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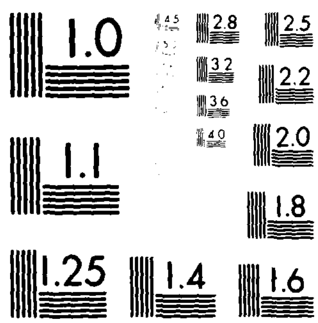

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Report No. FAA-ASP-80-7

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FAA COMMUNICATIONS COST MODEL PROGRAM DOCUMENTATION (REVISED)

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R. Tanke
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APRIL 1980

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16. Abstract

The FAA Communications Cost Model described in this report is a computer program designed to be used as an overall communications planning tool. The program has been designed to address management questions dealing with long-term, national-level communications planning issues. The model was developed and coded in FORTRAN IV-G for the IBM 360/65 computer at the Transportation Computer Center and most time sharing systems. The documents related to this study are: Report No. FAA-ASP-80-6, "FAA Communications Cost Model User's Guide (Revised)," and Report No. FAA-ASP-80-8, "Impact of Selected FAA Programs on Switched and Non-switched Network Costs."

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METRIC CONVERSION FACTORS

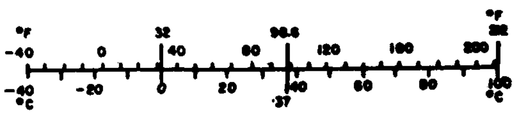
Approximate Conversions to Metric Measures

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

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

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



CONTENTS

CONTENTS (continued)

CHAPTER ONE

INTRODUCTION

The FAA Communications Cost Model ~~described in this report~~ is a computer program designed to answer management questions dealing with long-term, national-level communications planning issues. Therefore, the program is purposely directed toward estimating long-term macro-level (as opposed to near-term, micro-level) communications costs. The algorithms used emphasize cause-and-effect relationships (rather than direct extrapolation of cost data) to predict costs. This report documents the communications model computer program. It includes a description of the model equations, functional flow charts, and the program listings. It should be used in conjunction with the revised *FAA Communications Model User's Guide** for a comprehensive understanding of the computer software. This edition supersedes the issue dated May 1979.

Special care has been taken during the formulation of the model equations to concentrate on the high-cost areas of FAA communications. The program uses the FAA forecasts of aircraft traffic as the fundamental driver of communications requirements. This forecast employs four separate parameters:

- Instrument Flight Rules (IFR) Aircraft Handled at ARTCCs
- Total Operations at Airports
- Instrument Operations at Airports
- Total Flight Services

The numbers of sectors, towers, Terminal Radar Approach Control Facilities (TRACONs) and Flight Service Stations (FSSs) required to accommodate the forecast aircraft activity are calculated. The number of other facilities required to support the increased communication load is then determined using current facility planning methods. Finally, the cost of each facility is computed. The user has the option of providing a number of inputs to the program to modify certain costs (e.g., inflation rate, system implementation dates, and level of system automation).

**FAA Communications Model User's Guide*, (Revised), Report No. FAA-ASP-80-6. ARINC Research Corporation, Annapolis, Maryland.

This chapter has presented a brief overview of the cost model. Chapter Two describes the communication's cost model in detail, including how costs are determined, where and when the model may be applied, and the inputs and outputs required for proper model operation. Chapter Three addresses all the model equations that were derived, including the rationale for each equation. The model computer program source listing as well as a general flow chart and the Operations and Maintenance (O&M) and Facilities and Equipment (F&E) baseline cost data bases are included in Chapter Four. Chapter Five defines the symbols, both scalers and subscripted variables, that are used in the computer program. Finally, the appendix contains the FAA facility alpha codes and descriptions.

CHAPTER TWO

COMMUNICATIONS COST MODEL

An FAA communications cost study was required to evaluate the cost impact of several alternative approaches to meeting the FAA's operational communications requirements through the year 2008. This was accomplished by development and use of an analytic, computer-based communications cost model that calculates new facility and equipment costs, operations and maintenance costs for new and old equipment, leased circuit and equipment costs, and user-assigned costs that are added directly into the final model outputs. Results are computed on the basis of the specified inflation rate. The FAA communications model will compute cumulative and annual costs in the report format requested by the user.

2.1 DESCRIPTION OF THE COST DETERMINATION PROCESS

Examination of the operational functions of communications in the ATC system revealed that communications services and the types of communications facilities they require stem directly from the operational requirements associated with certain major components of the FAA's Air Traffic Control (ATC) system. These components can be categorized into the following types of ATC operational units:

- Individual En-Route Sectors
- Air Traffic Control Towers (ATCTs)
- Terminal Radar Approach Control Facilities (TRACONs)
- Flight Service Stations (FSSs)
- Air Route Traffic Control Centers (ARTCCs)

For each type of operational unit, a typical communications equipment configuration can be defined. This can be done through analysis of representative operational units and with the aid of FAA data bases describing the current deployment of communications equipment [e.g., the data base of the Transportation Systems Center (TSC) of the U.S. Department of Transportation]. With the communications for each type of ATC operational unit so described, the growth in the total communications plant can be directly related to the growth in the number of ATC operational units. This growth is, in turn, driven by the growth in number and type of aircraft movements according to established FAA criteria for commissioning of new ATC operational units.

The modeling approach permits consideration of a wide range of scenarios. Changes to operational requirements can be accommodated by modifying the communications services associated with a typical operational unit. The effect of future automation can be included by modifying the criteria defining the number of operational units required to service a given traffic level. Cost-saving advances in communications technology, tariff changes, etc., can be incorporated by modifying the cost data base. The general approach is summarized in Figure 2-1.

The initial step in the cost determination process is to compute the 1979 baseline communications cost from the data provided in the F&E and O&M data bases. To this baseline cost will be added the new facility costs, circuit costs, and leased equipment costs required to service the increased demand computed from air traffic forecasts. Four separate aircraft activity forecasts (identified in Figure 2-1) are used (based on FAA forecasts), extrapolated through the year 2008 (see Section 3.1, Chapter Three). The forecasts are then used to predict the number of operational units in each of the five major categories (sectors, towers, centers, terminal radar facilities, and FSSs). Most other communications facilities may be related to one of the five major categories on the basis of statistics developed from the existing communication system. Some facilities, however, increase independently of operational unit growth, while others remain fixed. The FAA has more than 120 facility types of which only 64 have been identified as relating to communication. Of the 64 it was determined that the percentage of facility costs due to communications varied between 3 percent and 100 percent. Communications costs are derived from the number of facilities and the estimated percentage of total facility costs attributed to communications. Before determining system costs, the requirements for voice, data, and radio circuits necessary for all facilities are computed. The quantity and length of communications circuits plus the cost of leased equipment required are then used to calculate the system costs. Finally, the cost model will output the calculated data in the form specified by the user from an optional list of report types. The model provides for inflation and discounting. (See the User's Guide* for a sample of output report types.)

The user may elect to override the model by (1) using different forecasts than those included in the internal equations, (2) entering optional inputs for the operational requirements and system costs, (3) entering fixed costs that are simply added to the annual costs computed, or (4) appending user-defined facility types. All user-elected options are provided as specific computer card inputs as described in the User's Guide. An example of the cost determination process for calculating the future communications costs of en-route sectors is given below.

**Ibid.*

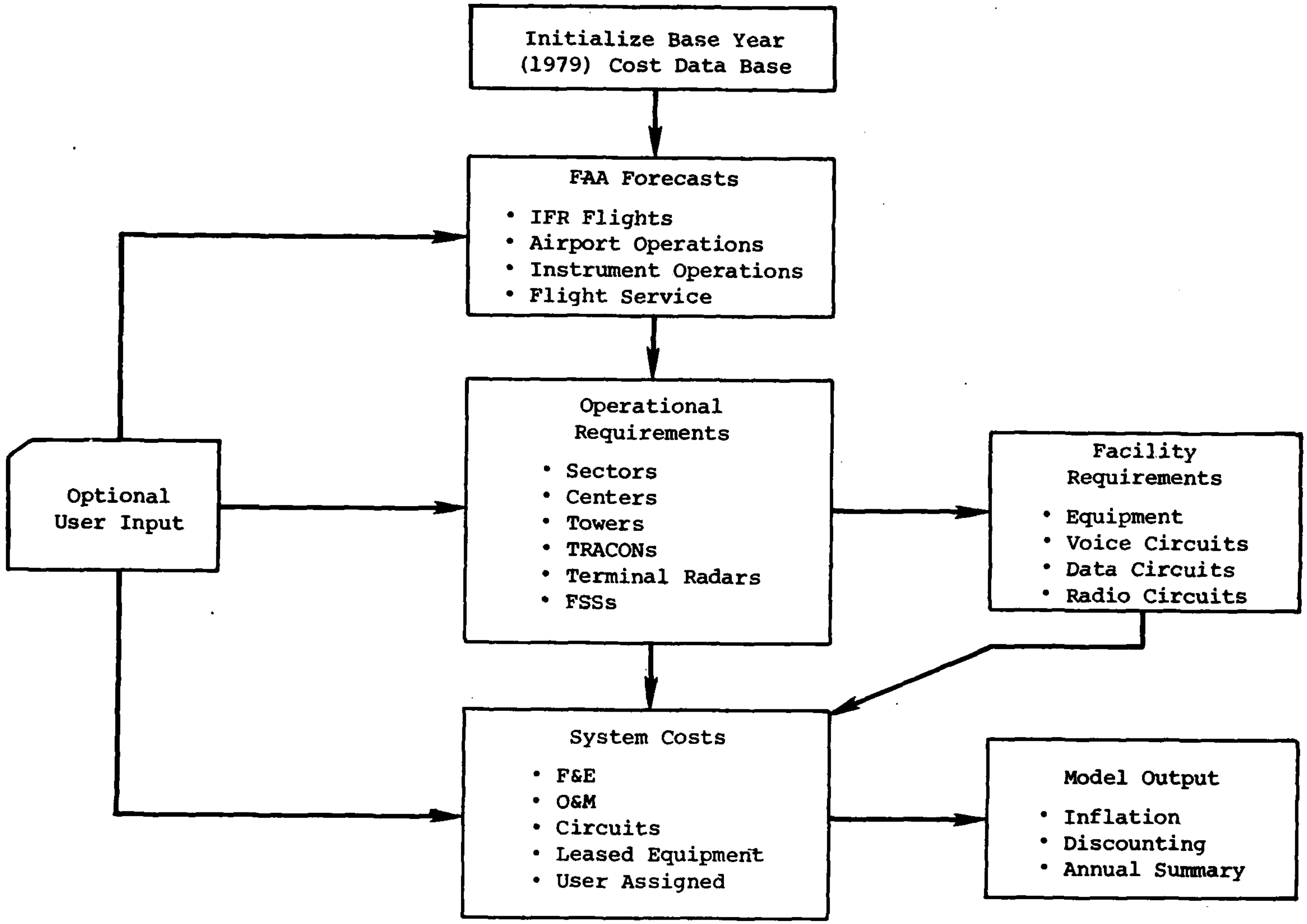


Figure 2-1. COMMUNICATIONS MODEL OPERATION

The number of en-route sectors is determined as a function of the number of IFR operations at ARTCCs. The number of sector-related communications facilities is determined as a function of the number of sectors and the average number of communications facilities per sector (including capital equipment, leased equipment, and maintenance). Total sector-related communications costs are then determined on the basis of projected F&E costs, O&M costs, and leased costs for the specific facilities involved. The cost model computer program contains an F&E and O&M cost data base from which the cost projections for various facility types are computed (see Section 4.3). Various common carrier tariffs such as Telpak and multi-schedule private line (MPL) are also included in the costing portion of the model. In addition, the user may specify a number of other options such as inflation rate or new system implementation schedule. Similarly, the model generates costs for towers, TRACONs, FSSs, centers, and other communications facilities.

2.2 APPLICABILITY

Several significant characteristics of the FAA Communications Model are discussed below:

- High-Level User Input. User inputs to the model are in terms of broad, operationally defined requirements that do not require detailed user knowledge of communications system design. Precise characteristics of new facilities and actual geographic locations are not needed. The advantage of this approach is that the model will be useful to a broad spectrum of users and not just communications engineers.
- Long-Term Macro Analysis. The model is primarily intended to address long-term, macro-level communications issues as opposed to short-term, micro-level issues. The shortest period the model is capable of analyzing is one year. It computes total FAA communications requirements for the 48 contiguous states and for Alaska, Hawaii, and Puerto Rico. The forecast algorithms employed permit analysis of any period from 1980 through 2008.
- Accuracy. The model is designed to provide order-of-magnitude costs rather than specific costs on which a detailed budget can be based. The primary interest is the relative cost of one communications system compared with an alternative system. Actual costs (from 1978 FAA cost data) are believed to be within 10 percent of the computed values.
- Limitations. The model does not currently include data for FAA facilities that do not have communications functions. Of the 64 different facilities included, many serve functions that are considered partially communications. However, storage space exists for 95 facilities; thus, other facilities of interest may be added at run time. Estimated communications percentages for each facility type are presented in Chapter Four. The correct percentage

will vary somewhat depending on the particular alternative being evaluated and the context in which the evaluation is performed. The model does not include the cost of operating personnel nor the cost of administrative communications circuits. These types of costs can be added directly to the output, if desired, using certain model options. A further limitation of the present program is that any circuit designated to be switched or priced under a new tariff will be switched and repriced for all years of the run beginning in 1979. This also applies to the user-specified productivity factors.

- General Issues to be Addressed by the Model. The model permits the evaluation of many specific issues affecting FAA communications:
  - Aviation growth (e.g., increases in total aircraft traffic or IFR traffic)
  - Communications system innovation (e.g., switched voice, combined voice and data)
  - Introduction of new FAA systems that affect FAA communications (e.g., automation, DABS)
  - Changing communications tariffs (e.g., introduction of satellite circuits)
  - FAA procedural or administrative changes (e.g., consolidation of centers, requiring all operations at 50 busiest airports to be IFR)

  The model computes the communications cost for the time period of interest. This provides absolute communications costs and data that can be used in comparative cost analyses. A model with this range of capability is able to address almost any specific communications issue that may be of interest to the FAA.

2.3 MODEL INPUTS

This section describes the inputs that are used by the model, their relationships to each other, and their interactions with the model's internal nominal data base. Figure 2-2 illustrates the various types of inputs and how they are related. The F&E and O&M data bases internal to the model are detailed in the User's Guide. Any of these nominal data values can be changed by the user as more current data become available. Specific considerations relating to model parameters and variables are discussed in the following paragraphs:

- Facilities and Equipment Costs. All F&E costs are assumed to be one-time expenses and, as a result, no depreciation is computed for existing equipment. New facilities and equipment will be added to the existing system in two ways: (1) normal system growth (based on user inputs or official FAA forecasts if no specific user input is provided), and (2) new systems that are added by

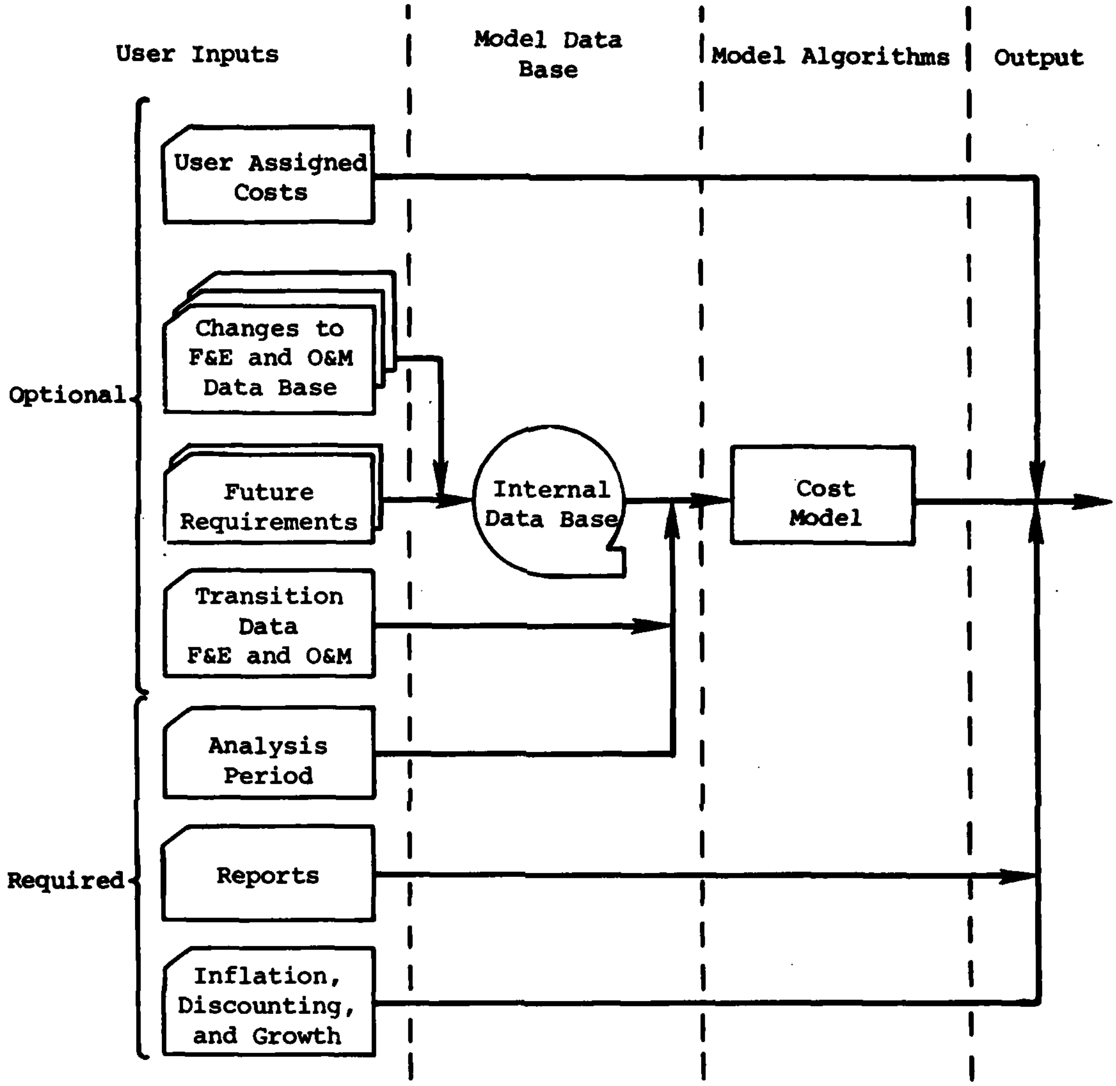


Figure 2-2. COST MODEL INPUTS

the model user. The model contains nominal facility costs for all present-day communications equipment and inflation factors that affect increases in the number of facilities required as a result of forecast aircraft traffic growth. The F&E cost corresponding to system growth is automatically computed by the model. However, since no depreciation is programmed, the user should consider the useful life of the equipment and should input F&E replacement costs in the appropriate years if the user wants to determine the total F&E expenditures in future years. A second category of F&E expense will be input by the user to cover the cost of new systems that are added to enhance the performance of the FAA's system. This category of F&E expenses includes projected costs for new systems such as DABS, ATARS, MLS, etc. These costs will be input to the model in the form of additional cards included at model run time.

