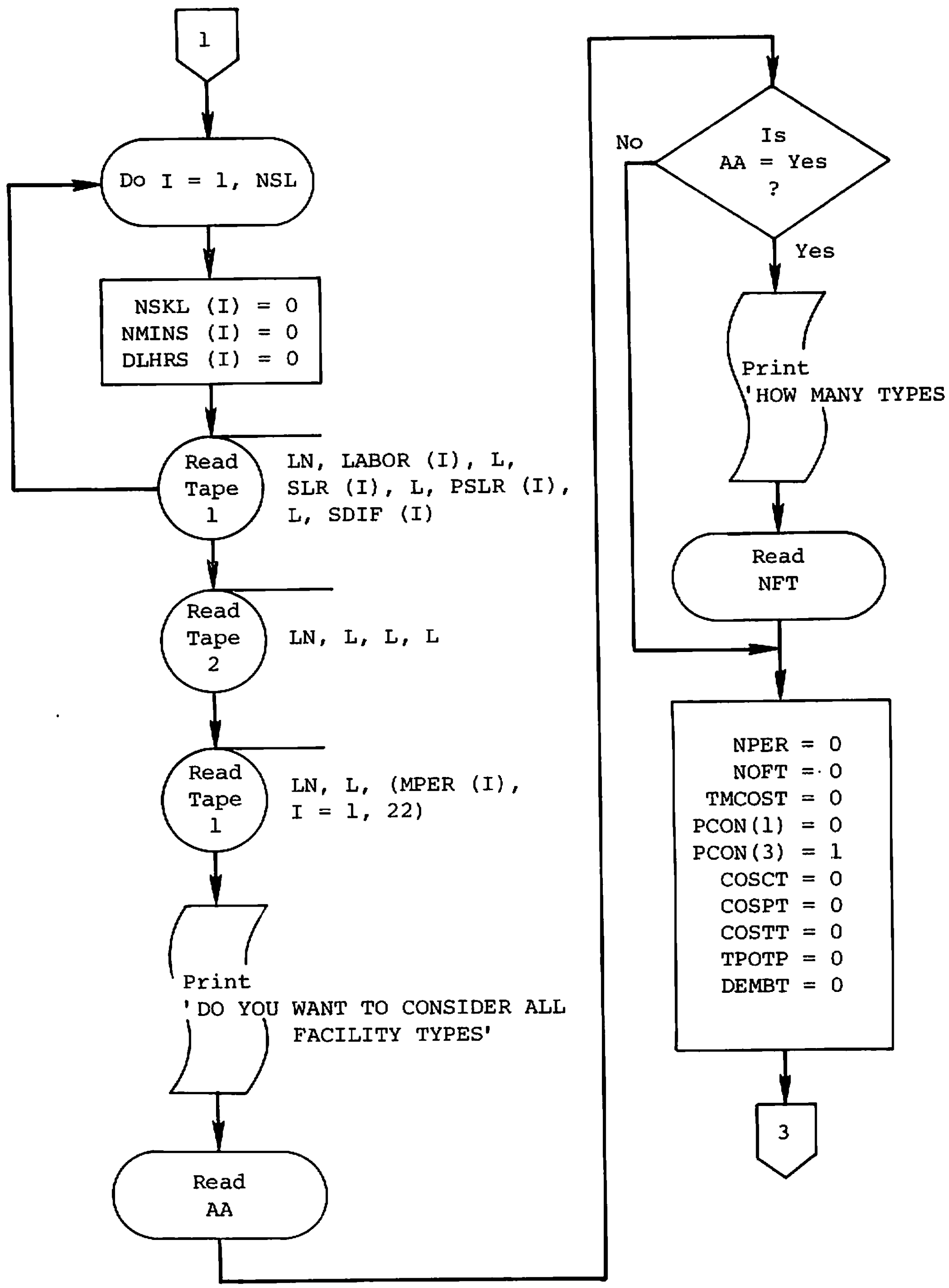


Figure 4-2. (continued)

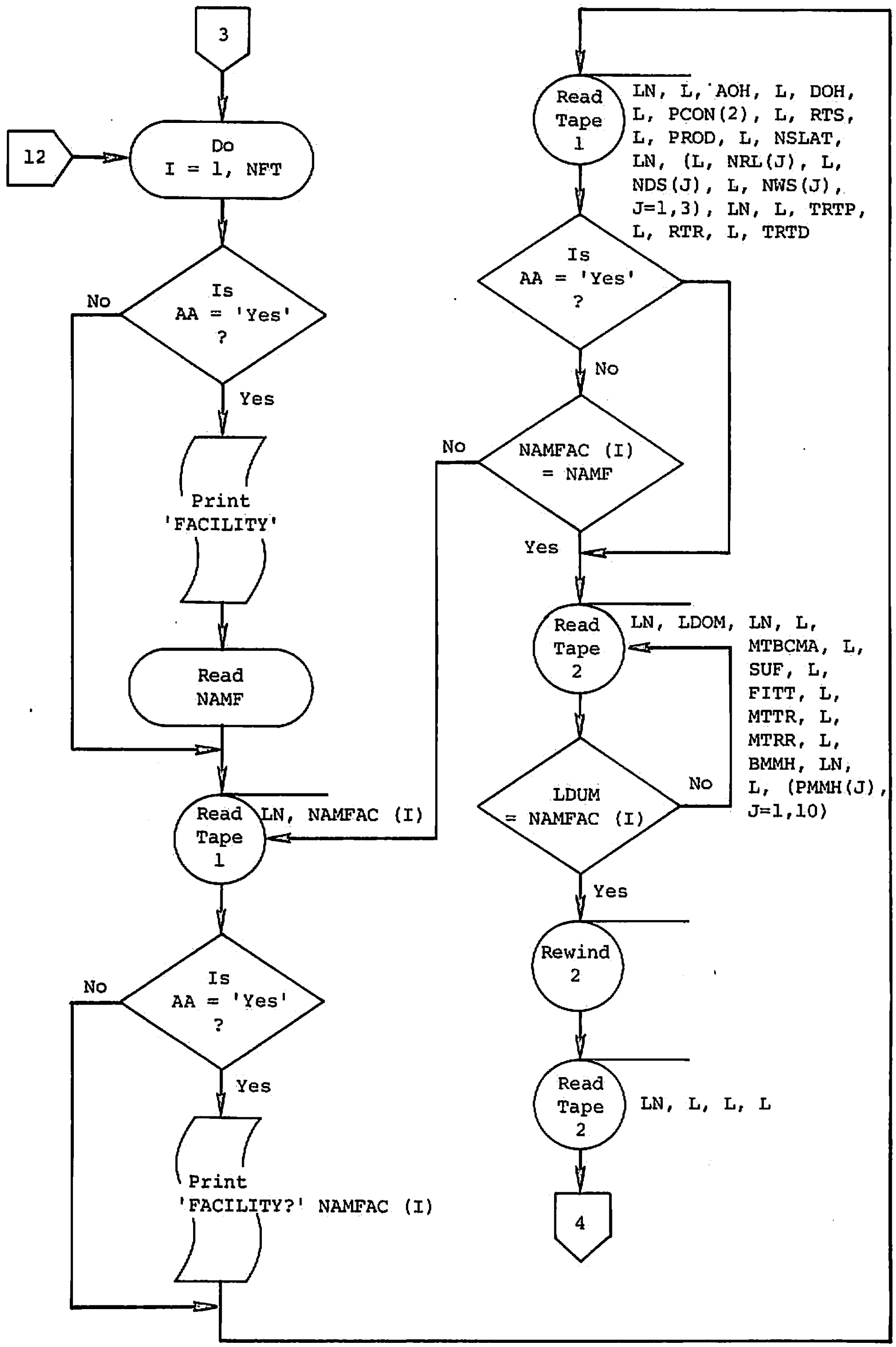


Figure 4-2. (continued)

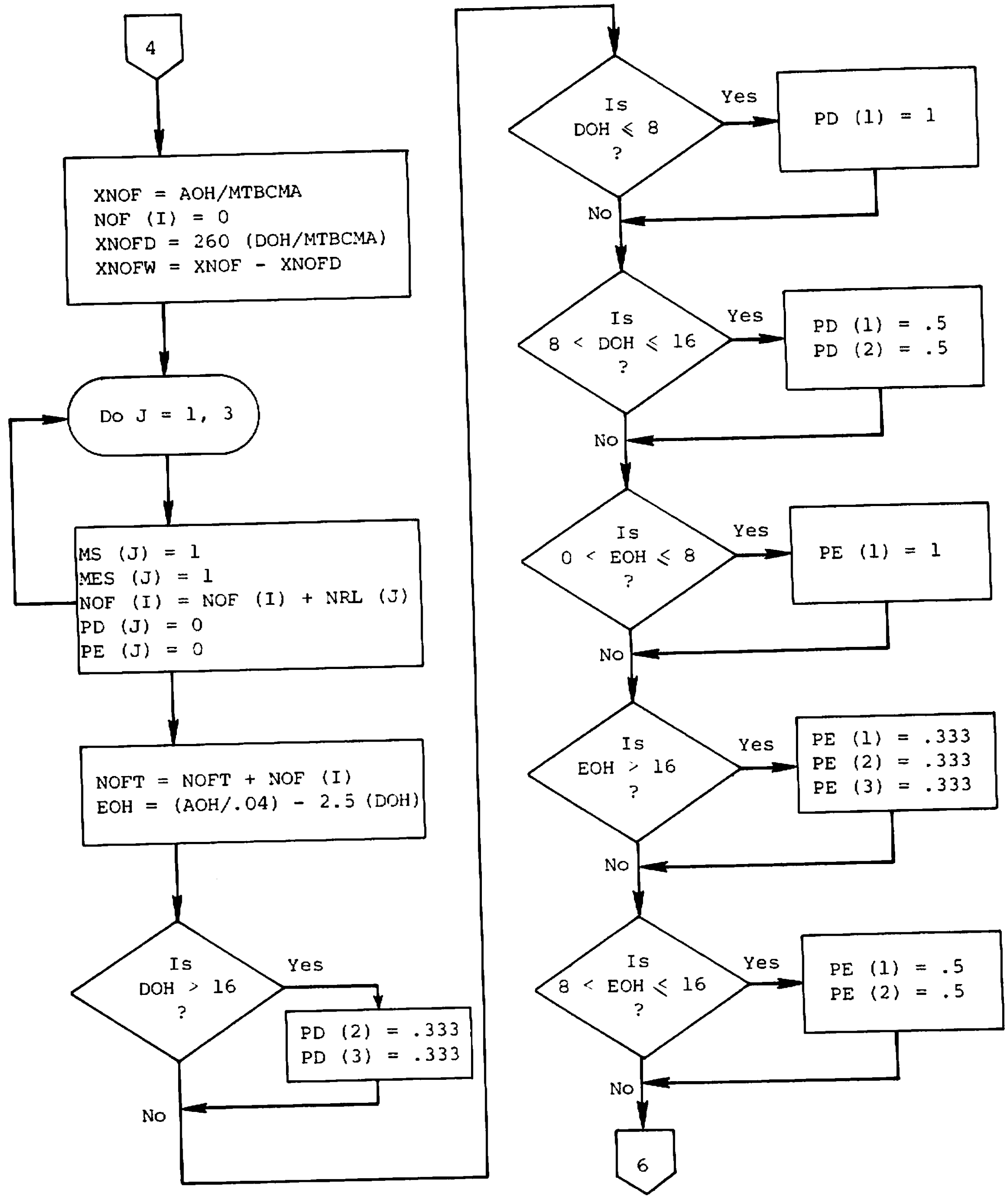


Figure 4-2. (continued)

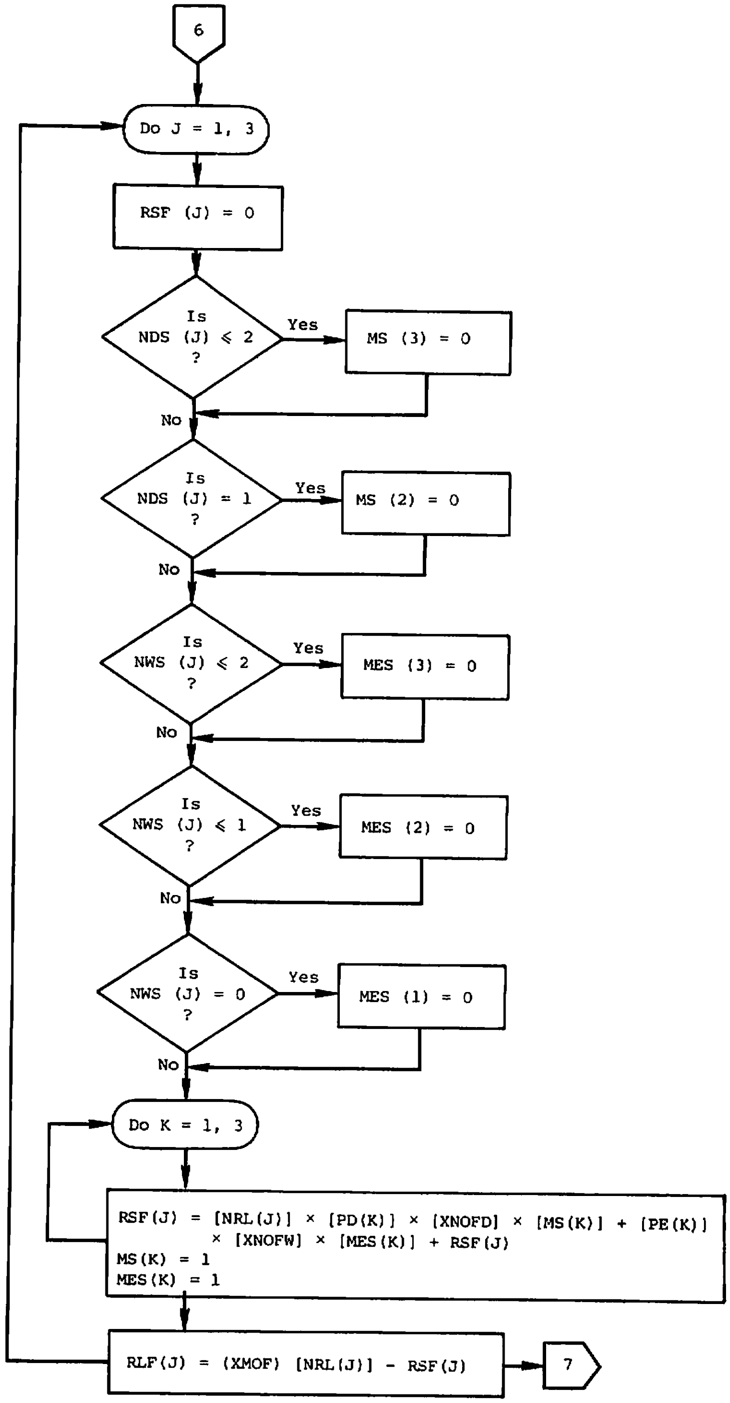


Figure 4-2. (continued)