The F&E expenditures must reflect the actual implementation schedule. For example, authorization in one year of an F&E program may result in a program that requires four years to implement fully. The F&E and O&M costs associated with the new equipment must, therefore, be spread over a four-year period. The user in these cases inputs an implementation schedule that gives the total percentage of the new system implemented by that year. A typical schedule might be 15 percent by 1980, 25 percent by 1981, 65 percent by 1982, 85 percent by 1983, 100 percent by 1984. Where an existing category of facilities is being replaced, another set of percentages can be used to compute the burden of maintaining the old system during the replacement period. These data for transition from an older to a modernized facility are directly applied to the cost model without affecting the baseline data.

- Operations and Maintenance. O&M costs are incurred to maintain the present communications facilities in operational status. These costs include labor costs for communications technicians, inventory, spares provisioning and, to some extent, replacement costs. The O&M costs will increase according to an inflation rate specified by the model user. Periodic increases in the O&M cost for particular facility types can be programmed by the user to reflect the burden of maintaining obsolescent equipment. New facilities, on the other hand, could experience a significant decrease in O&M costs if a transition is made from old vacuum tube technology to new solid-state technology equipment, and these costs reductions can also be specified by the model user.

- User-Assigned Costs. This category is used to reflect special costs that are not manipulated by the model but are important in the overall cost analysis being performed. User-assigned costs could, for example, reflect costs to the airlines to install avionics equipment on aircraft that operate in conjunction with a new FAA system such as DABS. Estimates of these costs are input by the user at run time and are directly added to the output of the cost model computations.

- Required Variables. In addition to these general model inputs, there are a number of specific variables that must be defined for each run:

  - Inflation, discounting, and growth rate
  - Period of analysis, e.g., 1980 through 1989
  - Type of output reports required (see Section 2.4)

- Other Variables. Additional specific variables that can be defined for each run are:
  - Annual increase in IFR aircraft operations
  - Annual increase in VFR aircraft operations
  - Type of tariff to use for pricing point-to-point circuits (Telpak, private line, microwave, satellite, other)
  - Number of switches and type of circuits to be switched (voice, radio, or data)
  - Grade of service to be used in switched system
  - Changes to nominal F&E costs
  - Changes to nominal O&M costs
  - Changes to percentage allocations for communications
  - Changes to circuit utilization estimates
  - Level of automation

  This information is keypunched for input at the beginning of each run. The specific data formats are defined in the User's Guide.

2.4 MODEL OUTPUTS

The model considers 64 different facility types in computing costs. These costs are summed and assigned to one of five categories for each analysis year:

- Non-Recurring Facilities and Equipment Costs
- Recurring FAA Operations and Maintenance Costs
- Annual Leased-Circuit Costs
- Annual Leased-Equipment Costs
- User-Assigned Costs

All costs are converted to 1979 dollars on the basis of the inflation rate specified. In addition, the model computes the net present value of all expenditures for each year and the cumulative cost from year to year. The user has eight output options to select the quantity of data printed after each run:

- Detailed Cost Summary
- Short Summary
- F&E Data Base
- O&M Data Base
- Tariff Schedules

- Operational Units
- Circuit Array Data
- Main Array Data

The User's Guide presents detailed examples of all FAA communications cost model outputs.

When intepreting these reports, the user should keep in mind that the model has been designed for order-of-magnitude cost estimates at the national level. By iteratively applying the model and changing only a few variables, it is possible to determine the relative advantages of different alternatives at a macro-economic level. The same technique is also useful for demonstrating the particular cost sensitivities of a given system concept.

CHAPTER THREE

MODEL EQUATIONS

This section contains the equations used by the FAA Communications Cost Model. They are presented in algebraic form to facilitate understanding; they can be translated directly into the FORTRAN Code used in the program. All symbols used are defined in Chapter Five.

The rationale underlying the model assumes that FAA ATC services are supported by ATC operational units that in turn are serviced by various types of communications facilities and circuits. The ATC operational units can be categorized into five types:

- En-Route Sectors
- Air Traffic Control Towers
- Terminal Radar Facilities
- Flight Service Stations (FSSs)
- Air Route Traffic Control Centers (ARTCCs)

To perform the communications associated with their operational mission, the operational units draw upon an array of 64 different types of facilities and their supporting circuits. Most of these facilities and circuits service one or more of the operational unit types. Expansion (or contraction) of the number of operational units requiring communications facility services may result in a related expansion or contraction of some portion of the existing communications facilities and/or the creation of entirely new facilities and circuits. Changes in the traffic environment, introduction of new ATC services, advances in communication technology, etc., will affect the growth of the operational units, the development of the communications facilities, and the cost of the facilities and circuits.

As shown in Figure 3-1, the process described above is implemented by organizing the model into seven modules that operate on the inputs supplied at run time and a resident data base. The internal data base contains nominal values for all cost parameters required by the various modules. The user may alter any of these values at run time without having to recompile the program. The input module accepts the run time inputs supplied by the

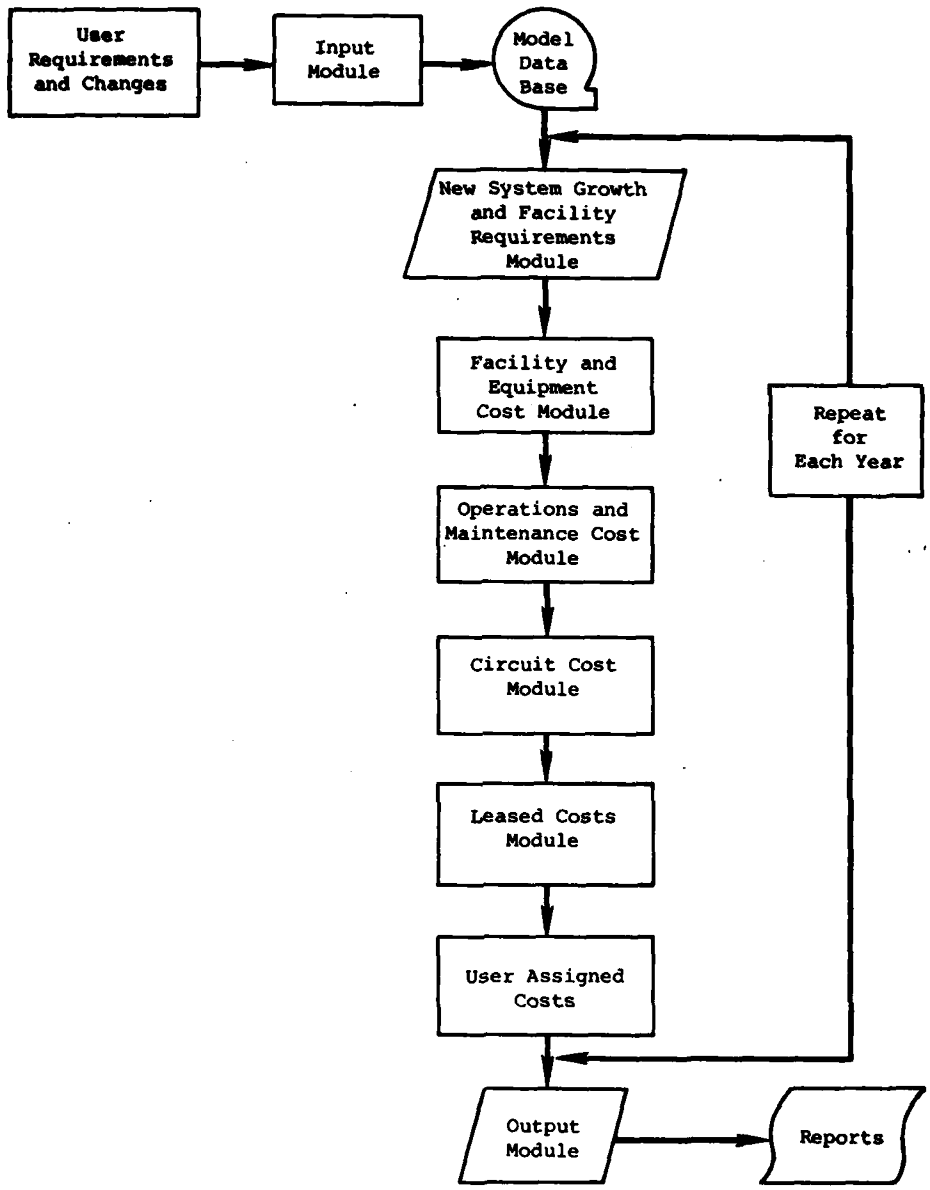


Figure 3-1. BASIC COMMUNICATIONS MODEL STRUCTURE

user in the form of a high-level description of the environment and the system alternative to be modeled. This module translates the input into the parameters and terms on which the costing modules operate. The New System Growth and Facility Requirements Module accounts for the expansion or contraction of operational units in accordance with traffic growth, automation, and FAA policy changes. The four costing modules (F&E, O&M, circuit, and lease costs) separately compute the costs for new equipment, operations and maintenance of the communications equipment plant, the communications network costs, and any leased communications equipment. The output module combines and categorizes the cost data and prepares cost reports as described in Section 2.4.

The technique for computing total cost involves adding together all incremental costs resulting from either changes to the baseline system or system growth. The generalized equation for F&E costs is given by the following equation:

F&E Cost = (Number of facilities added in year y) (Cost per facility) + Σ (Number of operational units added in year y) (Facility cost due to expansion)

This equation considers two factors in computing F&E costs:

- The number of additional facilities required
- Changes in facility cost due to expansion

The first part of the equation computes the basic cost for all new facilities. In many cases, however, facilities are upgraded to handle additional traffic. Therefore, the second part of the equation computes the cost of all expansions to existing facilities. The formulation thus accounts for increases in quantity as well as complexity within the system. Only an incremental cost for new facilities is computed; it is added to the baseline cost.

A similar equation is used for computing O&M costs:

O&M Cost = (Number of operational units in year y) (Cost per operational unit) + Σ (Number of operational units added since 1979) (O&M cost due to expansion)

This equation accounts for the total O&M cost, including increases in the number of facilities that need to be maintained as well as increases in the cost of maintenance due to increased complexity.

Circuit costs are computed in a somewhat different manner. The number of circuits required is primarily a function of the types of facilities that must be connected. The cost per circuit, however, depends on circuit length. The following equation is a generalized form of the circuit cost algorithm:

Ckt Cost = [2 (Cost per circuit end) + (Cost per mile) (Average length of Ckt)] $\{\Sigma$ (Number of Ckts per facility) (Number of facilities)$\}$

The actual algorithms used in the model are more complicated than the generalized equations given here. Factors such as inflation, implementation schedules, circuit types, and tariff types are dealt with in detail as described later in this section. The model uses these equations and parameters to compute costs one year at a time until the years of interest are reached. The model is thus able to compute annual as well as cumulative costs for any period between 1980 and 2008.

The remainder of this section describes the various program modules in greater detail.

3.1 INPUT MODULE

The input module translates a high-level user description of the FAA network into parameters that the various other modules can use. This is accomplished through appropriate changes to the baseline system data base and the construction of special requirements matrices that identify subsequent modifications to the data base for each year of analysis. Inputs that affect communications costs are considered to fall into one of the following categories:

- Technological changes
- Operational changes
- Automation
- Transitional changes

The first two types are handled by modifying the baseline system F&E and O&M cost parameters in the F&E and O&M cost data base. Remote Center Air/Ground Communications Facility (RCAG) modernization, for instance, would probably consist of replacing vacuum tube equipment with more reliable solid-state equipment. This would necessitate a change in the basic RCAG facility cost with a reduction in the baseline O&M cost due to greater reliability. The new data are entered at run time by the model user. Operational changes might be represented by the deletion of one equipment type or the addition of a new type. In either case, the user must estimate the various cost factors required by the model for each facility type that must be changed or added and input the number of such facilities required.

Automation will affect the appropriate operational unit module by reducing the total number of operational units required according to user-specified inputs.

The last type of input concerns transitional changes to the system. For each affected facility type, a special matrix is completed that indicates the rate at which the old system is to be phased out and the new system is to be phased in. The rates are specified in terms of the percentage of the old equipment that must be decommissioned in each year and the percentage of the system that is to be replaced by new equipment. Any desired level of redundancy can thus be specified by the model user for any period of time.

3.2 NEW SYSTEMS GROWTH AND FACILITY REQUIREMENTS MODULE

This module computes the number of ATC operational facilities that will be required to accommodate estimated future aircraft traffic levels. ATC operational facilities are those facilities that are required to provide air traffic services for en-route traffic, terminal area traffic, and flight advisory services.

Five types of operational facilities have been defined:

- En-Route Sectors
- Air Traffic Control Towers
- Terminal Radar Facilities
- Flight Service Stations
- Air Route Traffic Control Centers

Most facilities, equipment, and circuits vary with the number and types of ATC operational facilities. The following subsections describe the algorithms used to predict each of the ATC operational facilities as a function of the amount and type of forecast traffic. All algorithms are formulated from national averages, not instantaneous airborne counts at a particular region or sector. This is consistent with the philosophy that the model is to be used as a planning tool to address broad, national-level issues.

Data were obtained from two sources. Forecasts of IFR traffic, airport operations, instrument operations, and flight services were obtained from official FAA forecasts published by the Office of Aviation Policy (AVP-120). Forecasts for the five operational units were obtained from the FAA Air Traffic Service (AAT-110).

3.2.1 En-Route Sectors

The number of en-route sectors is determined as a function of the number of IFR operations at ARTCCs and the sector productivity factor. This relationship was determined from information provided by AAT personnel and FAA forecasts of air traffic and en-route sectors. The total number of en-route sectors was plotted as a function of the number of IFR aircraft handled at ARTCCs.

The FAA has prepared a sector forecast through 1983 (Figure 3-2) as a function of the expected increases in en-route IFR flights. From an analysis of the data, the following log-linear regression equation was developed for computing the total number of sectors.

$$\text{Number of Sectors} = [491.1 \, \text{Log}_e \, (\text{IFRTFK}) - 926.43] \, / \, \text{AUTOSE} \qquad (1)$$

where

IFRTFK = en-route IFR aircraft traffic, in millions of aircraft handled per year.

AUTOSE = sector productivity factor. This is defined as the ratio of the average sector size in the scenario under consideration to the average sector size in the current NAS. This factor has a nominal value of 1. Values greater than 1 imply that for whatever reason, a controller can handle more traffic per sector than is currently the case.

This equation is presented in Figure 3-2 (assuming AUTOSE = 1) to demonstrate its agreement with the present forecast and its extrapolation to further increases in IFR traffic.

To determine the number of sectors that will be in operation through the year 2008, it is necessary to forecast the en-route IFR traffic through the year 2008. A linear regression equation has been developed that closely matches the data available from official FAA air traffic forecasts. It has been extrapolated to develop estimates of IFR traffic beyond 1991. The equation is shown below and plotted in Figure 3-3. The factor of 27.75 in the equation below is the base year value; it must be subtracted before the growth factor can be applied, and then re-added.

$$\text{IFRTFK} = [(1.2505\ (\text{YR} - 1900) - 69.204) - 27.75]\ \text{IFRGRO} + 27.75 \qquad (2)$$

where

IFRTFK = En-route IFR traffic, in millions of aircraft handled per year

YR = Year under consideration

IFRGRO = Variation in IFR traffic growth. This is a factor, nominally 1, which is applied to the change of traffic over the nominal forecast. A value of 1.5 for example, would increase the IFR yearly traffic growth by 50 percent over the yearly growth in the nominal forecast.