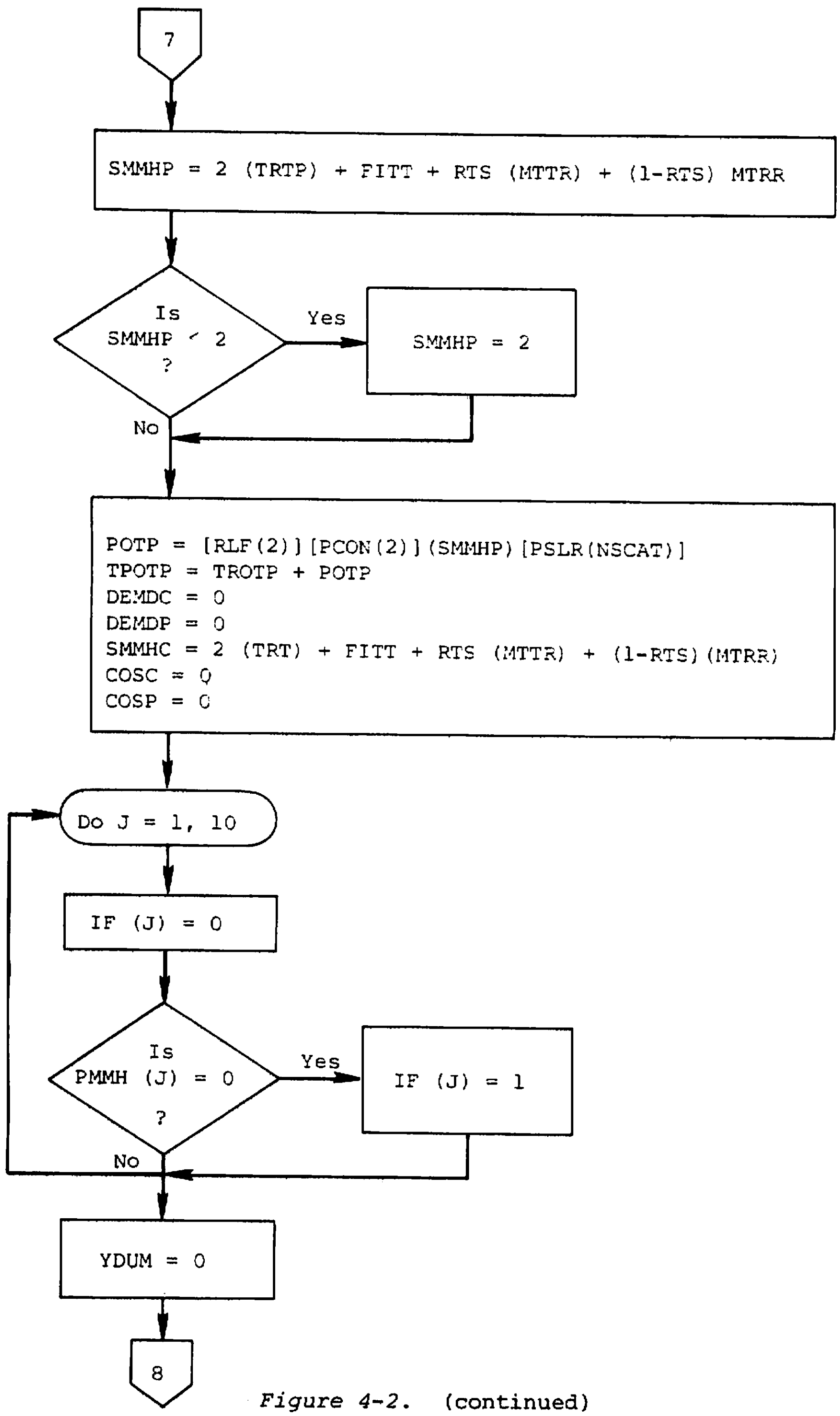


Figure 4-2. (continued)

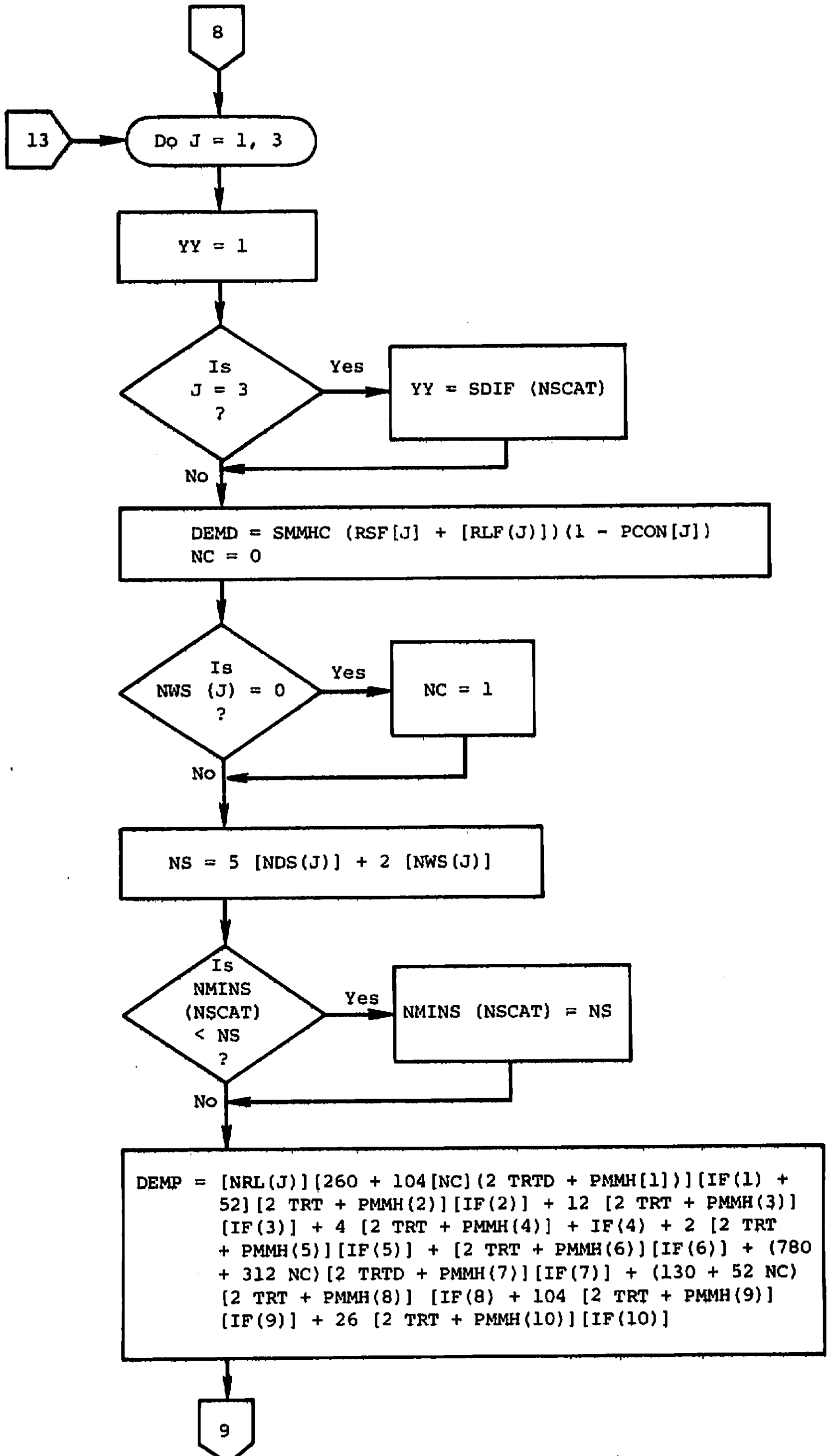


Figure 4-2. (continued)

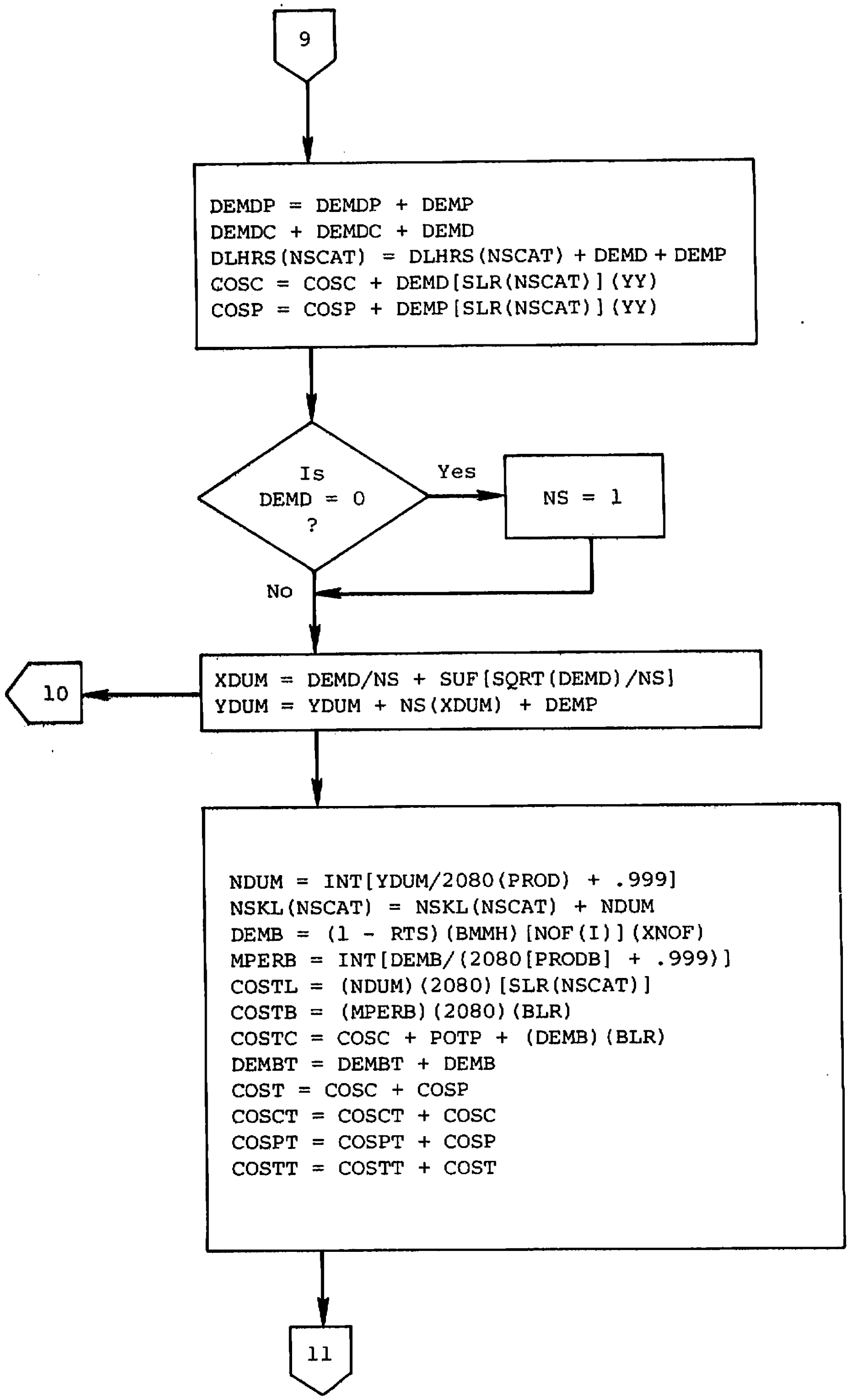


Figure 4-2. (continued)

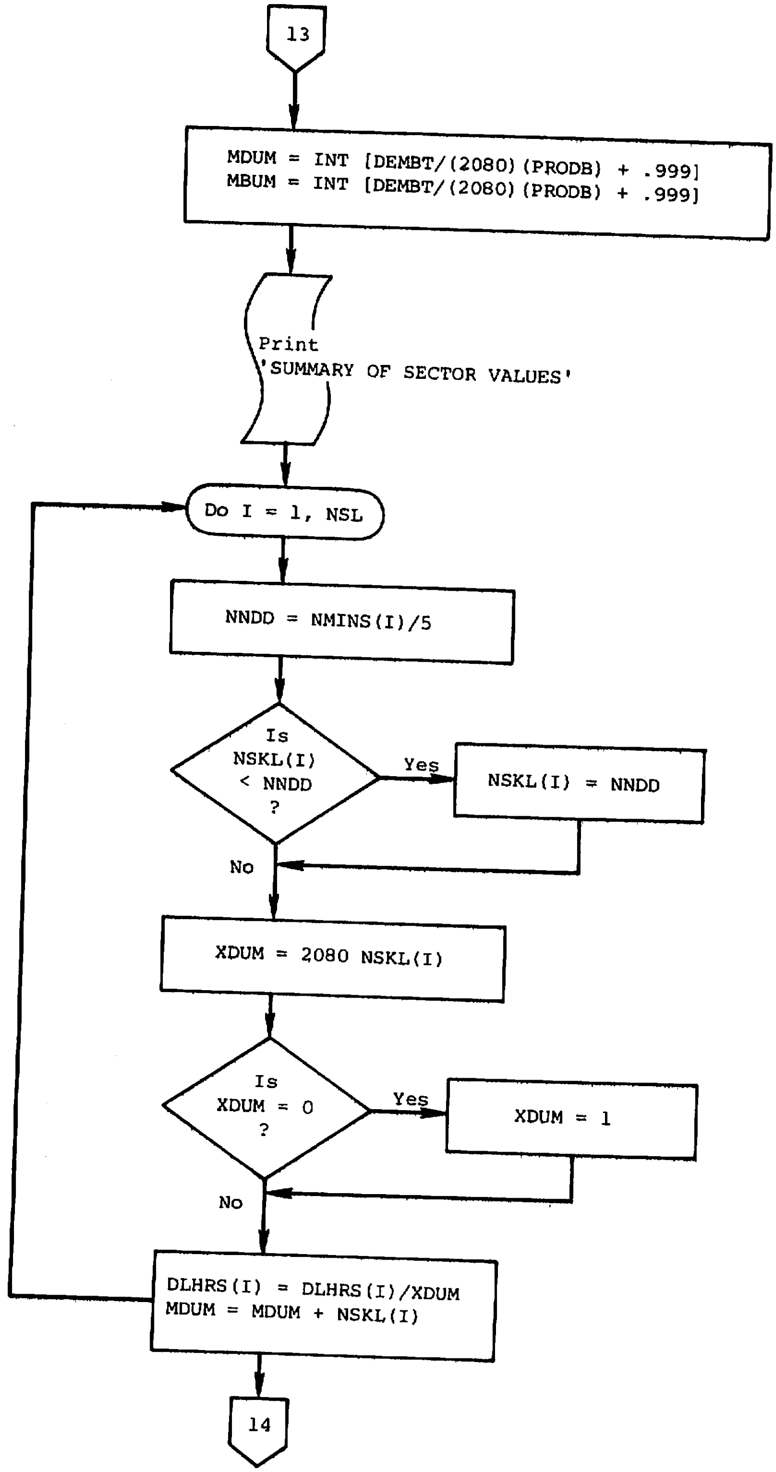


Figure 4-2. (continued)

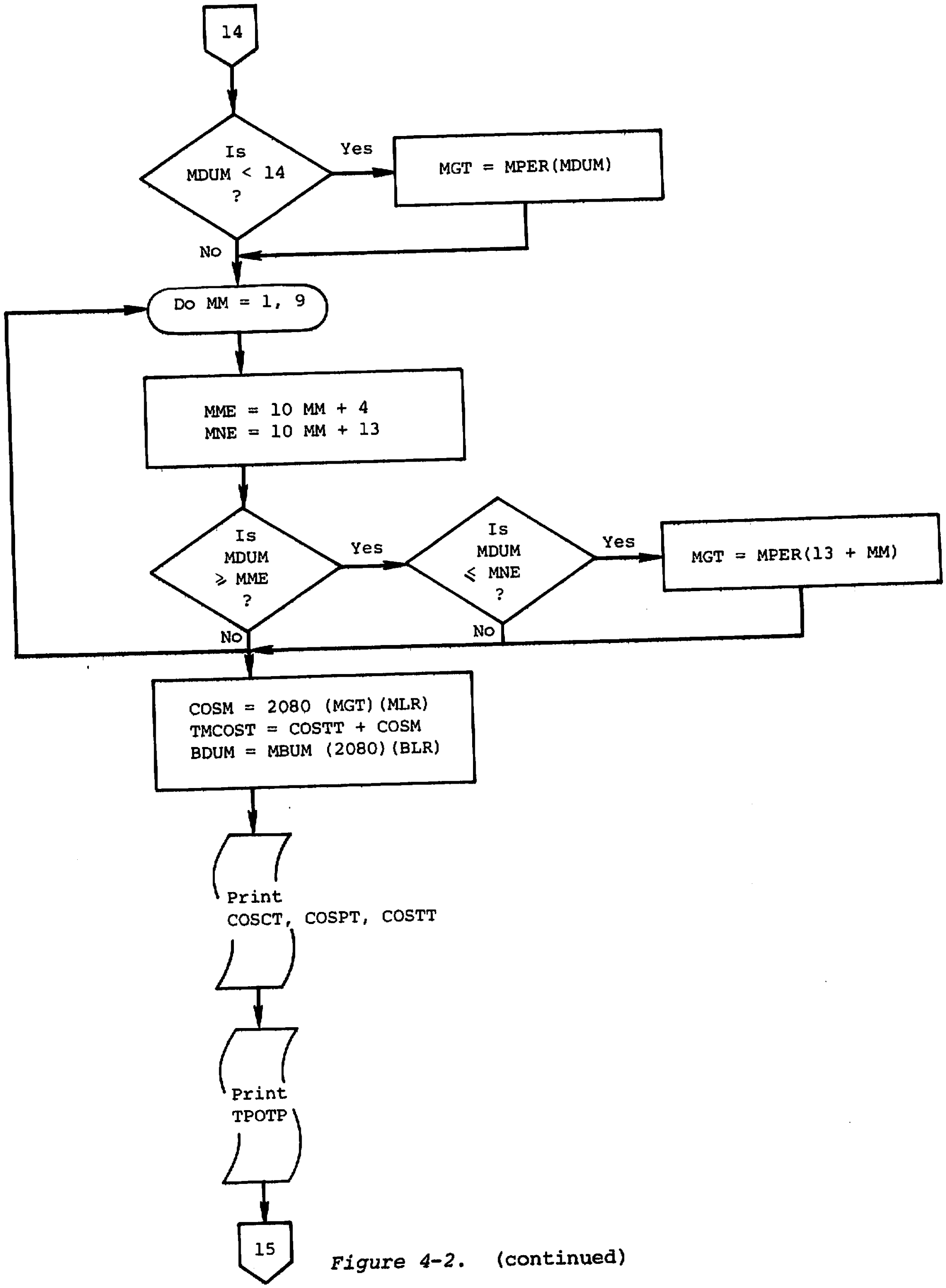


Figure 4-2. (continued)