If Equations 1 and 2 are combined, the results provide a projection of the increase in sectors through the year 2008, which can be used to determine the resulting increases in cost in the baseline scenario. These algorithms describe the number of en-route sectors that will be required to handle a given amount of en-route IFR aircraft traffic. The relationships reflect the present controller capability for handling peak aircraft traffic. The relationships describe the national aggregate of sectors as a function of the national aggregate of IFR aircraft handled. The model user may increase or decrease the projected IFR growth rate by entering a number other than one for AUTOSE. Changes in the controller capability for handling peak aircraft traffic (due to automation, for example) can also be incorporated by scaling the total number of sectors with the factor AUTOSE. Thus a productivity increase of 25 percent (AUTOSE = 1.25) would reduce the number of sector positions required by 20 percent.

3.2.2 Air Traffic Control Towers

All FAA-controlled airports have towers. For the busiest airports, terminal radar approach control (TRACON) facilities are provided when certain traffic levels are reached.

The FAA forecasts that the number of towers will increase an average of two per year as shwon in Figure 3-4. Although projected increases in air traffic would indicate that more than two airports per year will become qualified for tower service, budgetary considerations will limit the actual

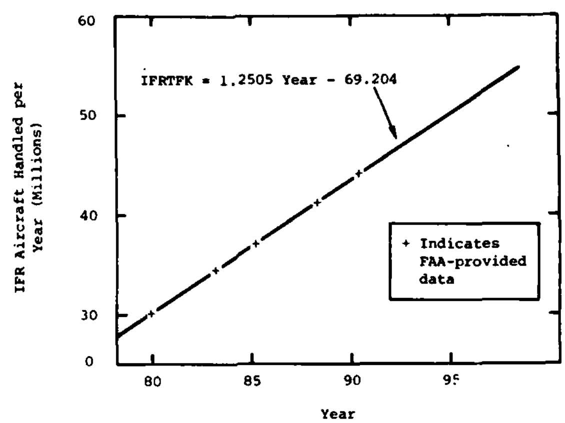


Figure 3-2. PROJECTED SECTOR GROWTH AS A FUNCTION OF IFR TRAFFIC

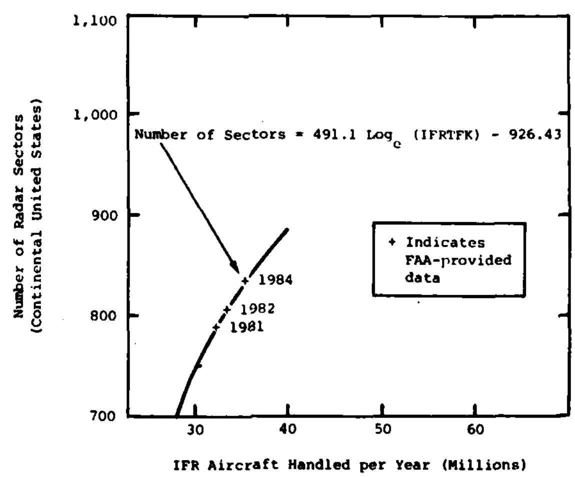


Figure 3-3. PROJECTED GROWTH IN IFR TRAFFIC

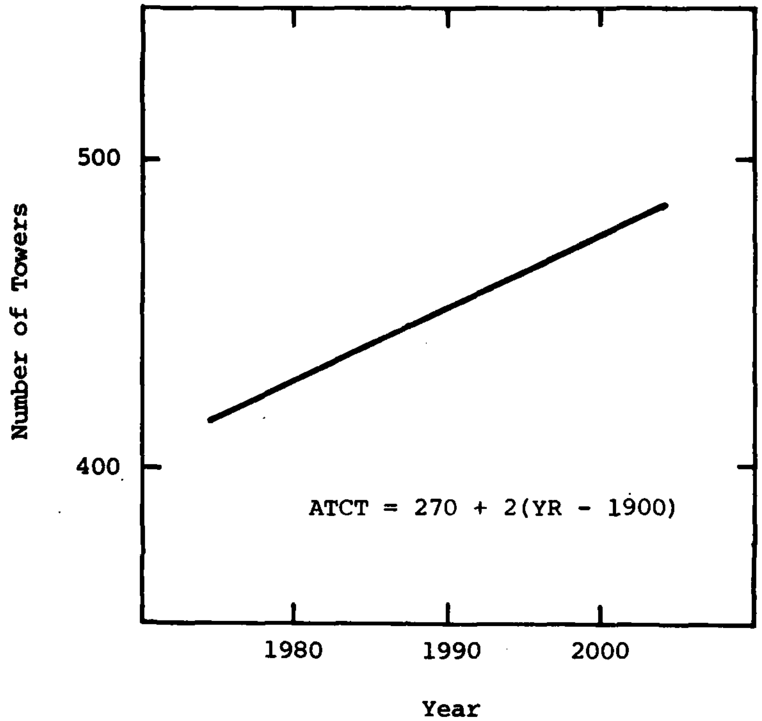


Figure 3-4. PROJECTED GROWTH IN TOWERS AS A FUNCTION OF AIRPORT OPERATIONS

number of new towers to two per year. The following equation represents this forecast:

$$ATCT = 270 + 2(YR - 1900) \qquad (3)$$

where

YR = Year under consideration

The FAA forecast of total local and itinerant airport operations is indicated in Figure 3-5. An analysis of the forecast data provides the following regression equation, which can be used to extrapolate the forecast through the year 2000 [again, the 70.46 figure represents the base (1979) figure]:

$$APTOPN = [(306.72 - 18429/(YR - 1900)) - 70.46]\ APOGRO + 70.46 \qquad (4)$$

where

APTOPN = Total local and itinerant airport operations, in millions per year

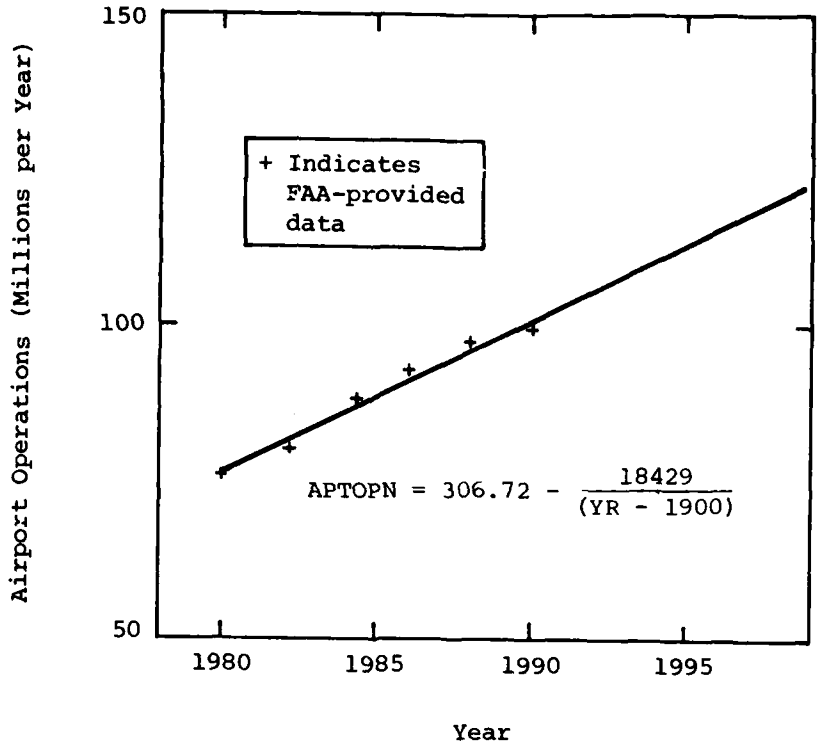


Figure 3-5. PROJECTED GROWTH OF TOTAL ITINERANT PLUS LOCAL AIRPORT OPERATIONS

YR = Year under consideration

APOGRO = Growth factor for airport operations. This is handled the same way as IFRGRO.

Equations 3 and 4 are combined in the baseline scenario to determine the increase in the number of towers and the resulting increase in communnications costs associated with these towers.

3.2.3 Terminal Radar Facilities (Airport Surveillance Radar)

When airport traffic loads become heavy, and particularly when the number of instrument operations at an airport becomes significantly large, the airport tower will be provided an airport surveillance radar (ASR). Some of the busiest airports with ASRs are designated as TRACONs. The FAA does not specifically forecast ASRs and TRACONs as a function of airport operations, but it is assumed that increases in airport instrument operations can be used to forecast increases in ASRs and TRACONs. There are currently 157 ASRs and 45 TRACONs. Therefore, the following equations are used in the baseline scenario:

$$\text{Number of ASRs} = (123.3 + \text{INSTOP}) / \text{AUTOTW} \qquad (5)$$

Number of TRACONs = 28.2 + 0.5 INSTOP (6)

where

INSTOP = Number of airport instrument operations, in million per year

AUTOTW = Tower productivity factor. This represents a factor which, if its value were greater than one, would imply that fewer towers are needed to cover the same ATC workload.

These equations are presented in Figure 3-6 for AUTOTW = 1. The number of airport instrument operations can be extrapolated from FAA forecast data by using the following equation:

$$INSTOP = \{[2.447e^{[0.0347(YR - 1900)]} - 33.64\} \; INOGRO + 33.64 \qquad (7)$$

where

INSTOP = Number of airport instrument operations, in millions per year

YR = Year under consideration

INOGRO = Growth factor for instrument operations

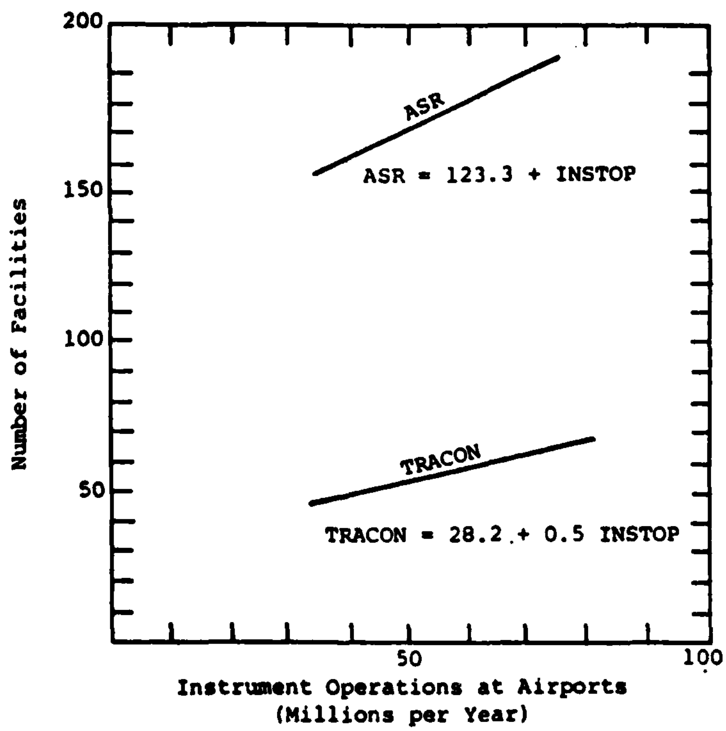


Figure 3-6. PROJECTED NUMBER OF ASRs AND TRACONs AS A FUNCTION OF INSTRUMENT OPERATIONS

Figure 3-7 shows the relationship between the FAA forecast and the derived equation.

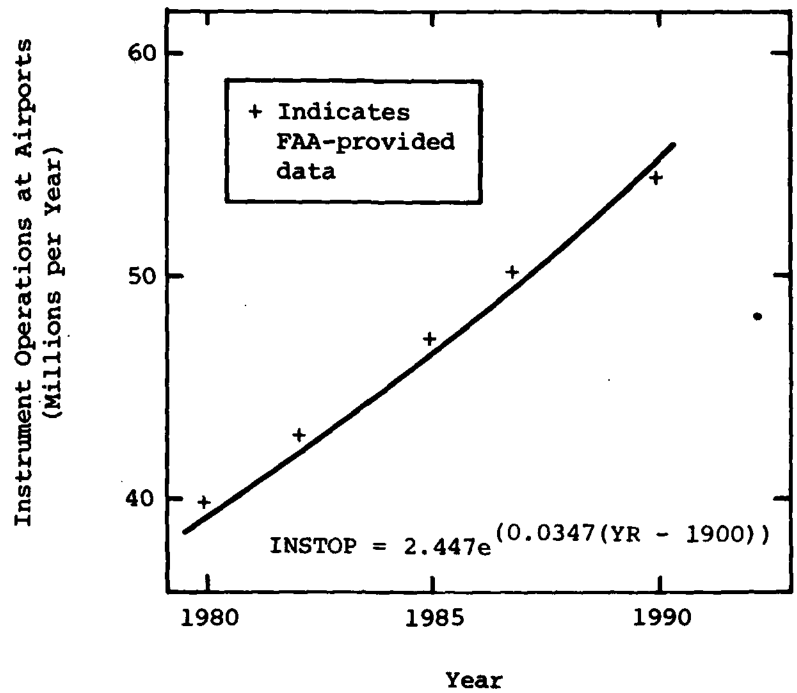


Figure 3-7. PROJECTED GROWTH IN INSTRUMENT OPERATIONS

3.2.4 Flight Service Stations

There are no plans to increase the number of Flight Service Stations, and it is likely that the number will decrease to achieve cost reductions through consolidation. However, the exact rate of consolidation was not identified. Therefore, in the baseline it is assumed that the number of FSSs will remain fixed and that the stations will have to be expanded to handle the expected increase in FSS operations. The projected growth in FSS operations is shown in Figure 3-8. The following equation can be used to extrapolate the data through the year 2000:

$$FLTSVC = [(365.466 - 23415.4/YR) - 67.80]\ FSVGRO + 67.80 \qquad (8)$$

where

FLTSVC = Total Flight Services, in millions per year

YR = Year under consideration

FSVGRO = Variation in FSS growth rate. This factor is handled in the same manner as IFRGRO

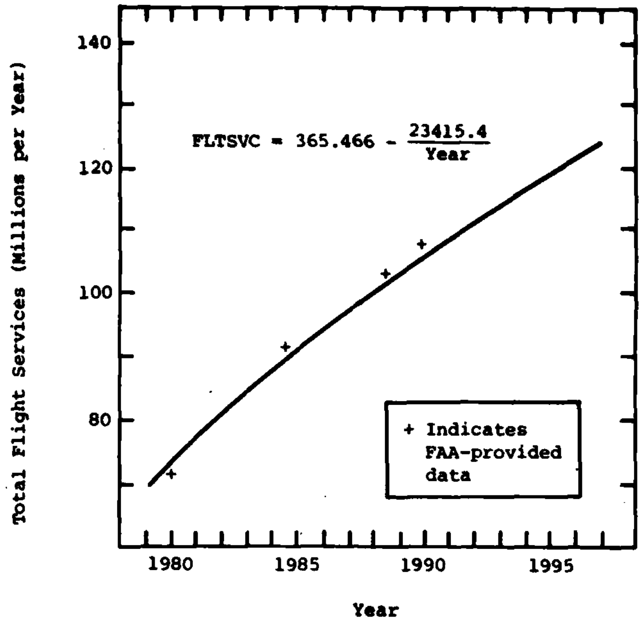


Figure 3-8. PROJECTED GROWTH IN LEASED CIRCUITS

3.2.5 Air Route Traffic Control Centers

The number of ARTCCs is treated in the model as a constant that can be changed by the user at run time if further communication scenarios are analyzed. However, the number of existing ARTCCs may be varied as a function of the total ARTCC productivity (AUTOCN).

Number of ARTCCs = (Number of ARTCC in baseline) / AUTOCN (9)

where

AUTOCN represents a productivity factor which, if its value were greater than one, would imply that fewer ARTCCs are necessary for the same ATC workload

3.3 FACILITIES AND EQUIPMENT COST MODULE

The F&E cost algorithm assumes that the annual cost burden in any given year results only from the addition of new equipment installed during that year, with the full cost of the new equipment charged off during the year (i.e., immediate full depreciation). Sunk costs for existing equipment are not included. Communications facilities are categorized into the 64 different types of facilities identified in the Present System Definition report.*

The growth of a given type of communications facility is generalized as consisting of two fundamental components. The first is the creation of additional basic facilities, where a basic facility is defined as the site, the structures required to house the communications equipment, and the minimum communications equipment required to operate the site. For example, an RCAG with four channels would be considered to be the basic RCAG facility. A certain minimum number of RCAGs are required to provide coverage of the national airspace. The second component of growth is the expansion of the capability of an existing basic facility by increasing its complexity and its amount of communications equipment. Expanding an RCAG from four to eight channels would be an example of this kind of growth.

The facilities equipment expansion component generally can be viewed as sensitive to the increase in the number of operational units of each type that the facility must serve. The general formulation therefore must have terms describing expansion of each operational unit type. To use the RCAG example, an existing RCAG facility will be expanded when the number of sectors it serves increases beyond the number the basic facility is designed to serve. Within an RCAG facility, expansion is achieved by adding more transmitters, receivers, etc., to the facility but not additional buildings or other support equipment. Since proliferation of other operational unit types such as towers or FSSs will not affect RCAG expansion, the general formulation when applied to the RCAG will have zero values for the expansion sensitivity terms associated with these other operational unit types.

Each type of communications facility can be expected to have its own unique array of sensitivities. Since these will be stored in a general matrix and applied, as appropriate, to a general input scenario that is evaluated element-by-element, it can be seen that any assumption can be easily modified.

In accordance with the foregoing, a general formulation for the F&E cost associated with type j communications facilities occurring in year y can be written as given in the following equations:

I. $y < T_j$ (before conversion)

$$C_{j(y)} = R_{oldj} [U_{j(y)} - U_{j(y-1)}] H_j \quad \text{Cost of adding facilities in current year} \tag{10}$$

$$+ \Sigma \frac{\partial_{foldj}}{\partial_{xi}} [X_{i(y)} - X_{i(y-1)}] \quad \text{Cost of upgrading existing facilities in current year}$$

*_A Study of the Economic Impact of Selected Communications Alternatives, Present System Definition,_ ARINC Research Publication 1339-01-1-1723, March 1978, prepared under Contract DOT-FAA77WA-4018.

where $U_{j(y)} = U_{j(o)} + \Sigma \frac{\partial g_{j(y)}}{\partial x_i} [X_{i(y)} - X_{i(o)}]$ Number of facilities required in current year (11)

The terms used in these and the following equations are defined in Table 3-1.

Model formulation also includes provisions for representing the conversion of a given type of communications facility from its present configuration to a modernized version presumably representing advanced cost-saving technology. The F&E cost algorithm accommodates this transition by using two equations: one, describing the old system, is applied if the year being analyzed is before the specified transition year; the other is applied if the year is the same as or follows the transition year. A fundamental assumption is that all new equipment or sites added after transition begins will be of the modernized (new) type.

The process of transition is described independently for each type of communications facility by using parameters defined in Table 3-1.

In this formulation, transition can occur at different rates and begin in different years for each type of communications facility. Also, where a communications facility serves more than one type of operational unit, transition for the portions of the facility associated with different units can occur at different rates. For example, those RTRs associated with towers can be modernized at a slower rate than those associated with TRACONs. Also, by specifying phase-out factors and switchover factors separately, it is possible to retain portions of the old equipment as a backup for any arbitrary period of time.

The formulation for the time periods beyond transition is given by equations listed below. In addition to accounting for new facilities and facility expansion due to the growth in operational units, this equation contains additional terms that account for the replacement of outmoded facilities and equipment by modernized facilities and equipment purchased during the year of analysis, y.

II. $Y \geq T_j$ (After conversion)

$C_{j(y)} = R_{newj} [U_{j(y)} - U_{j(y-1)}] H_j$ Cost of adding new facilities in current year

$+ \Sigma \frac{\partial f_{newj}}{\partial x_i} [X_{i(y)} - X_{i(y-1)}]$ Cost of upgrading facilities in current year (12)

$+ R_{newj} [P_{newj(y)} - P_{newj(y-1)}] U_{j(Tj)} H_j$ Cost of replacing old facilities with new in current year

Table 3-1. DEFINITIONS OF VARIABLES USED IN O&M AND F&E EQUATIONS	
$C_{j(y)}$	Annual communications cost in year y for facility type j
R_{oldj}	Basic facility costs per site for old type of facility j
R_{newj}	Basic facility costs per site for new type of facility j
$\frac{\partial_{foldj}}{\partial_{xi}}$	Increase in cost per unit of old facility type j resulting from the addition of a unit of facility i
$\frac{\partial_{fnewj}}{\partial_{xi}}$	Increase in cost per unit of new facility type j resulting from the addition of a unit of facility i
y	Year
T_j	Year in which transition begins for facility type j
$U_{j(y)}$	Number of type j facility sites in year y
$X_{i(o)}$	Base number of type j facility sites
$\frac{\partial_{gj(y)}}{\partial_{xi}}$	Basic COMM facility growth coefficient describing influence of operational unit type i on the number of facilities of type j
$P_{newj(y)}$	Fraction of all old equipment for facility type j that has been replaced by new equipment by y years after transition begins; applies to F&E costs only
$S_{oldj(y)}$	Fraction of all old equipment for facility type j that still remains y years after transition begins; applies to O&M costs only
$S_{newj(y)}$	Fraction of all old equipment for facility type j that is replaced by new equipment by y years after transition begins; applies to O&M only
H_j	Percentage communication for F&E (facility type j)
K_j	Percentage communication for O&M (facility type j)
A_{oldj}	Fixed (nonlabor) cost for old type of facility j
A_{newj}	Fixed (nonlabor) cost for new type of facility j
W_k	Wage rate for labor category k
H_{oldjk}	Hours of maintenance of labor category k required to service the old type of facility j
H_{newjk}	Hours of maintenance of labor category k required to service the new type of facility j

3.4 OPERATIONS AND MAINTENANCE COST MODULE

The O&M cost algorithm follows the same general form as the F&E cost algorithm. O&M costs are the product of the number of facilities (sites) required and the cost per facility. As in the case of F&E, the cost per facility is influenced by the growth of each type of operational unit through sensitivity coefficients.

O&M costs per facility are inputted in terms of a fixed component plus a given number of labor hours. The labor hours can be divided among as many as three labor categories, each having a different wage rate. Thus, O&M costs for a particular facility can be expressed as:

$$R_{oldj} = A_{oldj} + \sum_{k=1}^{3} W_k H_{oldjk} \tag{13}$$

$$R_{newj} = A_{newj} + \sum_{k=1}^{3} W_k H_{newjk} \tag{14}$$

If all the hours are set to zero, the O&M cost will be modeled as a constant, as was the case in previous versions of the model.

As with the F&E case, equation components were developed to incorporate the cost of both existing facilities and upgraded facilities, with the following resultant equations:

I. $y < T_j$ (Before conversion)

$$C_{j(y)} = R_{oldj}\, U_{j(y)}\, K_j \qquad \text{Cost of existing facilities}$$

$$+ \Sigma \frac{\partial f_{oldj}}{\partial x_i} [X_{i(y)} - X_{i(o)}] \qquad \text{Cost of upgraded facilities} \tag{15}$$

Incorporating transition to a modernized system requires, as for the F&E case, additional terms and modifications to the formulation. The formulation for transition year and beyond must include the following:

- O&M cost of all modernized facilities added to accommodate operational unit growth
- O&M cost of all modernized facilities and equipment commissioned to replace old facilities and equipment that existed at the time transition began
- O&M costs for all old facilities and equipment that existed at the time transition began and that remain in operation

The phasing out of obsolete sites and equipment and the switchover to the modernized version is described by the same transition parameters used in the F&E formulation. The resulting formulation for describing transition is then given by the following equations:

II. $y \geq T_j$ (After conversion)

$C_j(y) = R_{newj} U_{j(y)} S_{newj(y)} K_j$	Cost of new facilities
$+ \Sigma \frac{\partial_{fnewj}}{\partial_{xi}} [X_{i(y)} - X_{i(y-1)}]$	Cost of upgrading new facilities added since conversion began with new equipment
$+ \Sigma \frac{\partial_{fnewj}}{\partial_{xi}} [X_{i(y)} - X_{i(o)}] S_{newj(y)}$	Cost of upgrading new facilities that have replaced old facilities with new equipment (16)
$+ R_{oldj} U_{j(y)} S_{oldj(y)} K_j$	Cost of old facilities
$+ \Sigma \frac{\partial_{foldj}}{\partial_{xi}} [X_{i(y)} - X_{i(o)}] S_{oldj(y)}$	Cost of expanding old facilities using old equipment

3.5 CIRCUIT COST MODULE

For present applications it was not necessary to develop a model to assess the impact of a policy or scenario change on each of the 18,000 circuits in the FAA network. A macroscopic approach of examining major circuit groups, each containing circuits of similar characteristics, will produce sufficient accuracy for the purpose of planning. To accommodate a broad spectrum of circuit analyses, the leased circuit network has been categorized four different ways: (1) by circuit type, (2) by circuit type with a more detailed breakdown, (3) by terminating facility, and (4) by function or use. While each group accounts for all the circuits, the different stratifications make it possible to analyze technology changes that affect different cross sections of circuits. The user would select whichever stratification provides the best description of the types of circuits or services affected in a particular analysis. Once the choice has been made, the other three categorizations, for all practical purposes, do not exist. This is necessary to prevent double counting or overlooking circuits.

Whichever of the four groups is selected, the circuit cost algorithm considers the average number of circuits required to support any given facility. Once the F&E requirements for any future year are computed by the F&E Cost Module, the average quantity and length of each circuit type can be computed. These data are then stored in a matrix from which circuit costs are computed. The parameters required to compute circuit costs are the total number of circuits, the total circuit mileage, and the applicable tariff (cost schedule). These parameters are discussed individually in the following paragraphs.

The total quantity of circuits depends on such factors as the type and number of facilities in use, the forecast number of operational units required, and the expected utilization. Each VOR facility, for example, requires one radio circuit, while the number of circuits between centers and RCAGs is approximately equal to the number of sectors because each sector controller must have a separate communications channel. Utilization plays a significant role in computing circuit requirements whenever a group of circuits is switched. Public telephone lines into FSSs are an example of circuits that might be switched. The estimated utilization of such circuits during the busy hour is used to compute the number of circuits required when such circuits are switched.

Average circuit length is used to compute the total mileage once the quantity of each circuit type is known. In certain instances, however, it is necessary to modify the average length. If the number of FSSs were to decrease as a result of consolidation, the average distance between towers and FSSs would increase. For the purposes of this model, average length is assumed to be inversely proportional to the square root of the number of facilities. (See James Martin, *Systems Analysis for Data Transmissions*, pp. 739-763.) Equations were derived to incorporate the effect of changes in average circuit length due to changes in the overall number of FSS and ARTCC locations.

Average length factor of all FSS circuits (RTFSS) is:

$$\text{RTFSS} = \sqrt{(\text{FSSs in base year}) \,/\, (\text{FSSs in present year})} \tag{17}$$

Average length factor of all tower circuits (RTTWR)

$$\text{RTTWR} = \sqrt{(\text{Tower in base year}) \,/\, (\text{Towers in present year})} \tag{18}$$

Average length factor of all ARTCC circuits (RTCTR):

$$\text{RTCTR} = \sqrt{(\text{ARTCCs in base year}) \,/\, (\text{ARTCCs in present year})} \tag{19}$$

Since the utilization, quantity, and average length of each circuit type must be separately computed and stored in a matrix, a generalized formula is not used in the circuit cost module. A separate equation is used for each of the circuit categories. In some instances, circuits may not be associated with a specific facility; such circuits are grouped into a miscellaneous category and held fixed for the analysis period.

By keeping the circuit types separate, it is possible for the user to identify different tariffs for each part of the network. Radio circuits, for example, could be priced as private lines, data circuits as satellite communication links, and voice circuits as Telpak. A further reason is to permit various circuits to be incorporated into a switched network, as desired. Provisions are included for the user to change the tariff schedule or include new tariffs.

If a switched system configuration is specified, the model will compute the number of interswitch trunks, total trunk length, number of local distribution circuits, and cost of the switching equipment. Average circuit length for the switched system will be derived from the number of switches and number of facilities specified. The final step is to compute the interchange (IXC) cost for both switched and nonswitched circuits.

The following subsections describe the characteristics used to compute circuit costs within each circuit group. In the computer program, the length and quantities are contained in the switching array whose columns are defined in Table 5-8. There is a straightforward correspondence between the FORTRAN code and the equations described below for each of the circuit categories.

3.5.1 General Characteristics

FAA operating personnel need the ability to communicate in order to coordinate activities associated with ATC services. In addition, computer-to-computer communication is necessary to expedite the handling of the various types of information through the ATC system. These needs generate a demand for voice grade and data circuits. As a rule, the addition of new operational units results in a general requirement for new circuits to provide the same coordination function, while expansion of service at any facility usually results in an increase in the number of circuits between that facility and any others with which it must communicate.

Figure 3-9 shows the predicted growth of all FAA leased circuits as a result of nominal baseline facility expansion through 1990. The data for 1979 are derived from the leased circuit data base maintained by the Transportation System Center in Cambridge, Massachusetts. Growth of the network is mild because the major operating units are increasing in number at a slow pace. During the 1980s, the number of ARTCCs is expected to remain fixed, FSSs will stay constant or decline, and towers will increase at the rate of only 2 per year. Therefore, all the growth in the network is the result of growth in sectors and radars.

From the information contained in the TSC leased circuit data base, it was usually possible to determine where the end points of each circuit were, what the circuit was being used for, and what the current cost. Table 3-2 shows the format of a record from this data base. On the basis of this information algorithms were developed to assign each circuit to exactly one category in each of the four circuit groupings. These are further described in the following four subsections.

3.5.2 Circuits According to Type

The objective of this grouping was to categorize the circuits according to type; i.e., whether they were used for voice, data, or radio (air/ground) communications. Table 3-3 shows the logic for doing so. The primary variable used to divide the circuits was the four-letter circuit

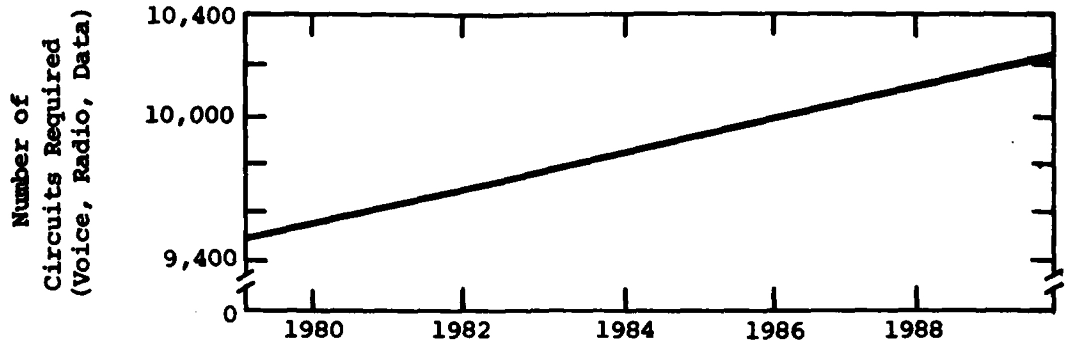


Figure 3-9. PROJECTED GROWTH IN LEASED CIRCUITS

Table 3-2. AVAILABLE INFORMATION FROM TSC DATA BASE

Identifier	Explanation	Values
CID	Circuit number	Integers 1-18132
CODE	Circuit type code	Four characters
ND	Number of drops	Integers 2 or greater
BPS	Bits per second	Integers (0=not a data circuit)
EMRC	Equipment cost per month	dollars
TMRC	Telpak cost per month	dollars
IMRC	IXC cost per month	dollars
TPKM	Telpak mileage	miles
IXCM	IXC mileage	miles
FV	"From" V coordinate	4-digit integer
FH	"From" H coordinate	4-digit integer
FR	"From" FAA region	2-character code
FFC	"From" facility type code	integers 1-303
FLID	"From" facility identifier	3-character code
TV	"To" V coordinate	4-digit integer
TH	"To" H coordinate	4-digit integer
TR	"To" region	2-character code
TFC	"To" facility type code	integers, 1-303
TLID	"To" facility identifier	3 character code

Table 3-3. DETERMINATION OF CIRCUIT TYPE		
Circuit Code	Other Information	Result
AA--	--	Voice
AB--	--	Data
ACE-	--	Radio
AC--	Between facilities 9 and 301	Voice
AC--	Between facilities 9 and 301	Radio
AD--	--	Data
AE--	--	Voice
AFA-	--	Voice
AFB-	--	Radio
AFD-	--	Radio
AFE-	BPS = 0	Voice
AFF-	BPS ≠ 0	Data
AFG-	BPS = 0	Data
AFG-	BPS ≠ 0	Voice
AFJ-	--	Radio
AGF-	BPS = 0	Voice
AGF-	BPS ≠ 0	Data

type code. Selection of a particular circuit is based on the first line, reading down the page, whose characteristics match those of the circuit type indicated. A dash (-) indicates that any value or characteristic will match. If the letter code alone was not sufficient to classify the circuit, the information in the second column was used to resolve the difficulty.

Once each circuit was classified as voice, data, or radio, the specific category to which it would be assigned could be determined by the "to" and "from" facility codes (TFC and FFC). These categories are shown in Table 3-4. The miscellaneous categories contain those circuits which could not specifically be identified with any of the other categories. They are thus a catch-all for special situations. Growth of the quantity of circuits in each category is proportional to the growth in one or more of the operational units; these are also indicated in the table. The last column shows which of the length adjustment factors, if any, applies to each category. Thus, Table 3-4 summarizes the categories in this circuit group. The equations used to forecast circuit growth can be inferred from this table and the program listings.