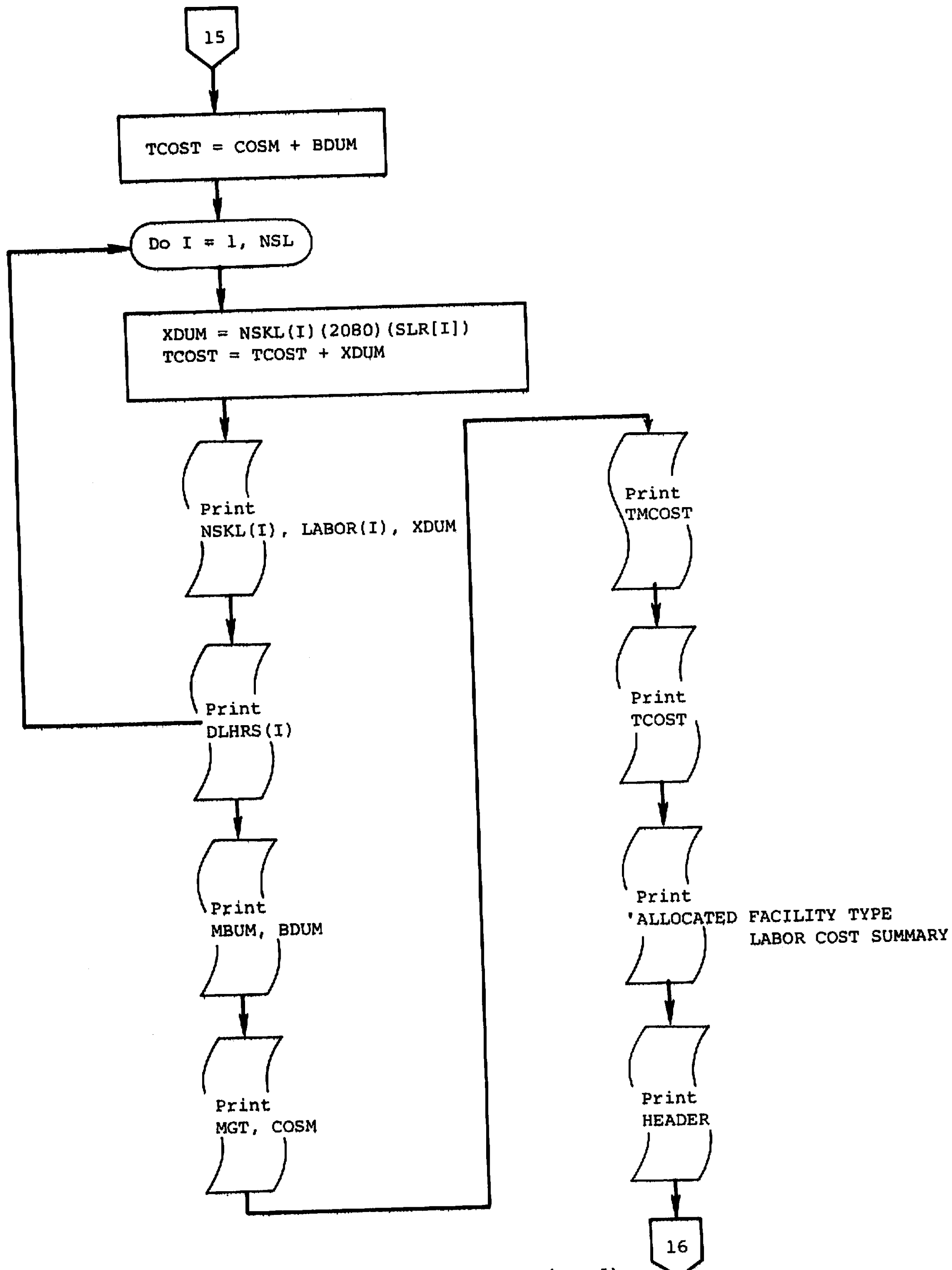


Figure 4-2. (continued)

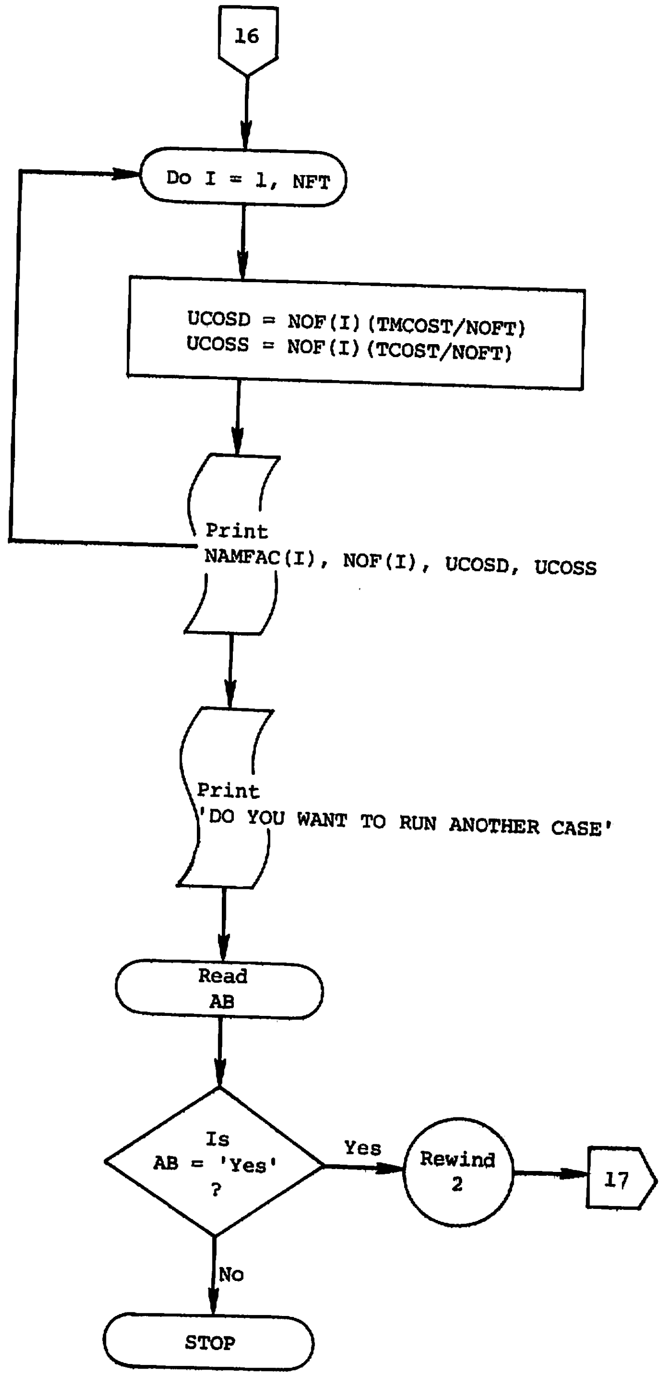


Figure 4-2. (continued)

CHAPTER FIVE

PROGRAM USE

5.1 TAPE SETUP

The program is contained in a standard magnetic tape cassette and is read into the time-share computer from a remote terminal by whatever procedures are appropriate to the terminal. Input files are read-in separately in accordance with the format described below.

5.2 INPUT DATA

Descriptions of the sector and facilities file data elements are given in Tables 5-1 and 5-2, respectively. The program considers as many sectors as there are sector files provided as data input. The number of facilities per sector is variable and is controlled solely by the program dimensioning statement.

The FMCM was exercised for the Logan maintenance sector by use of the input file data shown in Tables 5-3 and 5-4. Figures 5-1 and 5-2 present these same data in their input format. In Figure 5-1, the Logan Sector Data File, Lines 20 through 70 are personnel data inputs, and from Line 80 onward the data pertain to sector facilities. Line 20 in Figure 5-2 identifies the first set of data as that associated with the Glide Slope transmitter, here abbreviated GS. Lines 30 and 40 contain the data for the variables identified. Note that PMMH in Line 40 is a vector. In the remaining lines of the file the parameter names are further abbreviated to single letters. For example, in Line 60 "M 170" appears. This means the MTBCMA for the localizer is 170 hours.

5.3 MODEL OUTPUTS

Figures 5-3 through 5-5 are reproductions of outputs of model runs performed during the demonstration of the model. Figure 5-3 shows a run in which all facility types in the Logan sector are evaluated. The figure is truncated to show only the outputs associated with the first five facility types, out of a total of fourteen.

Table 5-1. SECTOR DATA FILE (SECFIL)

Mnemonic	Description
NFT	Number of facilities in the sector data file
NSL	Number of skill levels available within the sector
MLR	Average management support labor rate (dollars per hour)
BLR	Intermediate maintenance shop labor rate (dollars per hour)
PRODB	Intermediate maintenance shop labor productivity ratio
(1) XXX	Mnemonic for maintenance skill level
SLR	Labor rate (dollars per hour, defined for each skill level)
PSLR	Overtime labor rate (dollars per hour, defined for each skill level)
SDIF	Shift differential (a factor defined for each skill level)
MPER	Management support requirements as a function of maintenance staff size
(2) XXX	Mnemonic for a facility type within the sector
AOH	Average annual facility operating hours (hours per year)
DOH	Average daily facility operating hours (hours per day)
PCONB	Probability of contacting a maintenance man for a restoration level B facility
RTS	Fraction of failures repaired directly at the site
PROD	Average maintenance man productivity
NSCAT	Maintenance skill level identifier (see Note 1)
NRLA/NRLB/NRLC	Number of facilities having restoration levels A, B, or C
NDSA/NDSB/NDSC	Number of daily shifts for facilities having restoration levels A, B, or C
NWSA/NWSB/NWSC	Number of weekend shifts for facilities having restoration levels A, B, or C
TRTP	Average authorized travel time to one of these facilities for a call-back (hours)
TRT	Average travel time to one of these facilities from the central location (hours)
TRTD	Average travel time to one of these facilities for daily PM (hours)

Notes: 1. These parameters are repeated for each skill level available within the sector.
2. These parameters are repeated for each facility type within the sector.