Table 3-4. CIRCUIT CHARACTERISTICS FOR GROUPING BY TYPE

Category	Average Length (Miles)	Quantity per Service	Total Length (Miles)	Total Quantity	Operational Unit for Growth	Length Adjustment Factor
1. Miscellaneous voice	142	1487.00	211,035	1,487	Constant	--
2. FSS to tower voice	75	0.41	13,143	175	Towers	RTFSS
3. FSS to center voice	257	0.32	26,182	102	FSS	RTCTR
4. Tower to center voice	149	1.41	90,087	603	Towers	RTCTR
5. Center to center voice	435	11.91	119,274	274	Sectors	RTCTR
6. FSS to public voice	44	4.44	61,859	1,420	Flight services	RTFSS
7. Miscellaneous data	457	947.00	432,741	947	Constant	--
8. FSS to tower data	0	0.00	0	0	Towers	RTFSS
9. FSS to center data	543	0.09	15,528	28	FSS	RTCTR
10. Tower to center data	113	0.56	27,074	240	Towers	RTCTR
11. Center to center data	500	4.13	47,529	95	Sectors	RTCTR
12. Miscellaneous radio	88	128.00	11,278	128	Constant	--
13. RCAG radio	168	3.48	326,627	1,942	RCAGs	--
14. FSS radio	64	3.15	63,958	1,002	FSS	--
15. Tower radio	32	1.55	21,175	663	Towers	--
16. BUEC radio	193	3.65	16,175	84	Sectors	--
17. Miscellaneous	107	311.00	33,308	311	Constant	--

3.5.3 Circuits According to Type, with Additional Voice, Data Categories

The second circuit categorization is the same as the first for radio circuits. However, voice and data are divided into several additional categories. The same logic is used to subdivide the circuits into the voice/data/radio groups (Table 3-3). A more extensive analysis of the to/from facility codes was necessary to obtain this additional breakdown.

Table 3-5 shows the categories in this circuit grouping.

3.5.4 Circuits According to Terminating Facility

This grouping is strictly oriented toward the three major operational units. Categorizations are based solely on whether the circuit terminates at a tower, center, or FSS; no attempt is made to distinguish between voice, data, and radio circuits.

Table 3-6 shows the logic used to classify each circuit. It is based on the TFC and FFC variables. The logic is symmetric in that if the first two columns of the table are transposed, the same group of circuits still results. For simplicity, the lower-numbered facility code will always be in the left column. "Special Circuits" refers to circuits used at NAFEC, FAA Headquarters, the Aeronautical Center, and similar facilities. As in the other groupings, "miscellaneous" refers to those circuits which cannot be categorized elsewhere.

Table 3-7 shows the categories in this circuit grouping.

3.5.5 Circuits According to Function or Use

The fourth and final circuit grouping categorizes circuits by their service function, that is, whether they are used for voice or data communications, navigation (ILS, DF, VORTAC), military operations, weather data, radar, or special purposes.

The logic used to make the category assignments is shown in Table 3-8. As in the tower/center/FSS case, most of the categorizations are based on the TFC and FFC codes. "Foreign exchange" includes both center and FSS Foreign Exchange circuits, and "weather" includes National Weather Service as well as Weather Message Switching Center (WMSC) circuits.

Table 3-9 shows the categories in this circuit grouping.

3.5.6 Switching Calculations

If a group of circuits is switched, the number of interswitch trunks required will depend on the utilization and required grade of service for that group. Grade of service is expressed as the probability of a blocked call and must therefore be between 0 and 1. A practical range would be about 0.001 to 0.1. The number of circuits required to satisfy a given

Table 3-5. CIRCUIT CHARACTERISTICS FOR DETAILED VOICE/DATA GROUPING

Category	Average Length (Miles)	Quantity per Service	Total Length (Miles)	Total Quantity	Operational Unit for Growth	Length Adjustment Factor
1. FSS to tower voice	75	0.41	13,143	175	Towers	RTFSS
2. FSS to center voice	257	0.32	26,182	102	FSS	RTCTR
3. Tower to center voice	149	1.41	90,087	603	Towers	RTCTR
4. Center to center voice	435	11.91	119,274	274	Sectors	RTCTR
5. FSS to public voice	44	4.44	61,859	1,421	Flight services	RTFSS
6. FSS to FSS voice	223	0.16	11,343	51	FSS	RTFSS
7. Tower to tower voice	101	1.06	45,885	454	Towers	RTTWR
8. Miscellaneous voice	157	978.00	153,350	978	Constant	--
9. FSS to center low-speed data circuits	543	0.09	15,528	29	FSS	RTCTR
10. Miscellaneous low speed data circuits	372	332.00	123,504	332	Constant	--
11. Tower to center FDEP	74	0.42	13,379	180	Towers	RTCTR
12. Tower to center ARTS	224	0.15	14,358	64	Towers	RTCTR
13. Center to center high-speed data circuits	500	4.13	47,529	95	Sectors	RTCTR
14. Miscellaneous high-speed data circuits	227	397.00	90,083	397	Constant	Constant
15. WMSC	1,005	0.29	218,921	218	Towers and FSS	RTTWR and RTFSS
16. RCAG radio	168	3.48	326,627	1,942	RCAGs	--
17. FSS radio	64	3.15	63,958	1,002	FSS	--
18. Tower radio	32	1.55	21,175	663	Towers	--
19. BUEC radio	193	3.65	16,175	84	Sectors	--
20. Miscellaneous radio	88	128.00	11,278	128	Constant	--
21. Other	86	312.00	26,772	312	Constant	--

Table 3-6. DETERMINATION OF TERMINATING FACILITY CATEGORIES		
Code 1	Code 2	Category
1-6	1-6	Tower to tower
1-6	8	Tower to FSS
1-6	9	Tower to center
1-6	10-65	Tower to military
1-6	80	Tower to weather
1-6	100-103	Tower to VORTAC
1-6	81-89	Special
1-6	110	Tower to foreign exchange
1-6	150-157	Tower to RCO
1-6	162	Tower to ILS
1-6	200-299	Tower to weather
1-6	--	Tower miscellaneous
8	8	FSS to FSS
8	9	Center to FSS
8	10-65	FSS to military
8	80	FSS to weather
8	81-89	Special
8	100-103	FSS to VORTAC
8	110	FSS to RCO
8	162	FSS to RTR
8	200-299	FSS to weather
8	301	FSS to foreign exchange
8	--	FSS miscellaneous
9	9	Center to center
9	10-65	Center to military
9	81-89	Special
9	130	Center to RCAG
9	131	Center to BUEC
9	132	Center ARSR
9	162	Center to RTR
9	301	Center to foreign exchange
9	303	Center to military
9	--	Center miscellaneous
81-89	--	Special
--	--	Miscellaneous

grade of service constraint can be calculated from a standard queuing theory formula:

$$\mathrm{GOS} = \frac{\frac{\rho^N}{N!}}{\sum_{k=0}^{N} \frac{\rho^k}{k!}}$$

Table 3-7. CIRCUIT CHARACTERISTICS FOR TERMINATING FACILITY GROUPING

Category	Average Length (Miles)	Quantity per Service	Total Length (Miles)	Total Quantity	Operational Unit for Growth	Length Adjustment Factor
1. Tower to tower	78	1.41	46,836	603	Towers	RTTWR
2. Tower to FSS	123	0.66	34,697	282	Towers	RTCTR
3. Tower to center	138	2.20	130,355	942	Towers	RTCTR
4. Tower to military	93	0.47	18,758	201	Towers	RTTWR
5. Tower to VOR	34	0.11	3,420	100	Airport operations	--
6. Tower to foreign exchange	34	0.12	1,758	51	Airport operations	--
7. Tower to RCO	21	0.44	4,043	188	Towers	--
8. Tower to ILS	22	0.82	7,798	351	Towers	--
9. Tower to weather	780	0.04	13,349	17	Towers	RTTWR
10. Miscellaneous tower	161	0.50	34,488	214	Towers	--
11. Center to center	460	16.30	172,461	375	Sectors	RTCTR
12. Center to FSS	296	0.54	50,866	172	FSS	RTCTR
13. Center to military	201	8.43	39,063	194	Sectors	RTCTR
14. Center to RCAG	167	3.48	324,684	1,942	RCAGs	--
15. Center to BUEC	203	3.30	15,388	75	Sectors	--
16. Center to ARSR	212	2.46	84,271	397	ASRS	RTCTR
17. Center to RTR	44	0.06	1,936	44	Centers	RTCTR
18. Center foreign exchange	42	23.09	22,288	531	Sectors	RTCTR
19. Center miscellaneous	444	6.43	65,614	148	Sectors	RTCTR
20. FSS to FSS	510	0.37	60,018	118	FSS	--
21. FSS to military	100	0.34	10,896	108	FSS	--
22. FSS to VOR	53	0.66	29,961	561	VFR operations	RTFSS
23. FSS foreign exchange	49	2.51	39,919	817	Flight Services	RTFSS
24. FSS to RCO	87	0.60	16,593	191	FSS	RTFSS
25. FSS to RTR	50	0.41	6,556	130	FSS	RTFSS
26. FSS to weather	496	0.30	47,329	95	FSS	RTFSS
27. Miscellaneous FSS	86	0.58	15,834	184	FSS	RTFSS
28. Special	314	63.00	19,756	63	Constant	--
29. Other	527	342.00	180,189	342	Constant	--

Table 3-8. DETERMINATION OF CIRCUIT FUNCTION OR USE			
Code 1	Code 2	Other	Category
81-89	--	--	Special
300	--	--	AUTOVON
303	--	--	AUTOVON
10-65	8	--	Military to FSS
10-65	1-6	--	Military to tower
10-65	9	--	Military to center
10-65	--	--	Miscellaneous military
200-299	--	--	Weather
164	--	--	Weather
159	--	--	Weather
80	--	--	Weather
--	--	NET = 'WMSC'	Weather
--	--	TLID = 'NKA' or FLID = 'NKA'	Weather
132	--	--	ARSR
50-158	--	--	ILS
100-103	--	--	VORTAC
120	--	--	DF
123-124	--	--	DF
160	--	--	Miscellaneous navigation
163	--	--	Miscellaneous navigation
165	--	--	Miscellaneous navigation
301	--	--	Foreign exchange
1-6	9	--	Tower to center
8	9	--	FSS to center
1-6	8	--	FSS to tower
9	130	--	Center to RCAG
1-6	162	--	Tower to RTR
9	131	--	BUEC
8	110	--	FSS to RCO
7	--	--	Miscellaneous communications
1-6	1-6	--	Miscellaneous communications
8	8	--	Miscellaneous communications
9	9	--	Miscellaneous communications
--	--	--	Other

where

GOS = grade of service

N = number of circuits available

Q = traffic in erlangs

There are two problems with this equation however: (1) it is not possible to solve for N algebraically; and (2) it is cumbersome to evaluate

Table 3-9. CIRCUIT CHARACTERISTICS FOR FUNCTION OR USE GROUPING

Category	Average Length (Miles)	Quantity per Service	Total Length (Miles)	Total Quantity	Operational Unit for Growth	Length Adjustment Factor
1. Military to FSS	101	0.84	10,896	108	FSS	RTFSS
2. Military to tower	76	0.45	14,679	192	Towers	RTTWR
3. Military to center	227	7.13	37,266	164	Sectors	RTCTR
4. AUTOVON	59	40.00	2,361	40	Constant	--
5. Miscellaneous military	419	56.00	23,483	56	Constant	--
6. ILS circuits	24	0.52	5,234	223	Towers	--
7. VORTAC circuits	52	0.81	38,131	739	Airport operations	--
8. DF circuits	64	0.09	1,759	27	FSS	RTTWR
9. Tower to center	138	2.20	130,355	942	Towers	RTCTR
10. FSS to center	287	0.53	65,039	227	Towers	RTCTR
11. FSS to tower	98	0.65	27,152	278	Towers	RTTWR
12. Center to RCAG	167	3.48	324,684	1,942	RCAGs	RTCTR
13. Tower to RTR	22	0.83	7,893	355	Towers	RTTWR
14. Center to BUEC	203	3.30	15,388	76	Sectors	--
15. FSS to RCO	87	0.60	16,593	191	FSS	RTFSS
16. Foreign exchange	46	1503.00	65,722	1,417	Flight services and Sectors	RTFSS
17. Miscellaneous communications	199	1640.00	325,638	1,640	Constant	--
18. Special	533	113.00	60,187	113	Constant	--
19. Weather	878	0.35	232,430	265	Towers and FSS	RTTWR and RTFSS
20. ARSR	211	2.48	84,548	400	ASRs	--
21. Other	563	51.00	28,727	51	Constant	--

for large N, even on a computer. Accordingly, a quadratic approximation was developed to handle these problems:

$$\log(\text{number of interswitch trunks}) = 1.506 + 0.399 \log(10^5 Q) + 0.082 (\log(10^5 Q))^2 + 0.119\ \text{GOS} - 0.017\ \text{GOS}^2 \qquad (20)$$

This equation was estimated by the use of linear regression analysis. The R-squared value of 0.9958 shows that it is indeed an excellent fit over the range required.

Two additional constraints ensure the validity of this estimate. The estimate of circuits required cannot be less than Q, the amount of traffic. Nor can it be greater than the number of circuits in the group before switching. Circuit lengths between switches are determined from the average distance between facilities that would normally contain switches or concentrators, FSSs and centers. The cost of switches has been estimated at $500 per switch for F&E and $30 per year per switch for O&M. These figures are derived from the average cost per termination of typical computer-controlled switching equipment for moderate to large installations.

3.5.7 IXC and Circuit Costs

Interexchange (IXC) costs are for those circuits or portions of circuits that are priced under the private-line tariff. An average cost per circuit has been derived from the existing system. Local distribution circuits described in Section 3.5.4 are also included in this category. Total circuit costs include IXC switched and nonswitched circuits. Switched and nonswitched costs are based on cost per mile and cost for service terminations. Up to nine different tariffs can be used to price each of the circuit types in the model. Each tariff is inputted as an average cost per mile for typical circuit lengths and an average cost for terminating two ends of a circuit.

$$\text{IXC} = (12 \text{ months})\ (\$86.60/\text{month}) \left[\sum_{i=1}^{N} \text{QTY}_i \right] \quad \text{IXC Charges} \qquad (21)$$

$$\text{CKT} = \text{IXC} + \left\{ \left[\sum_{i=1}^{N} L_i \text{CMP}_j \right] \right. \quad \text{Circuit Mileage Charges}$$

$$\left. + \left[\sum_{i=1}^{N} \text{QTY}_i \text{SVC}_j \right] \right\} \quad \text{Termination Charges}$$

$$\times\ 12 \text{ months} \qquad (22)$$

CKT = total circuit cost

QTY_i = quantity of circuit type i

j = index representing applicable tariff rate

i = index representing type of circuit

CMP = monthly cost per mile for tariff j

SVC = monthly cost for service terminals at each end for tariff j

N = number of categories in the specified circuit group

L = total circuit length

3.6 LEASED EQUIPMENT COST MODULE

This module computes the cost of leased equipment such as terminals and PBXs required for data, voice, and radio circuits. The equation was developed from equipment cost data in the TSC data base. The cost consists of two components, one based on recurring equipment cost per circuit (column 9 of SWARR, the switch array) and the other based on operational units. The \$5,467,000 figure was derived from those equipment costs that could not be allocated to either a tower, center, or FSS. The cost may be expressed as:

$$\text{Leased Equipment Cost} = 12 \sum_{K=1}^{N} QTY_i EQP_i + \$5,467,000$$
$$+ (\$647,800)(ARTCC) + (\$29,900)(ATCT) \tag{23}$$
$$+ (\$7,970)(FSS)$$

where

QTY_i = quantity of circuit category i

EQP_i = equipment cost per circuit category i

3.7 OUTPUT MODULE

The purpose of this module is to combine the outputs of each cost module and generate the cost reports described in the User's Guide. The basic calculations performed by the model are done in constant dollars. Where appropriate, labor rate increases, traffic increases, and changes in cost due to technology will be included on the basis of user-specified inflation rates. The user may also specify a discounting factor that reflects an annual decrease in the value of the dollar.

The effects of inflation on the constant dollar values (CD) were computed by using the following formulas:

$$COSTAR(I,1) = F\&E_y = (F\&E_{yCD}) \prod_{k=79}^{y} (1 + j_{yFE})^* \tag{24}$$

$$COSTAR(I,2) = O\&M_y = (O\&M_{yCD}) \prod_{k=79}^{y} (1 + j_{yOM}) \tag{25}$$

$$COSTAR(I,3) = Ckt_y = (Ckt_{yCD}) \prod_{k=79}^{y} (1 + j_{yCkt}) \tag{26}$$

$$COSTAR(I,4) = Leased_y = (Leased_{yCD}) \prod_{k=79}^{y} (1 + j_{yCkt}) \tag{27}$$

$$COSTAR(I,5) = User_y = (User_{yCD}) \prod_{k=79}^{y} (1 + j_{yFE}/2 + j_{yOM}/2) \tag{28}$$

where COSTAR(I,J) is the FORTRAN notation for the inflated values.

The discount value reflects an annual decrease in the value of the dollar and is computed by:

$$NPV_y = \frac{(F\&E_y + O\&M_y + Leased_y + Ckt_y + User_y)}{\prod_{k=80}^{y} (1 + j_{yDIS})}$$

The output module will list all changes to the baseline system inputted by the user at run-time. This provides a permanent record of the assumptions used for each run when several runs are entered at one time.