Table 5-2. FMCM FACILITIES DATA FILE FOR EACH FACILITY TYPE (FACFIL)

Mnemonic Code*	Description
Alphanumeric	Alphanumeric identifier for facility type (e.g., GS, ASR, LOM)
MTBCMA	Mean time between corrective maintenance actions (operating hours per failure)
SUF	Personnel sufficiency factor (nondimensional factor to provide safety margin in determining personnel requirements)
FITT	Average fault-isolation and test time (maintenance man-hours per action)
MTTR	Mean time to repair (maintenance man-hours per action)
MTRR	Mean time to remove and replace (maintenance man-hours per action)
BMMI	Average intermediate-level repair time (maintenance man-hours per action)
PMMI	Preventive maintenance time (maintenance man-hours per action)**

*These parameters are repeated for each facility type within the sector.
**This parameter is an array of preventive maintenance times, by facility type, for each of the following scheduled PM frequencies: daily, weekly, monthly, quarterly, semi-annually, annually, three times daily, every other day, twice a week, every other week.

Table 5-3. SECTOR DATA FILE (SECFIL)

Mnemonic	Sector Parameters
NFT	14
NSL	4
MLR	18
BLR	0
PRODB	.7

Mnemonic	Skill-Level Parameters			
	RAD	ART	NAV	ENV
SLR	12	12	12	12
PSLR	18	18	18	10.9
SDLF	1.25	1.25	1.25	1.25

Mnemonic	
MPER*	0 0 0 0 3 4 5 8 9 10 11 12 13 15 17 19 21 23 27 29 31

Mnemonic	Facility Parameters													
	ASR	ARSR	SECRA	CD	RMLT	ARTS-3	ALS	GS	LOC	LOM	MM	H	VOR	TACAN
AOH	8760	8760	8760	8760	8760	8760	4380	8760	8760	8760	8760	8760	8760	8760
DDH	24	24	24	24	24	24	12	24	24	24	24	24	24	24
PCONB	0	0	0	0	0	0	0	.95	.95	.95	.95	0	0	0
RTS	1	1	1	1	1	1	1	1	1	1	1	1	1	1
PROD	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6	.6
NSCAT	1	1	1	1	1	2	4	3	3	3	3	3	3	3
NRLA	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NDSA	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NWSA	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NRLB	0	0	0	0	0	0	2	1	2	1	1	0	0	0
NDSB	0	0	0	0	0	0	2	1	1	1	1	0	0	0
NWSB	0	0	0	0	0	0	2	1	1	1	1	0	0	0
NRLC	1	1	2	1	2	1	0	3	3	3	3	1	1	1
NDSC	3	3	3	3	3	3	0	3	3	3	3	3	3	3
NWSC	3	3	3	3	3	3	0	3	3	3	3	3	3	3
TRTP	0	0	0	0	0	0	0	2	2	2	2	0	0	0
TRT	.3	0	.3	0	0	0	.25	.25	.3	1	1	.3	.25	.25
TRTD	.3	0	.3	0	0	0	0	.25	.3	0	0	0	0	0

*Applies to composite of all skill levels.

Table 5-4. FACILITIES INPUT FILE (FACFIL)														
Parameter	Facility													
	GS	LOC	LOM	MM	H	VOR	TACAN	ASR	ARSR	SECRA	OD	ARTS-3	ALS	RMLT
MTBCMA	8760	170	8760	8760	35,000	340	500	550	730	738	8760	8760	365	180
SUF	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FITT	6	.1	.7	.7	10	.25	.5	.5	1.5	.5	.6	8	.5	.5
MTTR	2	.3	.3	.3	.3	12	.5	1	.5	1	.2	2	2	2
MTRR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BMMH	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PMMH	0	0	0	0	0	0	3	2	3	1	2	8	0	0
	1	3	0	0	0	1	4	6	3	6	2.5	7	7	2
	4	4	.25	.25	0	6	8	15	8	15	7	18	4	9
	4	4	1	1	0	5	0	8	10	0	14	25	0	40
	1	16	0	0	0	1	0	15	6	6	16	7	10	2
	1	2	1	1	.25	0	2	26	2	0	4	1	400	2
	.25	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	.25	0	0	0	0	0	0	0	0	0	0	0	0
	.5	.5	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	1	1	1	0	0	0	0	0	0	0	0	0

```
10 LOGAN SECTOR DATA FILE
20 APT 14 NPL 4 MPR 12. DLR 0. PRUDE .7
30 RAD SLR 12. PSLR 18. IDIF 1.25
40 APT SLR 12. PSLR 18. IDIF 1.25
50 NAV SLR 12. PSLR 14. SDIF 1.25
60 ENV SLR 12. PSLR 10.5 IDIF 1.25
70 MPER 0 0 0 0 3 4 5 8 9 10 11 12 13 15 17 19 21 23 25 27 29 31
80 ASR
90 ADH 8760. DDH 24. PCORR 0. RTS 1. PROB .6 NSCAT 2
100 NPLA 0 NDSH 0 NWSA 0 NPLB 0 NDSB 0 NWSB 0 NPLC 1 NDSC 3 NWSC 3.
110 TRTP 0. TPT .3 TRTD .3
120 ARSR
130 ADH 8760. D 24. P 0. R 1. P .6 N 2
140 N 0 N 0 N 0 N 0 N 0 N 0 N 1 N 3 N 3
150 T 0. T 0. T 0.
160 SECRA
170 ADH 8760. D 24. P 0. R 1. P .6 N 2
180 N 0 N 0 N 0 N 0 N 0 N 0 N 2 N 3 N 3
190 T 0. T .3 T .3
200 CD
210 ADH 8760. D 24. P 0. P 1. P .6 N 2
220 N 0 N 0 N 0 N 0 N 0 N 0 N 1 N 3 N 3
225 T 0. T 0. T 0.
240 RMLT
250 ADH 8760. D 24. P 0. R 1. P .6 N 2
260 N 0 N 0 N 0 N 0 N 0 N 0 N 2 N 3 N 3
270 T 0. T 0. T 0.
280 ARTS3
290 ADH 8760. D 24. P 0. R 1. P .6 N 4
300 N 0 N 0 N 0 N 0 N 0 N 0 N 1 N 3 N 3
310 T 0. T 0. T 0.
320 ALS
330 ADH 4380. D 12. P 0. R 1. P .6 N 4
340 N 0 N 0 N 0 N 2 N 2 N 2 N 0 N 0 N 0
350 T 0. T .25 T 0.
360 GS
370 ADH 8760. D 24. P .95 R 1. P .6 N 3
380 N 0 N 0 N 0 N 1 N 1 N 1 N 3 N 3 N 3
390 T 2. T .25 T .25
400 LOC
410 ADH 8760. D 24. P .95 R 1. P .6 N 3
420 N 0 N 0 N 0 N 2 N 1 N 1 N 3 N 3 N 3
430 T 2. T .3 T .3
440 LOM
450 ADH 8760. D 24. P .95 R 1. P .6 N 3
460 N 0 N 0 N 0 N 1 N 1 N 1 N 3 N 3 N 3
470 T 2. T 1. T 0.
480 MM
490 ADH 8760. D 24. P .95 R 1. P .6 N 3
500 N 0 N 0 N 0 N 1 N 1 N 1 N 3 N 3 N 3
510 T 2. T 1. T 0.
520 H
530 ADH 8760. D 24. P 0. R 1. P .6 N 3
540 N 0 N 0 N 0 N 0 N 0 N 0 N 1 N 3 N 3
550 T 0. T .3 T 0.
560 VOR
570 ADH 8760. D 24. P 0. R 1. P .6 N 3
580 N 0 N 0 N 0 N 0 N 0 N 0 N 1 N 3 N 3
590 T 0. T .25 T 0.
600 TACAN
610 ADH 8760. D 24. P 0. R 1. P .6 N 3
620 N 0 N 0 N 0 N 0 N 0 N 0 N 1 N 3 N 3
630 T 0. T .25 T 0.
```