*The sumbol Π is used to represent the product of successive terms.

CHAPTER FOUR

PROGRAM DESCRIPTION

4.1 OPERATING ENVIRONMENT

The FAA Communications Cost Model program has been developed to run on a batch operating system from a remote card terminal. The model was developed and coded in FORTRAN IV-G for the IBM 360/65 computer at the Transportation Computer Center. It will accept user inputs in punched card format.

The source program consists of about 1,000 cards. Memory requirements on an IBM computer are 56,000 words. Approximately 15,000 words of additional core are required to compile and execute the program. This figure will vary depending on the operating system. Execution time varies depending on processor load at the time the program is run, the period of the analysis, and the reports desired. Typical execution times range from 30 seconds to one minute per scenario. Compilation time is primarily dependent on the processor load and may range from 2 to 5 minutes.

4.2 SOURCE LISTING

The complete source listing in FORTRAN code for the FAA Communications Cost Model Program is presented in Figure 4-1. The program is self-documenting in that comment cards have been used liberally throughout to mark the various routines. To facilitate understanding of the coding flow, the specific functions performed by the lines or group of lines of code are summarized in Table 4-1. There is one subroutine called by the program, TNSARR. It is used to store the transition parameters and is listed following the main program. A general flow chart of the program is presented in Figure 4-2.

4.3 DATA

This section contains the cost data base on which the cost projections for various facility types are based. The number of facilities has been updated to September 1979. Costs are estimated 1978 values, extrapolated where necessary from prior-year data. Table 4-2 is the O&M data base. Table 4-3 is the F&E data base.

For three facility types (RMLR, RMLT, and TRACON)*, the number of facilities is computed by the program and is not inputted with the O&M and F&E data base. The equations to compute the number of facilities are:

$$RMLR = (ARSR)\ 511/97 \tag{30}$$

$$RMLT = (ARSR)\ 212/97 \tag{31}$$

$$TRACON = (28.2 + 0.5\ INSTOP) \tag{32}$$

```
           C   MAIN PROGRAM--COMMUNICATIONS MODEL
           C
0001             INTEGER W.TT.CT.FT.FR.Y.Y1.Y2.YEAR.NUM
0002             INTEGER STRTYR.ENDYR.NEWOLD.FRSTYR.AT.CKTP
0003             INTEGER RPTYP(9).REP(9).TNINDX(1000).NTN
0004             INTEGER CTFE.I.J.K.JJ.KK.L
0005             INTEGER SWMAP(120.2).SWINDX(30.2)
0006             INTEGER CL(7).COL(40).ELIFE(95)
0007             REAL NAMARR(99).FELBL(10.14).OMLBL(10.19)
0008             REAL OPARR(5.3).ARRAY(95.23).A(30).CH(7).UASGN(30)
0009             REAL MARRAY(95.19).FARRAY(95.14).CKTARR(120.10).OLDFAC(95)
0010             REAL NPV(30).CNPV(30).COSTAR(30.5).TOT(30)
0011             REAL TRFARR(9.2).TNVALU(1000).SWARR(30.10)
0012             REAL CST.SVC.LENGTH.QTY.SUM.YR.TSUM.REPL.V.B
0013             REAL IFE(30).IOM(30).ICKT(30).IDIS(30).WGRATE(3)
0014             REAL IFRIN.INSIN.APTIN.APTOPN.IFRTFK.INSTOP.FLTSVC
0015             REAL AUTOSE.AUTOTW.AUTOCN.AUTOAS
0016             REAL IFRGRO.APOGRO.INOGRO.FSVGRO
0017             REAL OLDONM.NEWONM
0018             REAL CKT1(120.4)
0019             EQUIVALENCE(CKTARR(1.7).CKT1(1.1))
0020             COMMON NTN.TNINDX.TNVALU
0021             DATA NPV.CNPV.COSTAR/30*0.0.30*0.0.150*0.0/
0022             DATA TRFARR.ARRAY.SWARR/18*0.0.2185*0.0.300*0.0/
0023             DATA OPARR.MARRAY.FARRAY.CKTARR/15*0..1805*0..1330*0..1200*0./
0024             DATA RPTYP.REP.W /9*0.9*0.0/
0025             DATA CTFE.NSTAR /'FE'.'*'/
0026             DATA UASGN/30*0.0/
0027             DATA WGRATE/23..26.5.30./
0028             DATA CKTP/1/
           C  DATA FOR FACILITIES AND EQUIPMENT ARRAY
0029            DATA FARRAY /0..15..3298..20599..989..975..620..0..80..11345..
              2  201..    0..    0..   76..   70..   42..1039..1664..    0..   54..
              3 49372..  22..   30..   18..  116..  120..  699..  130..3403..1203..
              4 2405..  794..   11..   50..   17..   28..   50..  186..   28..   18..
              5   18..   30..   18..  241..1189..  182..  151..  244..  239..  166..
              6  163..  132..   41..   76..  151..  142..  999..  749..  613..    0..
              7    0..  374..   12..7551..31*0..   1045*0..1.00.1.00.0.25.0.60.0.60.
              8 0.25.0.85.1.00.1.00.0.25.1.00.0.80.0.60.1.00.1.00.1.00.0.85.0.60.
              9 0.60.1.00.0.25.0.03.1.00.0.25.0.85.0.25.0.25.0.25.1.00.1.00.1.00.
              A 0.25.1.00.1.00.0.25.0.25.1.00.0.25.0.25.1.00.0.25.1.00.0.25.1.00.
              B 0.25.0.85.0.25.1.00.1.00.1.00.1.00.1.00.1.00.1.00.1.00.0.60.0.60.
              C 0.60.1.00.1.00.1.00.0.25.0.25.1.00.31*0.0.     12..  10..102..  23..
              D  98..159..428..   2..239..  20..102..  15..   3..   5..  13..  18..   5..
              E  25..   5..205..   1..  21..222..  36..318..600..209..   9..   1..   6..
              F   6..   9..  57..  84..  10..  17..   8..669..316..581..577..  22..615..
              G   1..   8..   6..101..550..909..515..204..786..132..   3..   5..302..
              H  40..  36..   3..   1..398..929..  66..   1..31*0. /
```

Figure 4-1. SOURCE LISTING (FAA COMMUNICATIONS COST MODEL PROGRAM)

*The appendix contains a complete list of FAA facility alpha codes used in the communications model and the model documentation.

```
0030          DATA FARRAY(04,03),FARRAY(23,06),FARRAY(48,03)/100.,10.,20./
0031          DATA FARRAY(23,03),FARRAY(23,04),FARRAY(23,05)/5.,150.,10./
      C  DATA FOR OPERATIONS AND MAINTENANCE ARRAY
0032          DATA MARRAY(01,01),MARRAY(04,01),MARRAY(05,01)/127.,457.,211./
0033          DATA MARRAY(07,01),MARRAY(08,01),MARRAY(09,01)/52.,54.,26./
0034          DATA MARRAY(14,01),MARRAY(15,01),MARRAY(16,01)/22.,30.,99./
0035          DATA MARRAY(25,01),MARRAY(29,01),MARRAY(30,01)/63.,468.,98./
0036          DATA MARRAY(32,01),MARRAY(37,01),MARRAY(40,01)/249.,5.,23./
0037          DATA MARRAY(48,01),MARRAY(49,01),MARRAY(50,01)/36.,31.,32./
0038          DATA MARRAY(51,01),MARRAY(52,01),MARRAY(53,01)/37.,20.,11./
0039          DATA MARRAY(54,01),MARRAY(55,01),MARRAY(57,01)/7.,100.,45./
0040          DATA MARRAY(58,01),MARRAY(59,01),MARRAY(60,01)/49.,49.,218./
0041          DATA MARRAY(61,01),MARRAY(64,01),MARRAY(04,04)/14.,259.,405./
0042          DATA MARRAY(04,03),MARRAY(05,06),MARRAY(07,05)/5.,30.,27./
0043          DATA MARRAY(25,01),MARRAY(40,06),MARRAY(48,03)/63.,23.,25./
0044          DATA MARRAY(52,05),MARRAY(52,06),MARRAY(52,07)/20.,20.,20./
0045          DATA MARRAY(61,05),MARRAY(61,06),MARRAY(61,07)/14.,14.,14./
0046          DATA MARRAY(61,04),MARRAY(25,07)/14.,63./
0047          DATA MARRAY(01,13),MARRAY(04,13),MARRAY(05,13)/0.09,0.74,0.14/
0048          DATA MARRAY(07,13),MARRAY(08,13),MARRAY(09,13)/0.51,1.00,1.00/
0049          DATA MARRAY(14,13),MARRAY(15,13),MARRAY(16,13)/1.00,1.00,0.98/
0050          DATA MARRAY(25,13),MARRAY(29,13),MARRAY(30,13)/0.81,1.00,1.00/
0051          DATA MARRAY(32,13),MARRAY(37,13),MARRAY(40,13)/0.32,1.00,1.00/
0052          DATA MARRAY(48,13),MARRAY(49,13),MARRAY(50,13)/1.00,1.00,1.00/
0053          DATA MARRAY(51,13),MARRAY(52,13),MARRAY(53,13)/1.00,1.00,1.00/
0054          DATA MARRAY(54,13),MARRAY(55,13),MARRAY(57,13)/1.00,1.00,0.21/
0055          DATA MARRAY(58,13),MARRAY(59,13),MARRAY(60,13)/0.17,1.00,1.00/
0056          DATA MARRAY(61,13),MARRAY(64,13)/1.00,1.00/
      C  DATA FOR MAIN ARRAY
0057          DATA ARRAY(41,05),ARRAY(43,05),ARRAY(52,04)/4.,4.,1./
0058          DATA ARRAY(52,05),ARRAY(52,06),ARRAY(56,04)/1.,1.,1./
0059          DATA ARRAY(62,04),ARRAY(02,04),ARRAY(04,03)/1.,1.,1./
0060          DATA ARRAY(05,05),ARRAY(06,05),ARRAY(07,04)/1.,1.,1./
0061          DATA ARRAY(10,03),ARRAY(12,03),ARRAY(18,03)/1.,1.,1./
0062          DATA ARRAY(25,06),ARRAY(26,05),ARRAY(38,05)/1.,4.,4./
0063          DATA ARRAY(39,05)/3./
      C  COMPUTED ARRAY VALUES
0064          NTN = 0
0065          ARRAY(50,14)=ARRAY(3,14)*511./97.
0066          ARRAY(51,14)=ARRAY(3,14)*212./97.
0067          ARRAY(58,14)=ARRAY(6,14)*23./157.
      C  DATA FOR CIRCUIT ARRAY
0068          DATA CKTARR /120*0.,17*1.,13*-1.,21*1.,9*-1.,29*1.,-1.,21*1.,
            2 9*-1.,141.92,74.9,257.3,149.28,435.42,43.54,456.96,0.,542.59,
            2 112.96,500.36,88.11,168.18,63.85,31.92,192.68,107.10,13*0.,
            3 74.9,257.3,149.28,435.42,43.54,222.94,101.14,156.8,542.59,
            4 372.,74.43,223.65,500.36,226.91,1005.,168.18,63.85,31.92,192.68,
            5 88.11,85.81,9*0.,77.61,122.83,138.44,93.25,34.2,34.47,21.47,22.22
            6 ,779.76,161.16,460.02,296.22,201.47,167.18,202.75,212.45,43.78,
            7 41.97,443.67,510.1,100.78,53.42,48.88,86.97,50.29,496.12,85.85,
            8 313.6,526.87,0.,100.78,76.22,227.25,59.03,419.34,23.52,51.6,64.05
            9 ,138.44,286.72,97.6,167.18,22.22,202.75,86.97,46.39,198.56,532.63
            A ,877.66,211.43,563.28,2*0.,1487.,.41,.32,1.41,11.91,4.44,947.,0.,
            B .09,.56,4.13,128.,3.48,3.15,1.55,3.65,311.,13*0.,.41,.32,1.41,
            C 11.91,4.44,.16,1.06,978.,.09,332.,.42,.15,4.13,397.,.292,3.48,
            D 3.15,1.55,3.65,128.,312.,9*0.,1.41,.66,2.2,.47,.11,.12,.44,.82,
            E .04,.5,16.3,.54,8.43,3.48,3.3,2.46,.06,23.09,6.43,.37,.34,.66,
            F 2.51,.6,.41,.3,.58,63.,342.,0.,.34,.45,7.13,40.,56.,.52,.81,.0864
            G,2.2,.53,.65,3.48,.83,3.3,.6,1503.,1640.,113.,.355,2.48,51.,9*0.,
            H 120*0.,120*0.,120*0.,120*0.,120*0.,120*0./
```

Figure 4-1. (continued)

```
0069          DATA CKT1 /.08,.05,.05,.1,.1,.12,.13,.0,.85,.3,.3,.08,.3,.2,.3,
             2 .08,.17,13*0.,.05,.05,.1,.1,.12,.05,.1,.08,.8,.08,.25,.25,.25,
             3 2*.08,.3,.2,.3,2*.08,.17,9*0., .1,.3,.2,.05,.05,.12,.05,.05,.05,
             4 .05,.1,.2,.05,.3,.08,.25,.3,.05,.05,.05,.05,.1,.05,.05,.3,.05,
             5 .05,.05,.05,0.,.05,.05,.05,.05,.05,.05,.1,.05,.2,.3,.2,.3,.2,.08,
             6.05,.05,.05,.05,.05,.25,.05,9*0.,120*0.,122.27,119.05,261.21,
             7 123.36,114.49,65.18,254.33,0.,271.75,117.2,124.08,91.80,169.54,
             8 95.19,75.59,106.55,59.22,13*0.,119.05,261.21,123.36,114.49,65.18,
             9 176.4,109.86,125.26,271.75,263.1,85.39,208.59,124.08,114.15,
             *       495.9,169.54,
             A 95.19,75.59,106.55,91.8,59.22,9*0.,104.14,140.97,121.06,108.24,
             B 81.22,78.24,34.09,75.96,579.31,119.04,130.55,235.84,170.82,
             C 169.25,109.12,107.9,80.81,56.5,123.97,284.73,138.4,101.17,71.67,
             D 92.77,67.85,301.87,98.88,178.53,288.90,0.,138.4,109.86,155.74,
             E 223.93,474.45,35.44,98.3,78.37,121.06,228.68,127.52,169.25,75.96,
             F 109.12,92.77,64.03,119.96,148.19,410.78,107.87,264.93,9*0.,
             G 120*0.01/
          C    DATA FOR SWITCHING MAP
0070         DATA SWMAP /0,3,0,0,0,3,0,9,8*0,14*0,   2,3*0,2,2,3,14*0,9*0,
             2  3,3,0,3,3,3,0,0,3,0,9*0,7*12,4*0,  10,9,0,0,0,9,10,9,0,0,10,0,9,
             3 0,10,10,5*0,9*0,   0,4,0,0,0,1,0,10,8*0,14*0,   3,3*0,8,16*0,9*0,
             4   0,12,0,13,19,18,0,0,19,0,9*0,0,13,19,18,19,17,19,4*0,
             5  3,3,3*0,17,17,17,0,0,10,0,17,0,17,17,0,4*0,9*0/
          C  DATA FOR NAME ARRAYS
0071          DATA NAMARR /'ADCO','AID ','ARSR','ARTC','ARTS','ASR ','ATCT',
             2 'BDIS','BUEC','CCC','CD  ','CDC ','CERA','CKT ','CMBT','COMC',
             3 'CST','CTRB','DCC ','DF  ','EDPS','FAC ','FDEP','FM  ','FSS ',
             4 'GS ','H   ','HH  ','IATS','IFSR','IFSS','IFST','IM  ','LCOT',
             5 'LDA','LMM ','LNKR','LOC ','LOM ','LRCO','MM  ','OAW ','OM  ',
             6 'ORES','PAR','RAPC','RBDE','RCAG','RCO ','RMLR','RMLT','RTR ',
             7 'SFO','SSO ','TELE','TOWB','TRAC','TRCA','TROP','TTS ','TTY ',
             8 'VOR ','VOT ','WMSC','65','66','67','68','69','70','71','72',
             9 '73','74','75','76','77','78','79','80','81','82','83',
             A '84','85','86','87','88',
             B '89','90','91','92','93','94','95'/
0072          DATA FELBL /'BASI','C CO','ST O','F OL','D FA','CILI','TY',3*' ',
             2               'BASI','C CO','ST O','F NE','W FA','CILI','TY',3*' ',
             3'OLD','FACI','LITY',' COS','T IN','CREA','SE P','ER S','ECTO','R',
             4'OLD','FACI','LITY',' COS','T IN','CREA','SE P','ER C','ENTE','R',
             5'OLD','FACI','LITY',' COS','T IN','CREA','SE P','ER T','OWER',' ',
             6'OLD','FACI','LITY',' COS','T IN','CREA','SE P','ER A','SR',' ',
             7'OLD','FACI','LITY',' COS','T IN','CREA','SE P','ER F','SS',' ',
             8'NEW','FACI','LITY',' COS','T IN','CREA','SE P','ER S','ECTO','R',
             9'NEW','FACI','LITY',' COS','T IN','CREA','SE P','ER C','ENTE','R',
             A'NEW','FACI','LITY',' COS','T IN','CREA','SE P','ER T','OWER',' ',
             B'NEW','FACI','LITY',' COS','T IN','CREA','SE P','ER A','SR',' ',
             C'NEW','FACI','LITY',' COS','T IN','CREA','SE P','ER F','SS',' ',
             D'PERC','ENT','OF C','OST','DUE','TO C','OMMU','NICA','TION','S',
             E'NUMB','ER O','F FA','CILI','TIES',' REQ','UIRE','D IN',' SYS',
             F 'TEM'/
0073         DATA OMLBL /'MAIN','TENA','NCE','COST',' OF','OLD','FACI','LITY',
             2 2*' ',     'MAIN','TENA','NCE','COST',' OF','NEW','FACI','LITY',
             3 2*' ','OLD','MAIN','TENA','NCE','COST',' INC','REAS','E PE',
             4 'R SE','CTOR','OLD','MAIN','TENA','NCE','COST',' INC','REAS',
```