Figure 5-1. **LOGAN SECTOR FILE**

```
10 FACILITIES DATA FILE
20 GS
30 MTBCMA 8760. SUF 0. FITT 6. MTTR 2. MTRR 0. BMMH 0.
40 PMMH 0. 1. 4. 4. 1. 1. .25 0. .5 0.
50 LOC
60 M 170. S 0. F .1 M .3 M 0. B 0.
70 P 0. 3. 4. 4. 16. 2. 0. .25 .5 0.
80 LOM
90 M 8760. S 0. F .7 M .3 M 0. B 0.
100 P 0. 0. .25 1. 0. 1. 0. 0. 0. 1.
110 MM
120 M 8760. S 0. F .7 M .3 M 0. B 0.
130 P 0. 0. .25 1. 0. 1. 0. 0. 0. 1.
140 H
150 M 35000. S 0. F 10. M .3 M 0. B 0.
160 P 0. 0. 0. 0. 0. .25 0. 0. 0. 1.
170 VOR
180 M 340. S 0. F .25.M 12. M 0. B 0.
190 P 0. 1. 6. 5. 1. 0. 0. 0. 0. 0.
200 TACAN
210 M 500. S 0. F .5 M .5 M 0. B 0.
220 P 8. 4. 8. 0. 0. 2. 0. 0. 0. 0.
230 ASR
240 M 550. S 0. F .5 M .5 M 0. B 0.
250 P 2. 6. 15. 8. 15. 26. 0. 0. 0. 0.
260 APSR
270 M 730. S 0. F 1.5 M .5 M 0. B 0.
280 P 3. 3. 3. 10. 6. 2. 0. 0. 0. 0.
290 SECRA
300 M 730. S 0. F .5 M 1. M 0. B 0.
310 P 1. 6. 15. 0. 6. 0. 0. 0. 0. 0.
320 CD
330 M 8760. S 0. F 16. M .2 M 0. B 0.
340 P 2. 2.5 7. 14. 16. 4. 0. 0. 0. 0.
350 ARTS3
360 M 8760. S 0. F 8. M 2. M 0. B 0.
370 P 8. 7. 18. 25. 7. 1. 0. 0. 0. 0.
380 ALS
390 M 365. S 0. F .5 M 2. M 0. B 0.
400 P 0. 7. 4. 0. 10. 400. 0. 0. 0. 0.
410 RML1
420 M 180. S 0. F .5 M 2. M 0. B 0.
430 P 0. 2. 9. 40. 2. 2. 0. 0. 0. 0.
```

Figure 5-2. FACILITY FILE

```
INPUT SECTOR FILE NAME ? LOGAN
DO YOU WANT TO CONSIDER ALL FACILITY TYPES ? YES

FACILITY - ASR
CM COST =     501.21  PM COST =  23535.00  TM COST =  24036.21
COST OF CALLBACKS =        0.
  2 OF SITE LABOR CLASS  RAD          AT ANNUAL BASE COST =  49920.00
  0 OF BASE LABOR CLASS AT ANNUAL COST =        0.

FACILITY - ARSR
CM COST =     359.64  PM COST =  20970.00  TM COST =  21329.64
COST OF CALLBACKS =        0.
  2 OF SITE LABOR CLASS  RAD          AT ANNUAL BASE COST =  49920.00
  0 OF BASE LABOR CLASS AT ANNUAL COST =        0.

FACILITY - SECRA
CM COST =     755.24  PM COST =  33780.00  TM COST =  34535.24
COST OF CALLBACKS =        0.
  2 OF SITE LABOR CLASS  RAD          AT ANNUAL BASE COST =  49920.00
  0 OF BASE LABOR CLASS AT ANNUAL COST =        0.

FACILITY - CD
CM COST =     242.76  PM COST =  15510.00  TM COST =  15752.76
COST OF CALLBACKS =        0.
  1 OF SITE LABOR CLASS  RAD          AT ANNUAL BASE COST =  24960.00
  0 OF BASE LABOR CLASS AT ANNUAL COST =        0.

FACILITY - RMLT
CM COST =    3646.35  PM COST =  11340.00  TM COST =  14986.35
COST OF CALLBACKS =        0.
  1 OF SITE LABOR CLASS  RAD          AT ANNUAL BASE COST =  24960.00
  0 OF BASE LABOR CLASS AT ANNUAL COST =        0.
```

Figure 5-3. FMCM OUTPUT (PART A)

```
SUMMARY OF SECTOR VALUES
CM COST =  20434.41  PM COST = 337597.05  TM COST = 358031.46
COST OF CALLBACKS =   5492.94
  8 OF SITE LABOR CLASS  RAD          AT ANNUAL BASE COST = 199680.00
              WITH ACTUAL PRODUCTIVITY =  .4493
  4 OF SITE LABOR CLASS  ART          AT ANNUAL BASE COST =  99840.00
              WITH ACTUAL PRODUCTIVITY =  .4347
 14 OF SITE LABOR CLASS  NAV          AT ANNUAL BASE COST = 349440.00
              WITH ACTUAL PRODUCTIVITY =  .4179
  2 OF SITE LABOR CLASS  ENV          AT ANNUAL BASE COST =  29120.00
              WITH ACTUAL PRODUCTIVITY =  .4334
  0 OF BASE LABOR CLASS AT ANNUAL COST =        0.
 17 OF MGT SUPPORT AT ANNUAL COST = 424320.00
TOTAL SECTOR ANNUAL LABOR DIRECT COST = 737341.46
TOTAL SECTOR ANNUAL LABOR BASE COST =1102400.00
```

ALLOCATED FACILITY TYPE LABOR COST SUMMARY

FACILITY	QUANTITY	DIRECT LABOR COST	BASE LABOR COST
ASR	1	26078.05	36746.67
ARSR	1	26078.05	36746.67
SECRA	2	52156.10	73493.33
CD	1	26078.05	36746.67
RMLT	2	52156.10	73493.33
ARTS3	1	26078.05	36746.67
ALS	2	52156.10	73493.33
GS	4	104312.19	146986.67
LOC	5	130390.24	183733.33
LOM	4	104312.19	146986.67
MM	4	104312.19	146986.67
M	1	26078.05	36746.67
VOR	1	26078.05	36746.67
TACAN	1	26078.05	36746.67

```
DO YOU WANT TO RUN ANOTHER CASE? YES
```

Figure 5-4. FMCM OUTPUT (PART B)

```
INPUT SECTOR FILE NAME ? LOGAN
DO YOU WANT TO CONSIDER ALL FACILITY TYPES ? NO
HOW MANY TYPES ? 2
FACILITY ? ASR
CM COST =     501.21  PM COST =  23535.00  DM COST =  24036.21
COST OF CALLBACKS =         0.
  2 OF SITE LABOR CLASS  RAD              AT ANNUAL BASE COST =  49920.00
  0 OF BASE LABOR CLASS AT ANNUAL COST =        0.
FACILITY ? TACAN
CM COST =     393.81  PM COST =  48757.50  DM COST =  49151.31
COST OF CALLBACKS =         0.
  3 OF SITE LABOR CLASS  NAV              AT ANNUAL BASE COST =  74880.00
  0 OF BASE LABOR CLASS AT ANNUAL COST =        0.

SUMMARY OF SECTOR VALUES
CM COST =     895.01  PM COST =  72292.50  DM COST =  73187.51
COST OF CALLBACKS =         0.
  4 OF SITE LABOR CLASS  RAD              AT ANNUAL BASE COST =  99840.00
               WITH ACTUAL PRODUCTIVITY =  .1954
  0 OF SITE LABOR CLASS  AFT              AT ANNUAL BASE COST =       0.
               WITH ACTUAL PRODUCTIVITY = 0.
  4 OF SITE LABOR CLASS  NAV              AT ANNUAL BASE COST =  99840.00
               WITH ACTUAL PRODUCTIVITY =  .3939
  0 OF SITE LABOR CLASS  ENV              AT ANNUAL BASE COST =       0.
               WITH ACTUAL PRODUCTIVITY = 0.
  0 OF BASE LABOR CLASS AT ANNUAL COST =        0.
  9 OF MGT SUPPORT AT ANNUAL COST = 199680.00
TOTAL SECTOR ANNUAL LABOR DIRECT COST = 272867.51
TOTAL SECTOR ANNUAL LABOR BASE COST = 399360.00

ALLOCATED FACILITY TYPE LABOR COST SUMMARY
 FACILITY QUANTITY   DIRECT LABOR COST     BASE LABOR COST
ASR             1          136433.76            199680.00
TACAN           1          136433.76            199680.00

DO YOU WANT TO RUN ANOTHER CASE? NO
```

Figure 5-5. FMCM OUTPUT (PART C)

The first output block of Figure 5-3, for the ASR, shows corrective, preventive, and direct maintenance costs per year. It can be seen that direct maintenance cost is the sum of the costs of corrective and preventive maintenance. Since the ASR is subject to level C maintenance, there are no call-back costs. Two men in labor category RAD were considered in the calculation, at combined annual salaries of $49,920. Since only on-site repair is conducted at Logan, the base (intermediate) labor category is null; therefore, the cost is zero. Base repair is in the model as a logistic-support scenario option. After the ASR cost data are printed, the next facility to be evaluated, "ARSR", is identified. This cycle continues until all facilities in the sector file have been examined.

Figure 5-4 shows the summary output for the entire sector. It gives the total corrective, preventive, and direct maintenance costs for 14 facility types and, for those facilities which are restoration level B, the total cost of call-backs. The total basic salaries of the four labor classes are displayed, as well as their expected actual productivities. Productivity is defined as the ratio of actual maintenance time to total on-duty time.

The item denoted "total sector annual direct cost" is the sum of the direct maintenance cost and management/support cost. The item denoted "total sector annual labor base cost" is the sum of the annual base (salary) costs of four labor classes and management/support cost. It is assumed that management/support personnel productivity is unity.

The table in the lower portion of Figure 5-4 is a summary of allocated labor costs for the entire set of facilities. The basis for the allocation in this case is that the 30 facilities have equal weight. It is possible, of course, to allocate these costs by another weighting system.

Figure 5-5 displays the same kinds of data as Figures 5-3 and 5-4. The only difference is that in this run only two facilities have been selected (a program option): the ASR and TACAN, which must be identified by terminal inputs before each is evaluated.

5.4 RESTRICTIONS AND/OR LIMITATIONS

There are no hardware or software restrictions. Restrictions on data ranges or capacities are not anticipated.

5.5 EDITING AND DIAGNOSTICS

There are no program-generated diagnostic messages.

5.6 TEST CASE

The input and output data files presented in Section 5.3 were obtained from the program demonstration. These files, when considered with the program listing, constitute a test case.

5.7 APPLICATION OF THE FMCM

The model, as noted earlier, is structured to have a common file (FACFIL) containing data on all types of facilities maintained by the Airways and Facilities Division of the FAA that are common to all sectors, and a series of files each containing data peculiar to a specific maintenance sector (SECFIL). The principal uses of the model, therefore, are:

To evaluate specific sectors or selected facility types within specific sectors for their attendant expected annual maintenance labor (and management/support) personnel requirements, direct labor costs, and salary costs.

To determine the impact on the maintenance sector or on the facility-type baseline evaluations due to specific changes in reliability, maintainability, technical or support parameters, maintenance scenario, etc.

To conduct sensitivity analysis to determine the driving parameters and their associated ranges of impact.

Specific sector maintenance evaluations are handled through normal exercise of the program, with specific sectors and facility types to be evaluated being designated by terminal inputs. The model is structured to permit evaluation of successive sectors/facility types without the need to recompile each time.

Alternative maintenance scenario evaluations can be handled in two ways: through a permanent change to file data (or establishment of additional permanent files) or through the insertion of temporary program statements to modify the main program. Selecting between these approaches for a specific application will depend on the nature and extent of the changes. If they tend to be simple, then the temporary change to the main program approach is preferred; otherwise, the changes are better made as permanent changes to the affected files. In this latter case, additional permanent file changes would again be required to restore them to their original condition once the evaluations were completed.

The best means of accomplishing sensitivity analyses is to insert temporary changes to the main program and take advantage of the looping feature of the program. To illustrate, assume that the sensitivity to some parameter (PARM) is desired and that PARM is read from either the common or sector files. Following the read statement for PARM, we could then insert the following temporary statements:

```
PRINT, * VARIATION FACTORS*,
READ, VARF
PARM = VARF * PARM.
```

Thus, each time PARM is read from the file, its value is modified by a terminal input for the modification factor, which, if repeated over the range of interest for the parameter, would then provide the resultant output sensitivity curves for PARM (e.g., VARF could go from 0.1 to 10).

Table 5-5 summarizes the specific terminal responses required for normal exercise of the program. The responses for usages with temporary changes to the program will depend on the nature of the changes introduced and their formats. As shown in the table, program usage is extremely simple, with terminal inputs being needed only to specify what is to be evaluated (sector/facility) during a given terminal session. The set-up of the files whose specific contents and structure are described and presented in the program documentation for the Logan maintenance sector represents the only complex aspect of program preparation.

Table 5-5. SUMMARY OF TERMINAL RESPONSE REQUIREMENTS FOR NORMAL PROGRAM EXECUTION

Question	Terminal Response	FORTRAN Variable	Comments
1. Input sector file name?	Permanent file name of sector to be evaluated, e.,g., LOGAN	SECFIL	None
2. Do you want to consider all facility types?	YES or NO	AA	None
3. How many types?	Integer number	NFT	Only if AA = YES.
4. Facility?	Facility name (e.g., ASR)	NAMF	Only if AA = YES.
5. Do you want to run another case?	YES or NO	AB	If AB = NO, programs stops; otherwise, it recycles to question 1 for a new case.

CHAPTER SIX

SYMBOLS

All symbols and variables appearing in the program listing (shown in Figure 4-1 of Chapter Four) are summarized and described in this chapter.

Table 6-1 defines variables which are input via the sector and facility files. Table 6-2 is a listing of variable symbols and definitions.

Table 6-1. INPUT FILE SYMBOLS AND DEFINITIONS

Symbol	Definition	Units
AOH	Average annual facility operating hours	Hours per year
BLR	Intermediate level repair labor rate	Dollars per hour
BMMH	Average intermediate level repair maintenance man-hours per action	Maintenance man-hours per action
DOH	Average daily operate hours per facility type	Hours per day
FITT	Average fault isolate and test time per facility type	Maintenance man-hours per action
LABOR	Labor skill name	n/a
MLR	Average management support labor rate	Dollars per hour
MPER	Management support requirements	n/a
NAMFAC	Facility type name	n/a
MTBCMA	Minimum time between corrective maintenance action per facility type	Operate hours per failure
MTTR	Minimum time to repair per facility type	Maintenance man-hours per action
MTRR	Minimum time to remove and replace per facility type	Maintenance man-hours per action
NDS	Number of daily shifts per facility type per restoration level	n/a
NFT	Number of facility types	n/a
NRL	Number of facilities per restoration level per type	n/a
NSCAT	Skill level identifier per facility	n/a
NSL	Number of skill levels per sector	n/a
NWS	Number of weekend shifts per facility type per restoration level	n/a
PCON	Probability of contact per facility type for restoration level B	n/a
PMMH	Preventive maintenance man-hours per action per facility type	Maintenance man-hours per action
PROD	Average productivity per facility type	n/a
PRODB	Intermediate level productivity	n/a
PSLR	Overtime labor rate per skill level	Dollars per hour
RTS	Fraction of failures repaired at site per facility type	n/a
SDIF	Shift differential per skill level	n/a
SLR	Labor rate per skill level	Dollars per hour
SUF	Personnel sufficiency factor	n/a
TRT	Average travel time per facility type	Hours
TRTD	Average daily PM travel time per facility type	Hours

Table 6-2. INTERMEDIATE VARIABLE SYMBOLS AND DEFINITIONS

Symbol	Definition	Units
DEMB	Intermediate level repair demand per facility type	Maintenance man-hours
DEMBT	Total intermediate level repair demand	Maintenance man-hours
DEMD	Corrective maintenance demand per restoration level per facility type	Maintenance man-hours
DEMDC	Corrective maintenance demand per facility type	Maintenance man-hours
DEMDP	Preventive maintenance demand per facility type	Maintenance man-hours
DEMP	Preventive maintenance demand per restoration level per facility type	Maintenance man-hours
EOH	Average weekend operate hours per facility type	Hours per day
IF	Preventive maintenance frequency identified	1 or 0
LDUM	Dummy variable	n/a
MS	Daily maintenance shift identifier	1 or 0
NC	Weekend operations identifier	1 or 0
NDUM	Dummy variable	n/a
NMINS	Dummy variable	n/a
NNDD	Minimum required number of personnel per skill level	n/a
NOFT	Total number of facilities	n/a
NPER	Number of maintenance personnel per skill level	n/a
NS	Total number of shifts	n/a
PD	Daily failure allocation factor	n/a
PE	Weekend failure allocation factor	n/a
SECMCM	Program name	n/a
SMMHC	Total corrective maintenance man-hours per action per facility type	Maintenance man-hours per action
SMMHP	Total call-backs corrective maintenance man-hours per action per facility type	Maintenance man-hours per action
XDUM	Dummy variable	n/a
XNOF	Average number of failures per year per facility type	n/a
XNOFD	Average number of weekday failures	n/a
XNOFW	Average number of weekend failures	n/a
YY	Shift differential identifier	n/a
YDUM	Dummy variable	n/a

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