Figure 4-1. (continued)

```
     5 'E PE','R CE','NTER','OLD','MAIN','TENA','NCE','COST',' INC',
     6 'REAS','E PE','R TO','WER','OLD','MAIN','TENA','NCE','COST',
     7 ' INC','REAS','E PE','R AS','R','OLD','MAIN','TENA','NCE','COST',
     8 ' INC','REAS','E PE','R FS','S','NEW','MAIN','TENA','NCE','COST',
     9 ' INC','REAS','E PE','R SE','CTOR','NEW','MAIN','TENA','NCE',
     A 'COST',' INC','REAS','E PE','R CE','NTER','NEW','MAIN','TENA',
     B 'NCE','COST',' INC','REAS','E PE','R TO','WER','NEW','MAIN',
     C 'TENA','NCE','COST',' INC','REAS','E PE','R AS','R','NEW','MAIN',
     D 'TENA','NCE','COST',' INC','REAS','E PE','R FS','S','PERC','ENT',
     E 'OF C','OST','DUE','TO C','OMMU','NICA','TION','S','OLD','MAIN',
     F 'TENA','NCE','CTGY',' 1 L','ABOR',' YEA','RS',' ','OLD','MAIN',
     G 'TENA','NCE','CTGY',' 2 L','ABOR',' YEA','RS',' ','OLD','MAIN','T
     HENA','NCE','CTGY',' 3 L','ABOR',' YEA','RS',' ','NEW','MAIN','TENA
     I','NCE','CTGY',' 1 L','ABOR',' YEA','RS',' ','NEW','MAIN','TENA',
     J 'NCE','CTGY',' 2 L','ABOR',' YEA','RS',' ','NEW','MAIN','TENA',
     K 'NCE','CTGY',' 3 L','ABOR',' YEA','RS',' '/
C  DATA FOR TARIFF ARRAY
      DATA TRFARR(1,1),TRFARR(1,2)/0.50,86.60/
      DATA TRFARR(2,1),TRFARR(2,2)/1.75,156.90/
C  MISCELLANEOUS DATA INITIALIZATIONS
      DO 3 I=65,95
      FARRAY(I,13)=1.0
      MARRAY(I,13)=1.0
3     CONTINUE
      DO 6 I=1,95
      ARRAY(I,13)=110.
      ARRAY(I,23)=110.
      FARRAY(I,2)=FARRAY(I,1)
      MARRAY(I,2)=MARRAY(I,1)
      DO 4 J=3,7
      K=J+5
      FARRAY(I,K)=FARRAY(I,J)
      MARRAY(I,K)=MARRAY(I,J)
4     CONTINUE
      DO 5 J=14,16
5     MARRAY(I,J+3)=MARRAY(I,J)
6     CONTINUE
C
C  READ INPUT DATA
C
      READ(4,7)(COL(I),I=1,40)
7     FORMAT(40A2)
      WRITE(5,8)(COL(I),I=1,40)
8     FORMAT('1',20X,40A2///)
9     READ(4,10,END=160) CT,(COL(I),I=1,40)
10    FORMAT (I1,A1,39A2)
11    IF (CT.NE.0)GOTO 20
12    WRITE(5,15) CT, (COL(I),I=1,40)
15    FORMAT(5X,'ERROR-NO CARD TYPE ASSIGNED-FORMAT FOR DATA ENTRY
     # IS UNSPECIFIED-PROGRAM NOT EXECUTED',I1,A1,39A2)
      STOP
17    WRITE(5,18) CT
18    FORMAT(//' INVALID CARD TYPE ',I2,' --- PROGRAM NOT EXECUTED')
      STOP
```

Figure 4-1. (continued)

```
C
C   COMMAND SWITCH
C
20      GO TO (21,40,64,81,105,111,122,146,152), CT
C
C   CHANGES TO F&E COSTS
C
21      WRITE(5,22)
22      FORMAT('1',50X,'F AND E CHANGES'//)
24      READ(4,25,END=160) CT,FT,(CL(I),CH(I),I=1,7)
25      FORMAT(I1,1X,I2,7(1X,I2,1X,F6.0))
        IF(CT.NE.0) GOTO 20
30      DO 35 K=1,7
        IF(CL(K).EQ.0) GOTO 24
        IF(CL(K).EQ.13) CH(K)=CH(K)/100.
        WRITE(5,700) NAMARR(FT), (FELBL(I,CL(K)),I=1,10),
     2               FARRAY(FT,CL(K)),CH(K),ARRAY(FT,13)
33      FARRAY(FT,CL(K))=CH(K)
35      CONTINUE
        GOTO 24
C
C   CHANGES TO O&M COSTS
C
40      WRITE(5,41)
41      FORMAT('1',50X,'O AND M CHANGES'//)
44      READ(4,45, END=160) CT,FT,(CL(I),CH(I),I=1,7)
45      FORMAT(I1,1X,I2,7(1X,I2,1X,F6.0))
        IF(CT.EQ.0) GO TO 47
        WRITE(5,46)
46      FORMAT('1')
        GOTO 20
47      IF(FT.NE.0) GO TO 52
        DO 49 K=1,3
        IF(CL(K).EQ.0) GO TO 50
        WGRATE(CL(K))=CH(K)
49      CONTINUE
50      WRITE(5,51)(WGRATE(I),I=1,3)
51      FORMAT('0',50X,'MAINTENANCE WAGE RATE, INCL BENEFITS:',4X,3F16.2)
        GO TO 44
52      DO 55 K=1,7
        IF (CL(K).EQ.0) GOTO 44
        IF(CL(K).EQ.13) CH(K)=CH(K)/100.
        WRITE(5,700) NAMARR(FT), (OMLBL(I,CL(K)),I=1,10),
     2               MARRAY(FT,CL(K)),CH(K),ARRAY(FT,23)
53      MARRAY(FT,CL(K))=CH(K)
55      CONTINUE
        GOTO 44
C
C CHANGES TO CIRCUIT PARAMETERS
C
64      READ(4,67,END=160) CT,FT,(CL(I),CH(I),I=1,5)
67      FORMAT(I1,1X,I2,5(1X,I2,1X,F6.0))
        GO TO 20
C
```

Figure 4-1. (continued)

```
C  TRANSITION PARAMETERS
C
81      DO 82 I=1,30
82      A(I)=0.0
        READ(4,85,END=160)CT,FT,AT,J,LIFE,MODE,FRSTYR,(A(I),I=1,10),Y
85      FORMAT(I1,I3,1X,A2,I2,I4,I2,I5,10(1X,F3.2),19X,A1)
        IF(CT.NE.0) GOTO 20
        IF(Y.EQ.NSTAR) READ(5,89)(A(I),I=11,30)
88      FORMAT(1X,I1,I3,1X,A2,I2,I3,I2,I5,15F6.2,/,20X,15F6.2,/)
89      FORMAT(20(1X,F3.2))
        JJ=2
        IF(AT.EQ.CTFE) JJ=1
        ELIFE(FT) = LIFE
        B=TNSARR(FT,JJ,J,1)
        IF(JJ.EQ.1) ARRAY(FT,13)=FRSTYR-1900
        IF(JJ.EQ.2) ARRAY(FT,23)=FRSTYR-1900
        DO 95 L=1,30
        K=FRSTYR-1979+L
       IF (A(L).GT.0.0) GO TO 93
       IF(MODE-2) 92,94,96
92     IF(J.EQ.1) B=0.
       GO TO 94
93     B=A(L)
94     IF((J.EQ.1.AND.B.GE.0.999).OR.(J.EQ.2.AND.B.LE.0.001)) GO TO 95
       IF(K.GT.30) GO TO 95
       NTN = NTN+1
       TNINDX(NTN)=120*FT+60*JJ+30*J+K
       TNVALU(NTN) = B
       A(L) = B
95     CONTINUE
       GO TO 99
96     IF(LIFE.EQ.1)GO TO 99
       Y2 = L+LIFE-2
       IF(Y2.GT.30) Y2=30
       DO 97 Y=L,Y2
       NTN=NTN+1
       TNINDX(NTN) = 120*FT + 60*JJ + 30*J + Y
       TNVALU(NTN)=-1.
97     CONTINUE
99      WRITE(5,88)CT,FT,AT,J,LIFE,MODE,FRSTYR,(A(I),I=1,30)
        IF(J.NE.1.AND.J.NE.2) GO TO 17
        GO TO 81
C
C  CHANGES TO TARIFFS
C
105     READ(4,106,END=160) CT,TT,CST,SVC
106     FORMAT(2(I1,1X),2(F6.2,1X))
        IF(CT.NE.0) GOTO 20
        WRITE(5,107)CT,TT,CST,SVC
107     FORMAT(' ',2(I1,1X),2(F6.2,1X))
        TRFARR(TT,1)=CST
        TRFARR(TT,2)=SVC
        GOTO 105
C
```

Figure 4-1. (continued)

```
C  USER ASSIGNED COSTS
C
111     READ(4,112,END=160) CT,FRSTYR,(A(J),J=1,8)
112     FORMAT(I1,1X,I4,8(1X,F7.3))
        IF(CT.NE.0) GOTO 20
        IF(FRSTYR.LE.1978) GOTO 945
        DO 115 L=1,8
        K=FRSTYR-1979+L
        IF(K.GT.30)     GO TO 111
        IF(A(L).EQ.0.) GO TO 111
        UASGN(K)=A(L)
115     CONTINUE
        GOTO 111
C
C  INTEREST AND AUTOMATION FACTORS
C
122     READ(4,123,END=160) CT,IFE(1),IOM(1),ICKT(1),IDIS(1),SECTOR,
     2 AUTOSE,AUTOCN,AUTOTW,AUTOAS,AUTOFS
123     FORMAT(I2,4(1X,F3.2),1X,F4.0,5(1X,F4.2))
        IF(CT.NE.71) GOTO 17
        DO 124 I=2,30
        IFE (I)=IFE (1)
        IOM (I)=IOM (1)
        ICKT(I)=ICKT(1)
        IDIS(I)=IDIS(1)
124     CONTINUE
        READ(4,125,END=160) CT,IFRIN,APTIN,INSIN,FLTIN,
     2 IFRGRO,APOGRO,INOGRO,FSVGRO
125     FORMAT(I2,4(1X,F6.1),4(1X,F3.2))
        IF(CT.NE.72) GOTO 17
126     READ(4,127,END=133) CT,Y1,Y2,(A(I),I=1,16),Y
127     FORMAT(I2,2I5,16F4.2,3X,A1)
        IF(CT.LT.73.OR.CT.GT.77) GO TO 133
        IF(Y.EQ.NSTAR) READ(4,128)(A(I),I=17,30)
128     FORMAT(14(1X,F3.2))
        DO 129 I=Y1,Y2
        J=I-1978
        K=I-Y1+1
C  PROCESSING OF THE 73,74,75,76,77 COMMANDS
        IF(CT.EQ.73) IFE (J)=A(K)
        IF(CT.EQ.74) IOM (J)=A(K)
        IF(CT.EQ.75) ICKT(J)=A(K)
        IF(CT.EQ.76) IDIS(J)=A(K)
        IF(CT.EQ.77) GO TO 6509
129     CONTINUE
        GO TO 126
6509    DO 6510 I=1,95
        PERCOM=FLOAT(Y1)/100.
        FARRAY(I,13)=PERCOM
        MARRAY(I,13)=PERCOM
6510    CONTINUE
        WRITE(5,6511) PERCOM
6511    FORMAT(1H0,'          ALL COMMUNICATIONS PERCENTAGES ARE  ',F5.2)
        GO TO 126
```

Figure 4-1. (continued)

```
C     PRINT INTEREST AND AUTOMATION FACTORS
133     WRITE(5,136)
136     FORMAT(1H0,//,23X,'INFLATION FACTORS',//,2X,'YEAR',11X,'F&E',11X,
     2 'O&M', 7X,'CIRCUITS', 7X,'DISCOUNT',/)
        DO 134 I=1,30
        J=I+1978
134     WRITE(5,135)J,IFE(I),IOM(I),ICKT(I),IDIS(I)
135     FORMAT(I6,4(2X,F12.3))
140     WRITE(5,141) AUTOSE,AUTOCN,AUTOTW,AUTOAS,AUTOFS
141     FORMAT('0','AUTOMATION FACTORS  ',5(1X,F8.3))
142     WRITE(5,143) IFRIN,APTIN,INSIN,FLTIN
143     FORMAT(' ','TRAFFIC DATA   ',6X,4(1X,F8.3))
        WRITE(5,144) IFRGRO,APOGRO,INOGRO,FSVGRO
144     FORMAT(' ','TRAFFIC FACTORS  ',3X,4(1X,F8.3))
        CT=CT/10
        GO TO 20
C
C CHANGES TO THE SWITCHING MATRIX
C
146     READ(4,1461)CT,CKTP
1461    FORMAT(I1,7X,I2)
1465    READ(4,147,END=160) CT,FT,(CL(I),CH(I),I=1,5)
147     FORMAT(I1,1X,I2,5(1X,I2,1X,F6.0))
        IF(CT.NE.0) GOTO 20
148     FORMAT(' CIRCUIT TYPE',I3,'.',5X,5(5X,'(',I2,',',I2,') ',F8.2))
        DO 149 K=1,5
        IF(CL(K).EQ.0) GOTO 1495
        CKTARR(30*CKTP+FT-30,CL(K)) = CH(K)
149     CONTINUE
1495    K = K-1
        WRITE(5,148)CKTP,(FT,CL(I),CH(I),I=1,K)
        GOTO 1465
C
C   REPORT PERIOD
C
152     READ(4,155,END=160) CT,STRTYR,ENDYR,(REP(I),I=1,9)
153     WRITE(5,154)STRTYR,ENDYR
154     FORMAT(1H0,'REPORTS WILL RUN FROM',I5,' TO',I5)
155     FORMAT(I1,2(1X,I4),9(1X,I1))
        IF(REP(1).EQ.0) REP(1)=1
        DO 156 K=1,9
        L=REP(K)
        IF(L.EQ.0) GOTO 157
        RPTYP(L)=1
156     CONTINUE
157     K = K-1
        WRITE(5,158) (REP(I),I=1,K)
158     FORMAT(' ','REPORTS:',9(2X,I2))
C  INSERT CHANGES INTO MAIN ARRAY
160     DO 161 I=1,95
        ARRAY(I,01)=FARRAY(I,14)
        ARRAY(I,14)=FARRAY(I,14)
        ARRAY(I,15)=FARRAY(I,14)
        ARRAY(I,17)=FARRAY(I,14)
```

Figure 4-1. (continued)

```
161    CONTINUE
162    IF(RPTYP(3).NE.1) GOTO 168
       WRITE(5,163)
163    FORMAT('1',53X,'FACILITIES AND EQUIPMENT MATRIX',//,27X,'I',9X,'O
      2LD FACILITY COST INCREASE',9X,'I',9X,'NEW FACILITY COST INCREASE'
      3,9X,'I',/,27X,'I',44X,'I',44X,'I',/,14X,'OLD       NEW I     PER
      4 PER       PER       PER       PER I     PER       PER       PER      P
      5ER       PER I    PCT          NO',/,' ','FACILITY     COST      COST I S
      6ECTOR    CENTER    TOWER     ASR       FSS I SECTOR    CENTER     TOW
      7ER       ASR       FSS I  COMM FACILITY',/)
164    DO 167 I=1,95
165    WRITE(5,166)NAMARR(I),(FARRAY(I,J),J=1,14)
166    FORMAT(' ',A4,3X,12(2X,F7.1),2X,F6.2,2X,F7.0)
167    CONTINUE
168    IF(RPTYP(4).NE.1) GOTO 940
169    FORMAT('1',53X,'OPERATIONS & MAINTENANCE MATRIX',//,27X,'I',9X,'O
      2LD FACILITY COST INCREASE',9X,'I',9X,'NEW FACILITY COST INCREASE'
      3,9X,'I',/,27X,'I',44X,'I',44X,'I',/,14X,'OLD       NEW I     PER
      4 PER       PER       PER       PER I     PER       PER       PER      P
      5ER       PER I    PCT          NO',/,' ','FACILITY     COST      COST I S
      6ECTOR    CENTER    TOWER     ASR       FSS I SECTOR    CENTER     TOW
      7ER       ASR       FSS I  COMM FACILITY',/)
       WRITE(5,169)
170    DO 173 I=1,95
171    WRITE(5,166)NAMARR(I),(MARRAY(I,J),J=1,13),FARRAY(I,14)
173    CONTINUE
C
C  INITIALIZATION ROUTINE FOR COSTS
C
940    YR=79.
       STRTYR=STRTYR-1900
       ENDYR=ENDYR-1900
       IF(STRTYR.GE.79.AND.STRTYR.LE.108.AND.ENDYR.GE.79.AND.ENDYR.LE.
      2 108)GO TO 952
945    WRITE(5,946)
946    FORMAT('1','START YEAR AND END YEAR MUST BE IN THE RANGE ',
      # '1979 TO 1999 --- PROGRAM NOT EXECUTED.')
       STOP
952    IF(SECTOR.EQ.0.) SECTOR=723.
       OPARR(1,1)=SECTOR
       OPARR(2,1)=ARRAY(4,14)
       OPARR(3,1)=ARRAY(7,14)
       OPARR(4,1)=ARRAY(6,14)
       OPARR(5,1)=ARRAY(25,14)
       DO 955 I=1,5
       OPARR(I,3)=OPARR(I,1)
955    CONTINUE
2006   IF(RPTYP(9).EQ.0) GOTO 999
       DO 971 K=1,2
       I=0
       DO 970 J=1,10
       I=I+1
       A(I)=TNSARR(48,K,1,J)
       I=I+1
```

Figure 4-1. (continued)

```
                 A(I)=TNSARR(48,K,2,J)
       970       CONTINUE
                 WRITE(5,2008) (A(J),J=1,20)
       971       CONTINUE
       2008      FORMAT('0','RCAG',10(5X,F4.2)/5X,10(5X,F4.2))
       C
       C  COMPUTE OPERATIONAL UNIT REQUIREMENTS FOR CURRENT YEAR
       C
       999       Y1=YR-78.
                 IFRTFK=1.2505*YR-69.204
                 IF(IFRIN.NE.0.) IFRTFK=IFRIN
                 IF(IFRGRO.EQ.0.) IFRGRO=1.0
                 IFRTFK=IFRGRO*(IFRTFK-27.75)+27.75
       1000      IF(AUTOSE.EQ.0.0) AUTOSE=1.0
                 OPARR(1,2)=(491.1*ALOG(IFRTFK)-926.43)/AUTOSE
                 IF(OPARR(1,2).GT.1200.) OPARR(1,2)=1200.
                 IF(AUTOCN.EQ.0.0) AUTOCN=1.0
                 OPARR(2,2)=OPARR(2,1)/AUTOCN
                 APTOPN=306.7-18429./YR
                 IF(APTIN.NE.0.) APTOPN=APTIN
                 IF(APOGRO.EQ.0.) APOGRO=1.0
                 APTOPN=APOGRO*(APTOPN-70.46)+70.46
       1005      IF(AUTOTW.EQ.0.0) AUTOTW=1.0
                 OPARR(3,2)=270. + 2.*YR
                 INSTOP=2.447*EXP(0.0347*YR)
                 IF(INSIN.NE.0.) INSTOP=INSIN
                 IF(INOGRO.EQ.0.) INOGRO=1.0
                 INSTOP=INOGRO*(INSTOP-33.64)+33.64
       1010      IF(AUTOAS.EQ.0.0) AUTOAS=1.0
                 OPARR(4,2)=(123.3+1.00*INSTOP)/AUTOAS
                 FLTSVC = 365.466 - 23415.4/YR
                 IF(FLTIN.NE.0.0) FLTSVC=FLTIN
                 IF(FSVGRO.EQ.0.) FSVGRO=1.0
                 FLTSVC=FSVGRO*(FLTSVC-67.80)+67.80
                 IF(AUTOFS.EQ.0.0) AUTOFS=1.0
                 OPARR(5,2)=OPARR(5,1)/AUTOFS
                 IF(RPTYP(6).NE.1) GOTO 1013
                 WRITE(5,1011)
       1011      FORMAT('1',50X,'OPERATION MATRIX',50X)
                 WRITE(5,1012) ((OPARR(I,J),J=1,3),I=1,5)
       1012      FORMAT(3(5X,F10.4))
       C
       C  COMPUTE FACILITY AND EQUIPMENT COST
       C
       1013      TSUM=0.
                 Y1=YR-78.
                 Y2=Y1-1
                 DO 1040 I=1,95
                 OLDFAC(I) = 0.
                 ARRAY(I,16)=ARRAY(I,15)
                 U=ARRAY(I,14)
                 IF(I.EQ.57) U=28.2+0.5*INSTOP
                 DO 1015 K=1,5
                 KK=K+1
```

Figure 4-1. (continued)

```
            B=OPARR(K,2)-OPARR(K,1)
            IF(B.LT.0.) B=0.
            U=U+ARRAY(I,KK)*B
      1015  CONTINUE
            ARRAY(I,01)=U
            ARRAY(I,15)=U
            IF (YR.GE.ARRAY(I,13))GOTO 1025
            SUM=FARRAY(I,1)*(ARRAY(I,15)-ARRAY(I,16))*FARRAY(I,13)
            IF(SUM.LT.0.) SUM=0.
            DO 1020 K=1,5
            KK=K+2
            B=OPARR(K,2)-OPARR(K,3)
            IF(B.LT.0.) B=0.
            SUM=SUM+FARRAY(I,KK)*B
      1020  CONTINUE
            GOTO 1035
      C
      C  F&E TRANSITION COSTS
      C
      1025  IF(YR.NE.ARRAY(I,13)) GOTO 1027
            IF(ARRAY(I,13).GT.ARRAY(I,23)) GOTO 1027
            ARRAY(I,17)=ARRAY(I,16)
            DO 1026 K=1,5
            ARRAY(I,K+17)=OPARR(K,3)
      1026  CONTINUE
      1027  SUM = 0.
           V = TNSARR(I,1,2,Y1)
           IF(V.EQ.0.) GO TO 1034
      C   FIND AVAILABLE NEW FACILITIES FROM PREVIOUS YEARS.  THIS IS DONE
      C   BY SEARCHING THROUGH THE TRANSITION DATA FOR THE PROPER ENTRIES.
      1028 LIFE = ELIFE(I)-1
           AVNEW=0.
           JJ = Y1 - LIFE
           IF(JJ.LE.0) JJ=1
           DO 1031 K=1,Y2
           II = 120*I + 120 + JJ
           JJ = JJ + 1
           DO 1029 J = 1,NTN
           IF(TNINDX(J).EQ.II) GO TO 1030
      1029 CONTINUE
           GO TO 1031
      1030 AVNEW = AVNEW+TNVALU(J)
      1031 CONTINUE
      C   NOW CALCULATE NEW 'NEW' FACILITIES NEEDED AND NEW 'OLD' FACILITIES
      C   (RELEVANT IF TRANSITION MODE 3 SPECIFIED)
           IF(V.GE.0) FENEW=AMAX1(ARRAY(I,15)*V-AVNEW,0.)
           IF(V.LT.0) FENEW=0.
           II = 120*I + 120 + Y1
           DO 1032 J=1,NTN
           IF(TNINDX(J).EQ.II) GO TO 1033
      1032 CONTINUE
      1033 TNVALU(J) = FENEW
           IF(V.GE.0.) FEOLD=0.
           IF(V.LT.0) FEOLD=AMAX1(0.,ARRAY(I,15)-AVNEW-FENEW-ARRAY(I,17))
```

Figure 4-1. (continued)

```
          SUM=FARRAY(I,2)*FENEW*FARRAY(I,13)+FARRAY(I,1)*FEOLD*FARRAY(I,13)
          OLDFAC(I) = 0.
          IF(V.LT.0.) OLDFAC(I)=ARRAY(I,15)-AVNEW-FENEW
 1034      DO 1036 K=1,5
           SUM=SUM+FARRAY(I,K+7)*AMAX1(0.,OPARR(K,2)-OPARR(K,3))
 1036      CONTINUE
 1035     TSUM = TSUM+SUM
 1040      CONTINUE
           COSTAR(Y1,1)=TSUM/1000.
C
C  COMPUTE OPERATIONS AND MAINTENANCE COSTS
C
           TSUM=0.
           DO 1065 I=1,95
           OLDONM=MARRAY(I,1)+MARRAY(I,14)*WGRATE(1)+MARRAY(I,15)*WGRATE(2)
         2 +MARRAY(I,16)*WGRATE(3)
           NEWONM=MARRAY(I,2)+MARRAY(I,17)*WGRATE(1)+MARRAY(I,18)*WGRATE(2)
         2 +MARRAY(I,19)*WGRATE(3)
           SUM=0.
           IF(YR.GE.ARRAY(I,23)) GOTO 1050
           SUM=ARRAY(I,15)*OLDONM*MARRAY(I,13)
           DO 1045 K=1,5
           SUM=SUM+MARRAY(I,K+2)*(OPARR(K,2)-OPARR(K,1))
 1045      CONTINUE
           GOTO 1060
C
C  O&M TRANSITION COSTS
C
 1050      IF(YR.NE.ARRAY(I,23)) GOTO 1052
           IF(ARRAY(I,13).LE.ARRAY(I,23)) GOTO 1052
           ARRAY(I,17)=ARRAY(I,16)
           DO 1051 K=1,5
           ARRAY(I,K+17)=OPARR(K,3)
 1051      CONTINUE
 1052      DO 1053 K=1,5
           SUM=SUM+MARRAY(I,K+7)*(OPARR(K,2)-ARRAY(I,K+17))
 1053      CONTINUE
          SUM=SUM+ARRAY(I,17)*TNSARR(I,2,2,Y1)*NEWONM*MARRAY(I,13)
          IF(OLDFAC(I).EQ.0.)
         2   SUM=SUM+ARRAY(I,17)*TNSARR(I,2,1,Y1)*OLDONM*MARRAY(I,13)
          IF(OLDFAC(I).NE.0.)SUM=SUM+OLDONM*OLDFAC(I)*MARRAY(I,13)
          DO 1055 K=1,5
 1055     SUM=SUM+(ARRAY(I,K+17)-OPARR(K,1))*(MARRAY(I,K+2)*TNSARR(I,2,1,Y1)
         2        +MARRAY(I,K+7)*TNSARR(I,2,2,Y1))
 1060      TSUM=TSUM+SUM
 1065      CONTINUE
           COSTAR(Y1,2)=TSUM/1000.
C
C  COMPUTE CIRCUIT COSTS
C
           RT2=OPARR(2,2)
           IF(RT2.EQ.0.0) RT2=1.0
           RT4=OPARR(5,2)
           IF(RT4.EQ.0.0) RT4=1.0
```

Figure 4-1. (continued)

```
        RT3=OPARR(3,2)
        IF(RT3.EQ.0.0) RT3=1.0
        RTTWR=SQRT(OPARR(3,1)/RT3)
        RTCTR=SQRT(OPARR(2,1))/SQRT(RT2)
        RTFSS=SQRT(OPARR(5,1))/SQRT(RT4)
        L=CKTP*30-29
        DO 1463 I=1,30
        DO 1462 J=1,10
        SWARR(I,J)=CKTARR(L,J)
        IF(J.LE.2)SWINDX(I,J)=SWMAP(L,J)
 1462   CONTINUE
 1463   L=L+1
        GO TO(1070,1170,1270,1370),CKTP
C
C  CIRCUIT GROUP 1
C
 1070   SWARR(1,6)=SWARR(1,4)
        SWARR(1,5)=SWARR(1,3)*SWARR(1,6)
        SWARR( 2,6)=SWARR( 2,4)*OPARR( 3,2)
        SWARR( 2,5)=SWARR( 2,3)*SWARR( 2,6)*RTFSS
        SWARR( 3,6)=SWARR( 3,4)*OPARR( 5,2)
        SWARR( 3,5)=SWARR( 3,3)*SWARR( 3,6)*RTCTR
        SWARR( 4,6)=SWARR( 4,4)*OPARR( 3,2)
        SWARR( 4,5)=SWARR( 4,3)*SWARR( 4,6)*RTCTR
        SWARR( 5,6)=SWARR( 5,4)*OPARR( 2,2)
        SWARR( 5,5)=SWARR( 5,3)*SWARR( 5,6)*RTCTR
        SWARR( 6,6)=322.0+FLTSVC*7.22+26.09*OPARR(2,2)
        SWARR( 6,5)=SWARR( 6,3)*SWARR( 6,6)*RTFSS
        SWARR(7,6)=SWARR(7,4)
        SWARR(7,5)=SWARR(7,3)*SWARR(7,6)
        SWARR( 8,6)=SWARR( 8,4)*OPARR( 3,2)
        SWARR( 8,5)=SWARR( 8,3)*SWARR( 8,6)*RTFSS
        SWARR( 9,6)=SWARR( 9,4)*OPARR( 5,2)
        SWARR( 9,5)=SWARR( 9,3)*SWARR( 9,6)*RTCTR
        SWARR(10,6)=SWARR(10,4)*OPARR( 3,2)
        SWARR(10,5)=SWARR(10,3)*SWARR(10,6)*RTCTR
        SWARR(11,6)=SWARR(11,4)*OPARR( 2,2)
        SWARR(11,5)=SWARR(11,3)*SWARR(11,6)*RTCTR
        SWARR(12,6)=SWARR(12,4)
        SWARR(12,5)=SWARR(12,3)*SWARR(12,6)
        SWARR(13,6)=SWARR(13,4)*ARRAY(48,1)+(OPARR(1,2)-OPARR(1,1))*2.0
        SWARR(13,5)=SWARR(13,3)*SWARR(13,6)
        SWARR(14,6)=SWARR(14,4)*OPARR( 5,2)
        SWARR(14,5)=SWARR(14,3)*SWARR(14,6)
        SWARR(15,6)=SWARR(15,4)*OPARR( 3,2)
        SWARR(15,5)=SWARR(15,3)*SWARR(15,6)
        SWARR(16,6)=SWARR(16,4)*OPARR( 2,2)
        SWARR(16,5)=SWARR(16,3)*SWARR(16,6)
        SWARR(17,6)=SWARR(17,4)
        SWARR(17,5)=SWARR(17,3)*SWARR(17,6)
        GO TO 1077
C
C  CIRCUIT GROUP 2
C
```

Figure 4-1. (continued)

```
 1170   SWARR(1,6)=SWARR(1,4)*OPARR(3,2)
        SWARR(1,5)=SWARR(1,3)*SWARR(1,6)*RTFSS
        SWARR(2,6)=SWARR(2,4)*OPARR(5,2)
        SWARR(2,5)=SWARR(2,3)*SWARR(2,6)*RTCTR
        SWARR(3,6)=SWARR(3,4)*OPARR(3,2)
        SWARR(3,5)=SWARR(3,3)*SWARR(3,6)*RTCTR
        SWARR(4,6)=SWARR(4,4)*OPARR(2,2)
        SWARR(4,5)=SWARR(4,3)*SWARR(4,6)*RTCTR
        SWARR(5,6)=322.+7.22*FLTSVC+26.09*OPARR(2,2)
        SWARR(5,5)=SWARR(5,3)*SWARR(5,6)*RTFSS
        SWARR(6,4)=SWARR(6,4)*OPARR(5,2)/OPARR(5,1)
        SWARR(6,6)=SWARR(6,4)*OPARR(5,2)
        SWARR(6,5)=SWARR(6,3)*SWARR(6,6)*RTFSS
        SWARR(7,4)=SWARR(7,4)*OPARR(3,2)/OPARR(3,1)
        SWARR(7,6)=SWARR(7,4)*OPARR(3,2)
        SWARR(7,5)=SWARR(7,3)*SWARR(7,6)*RTTWR
        SWARR(8,6)=SWARR(8,4)
        SWARR(8,5)=SWARR(8,3)*SWARR(8,6)
        SWARR(9,6)=SWARR(9,4)*OPARR(5,2)
        SWARR(9,5)=SWARR(9,3)*SWARR(9,6)*RTCTR
        SWARR(10,6)=SWARR(10,4)
        SWARR(10,5)=SWARR(10,3)*SWARR(10,6)
        SWARR(11,6)=SWARR(11,4)*OPARR(3,2)
        SWARR(11,5)=SWARR(11,3)*SWARR(11,6)*RTCTR
        SWARR(12,6)=SWARR(12,4)*OPARR(3,2)
        SWARR(12,5)=SWARR(12,3)*SWARR(12,6)*RTCTR
        SWARR(13,6)=SWARR(13,4)*OPARR(2,2)
        SWARR(13,5)=SWARR(13,3)*SWARR(13,6)*RTCTR
        SWARR(14,6)=SWARR(14,4)
        SWARR(14,5)=SWARR(14,3)*SWARR(14,6)
        SWARR(15,6)=SWARR(15,4)*(OPARR(3,2)+OPARR(5,2))
        SWARR(15,5)=SWARR(15,3)*SWARR(15,6)*SQRT((OPARR(3,1)+OPARR(5,1))/
     2 (OPARR(3,2)+OPARR(5,2)))
        SWARR(16,6)=SWARR(16,4)*ARRAY(48,1)+2.*(OPARR(1,2)-OPARR(1,1))
        SWARR(16,5)=SWARR(16,3)*SWARR(16,6)
        SWARR(17,6)=SWARR(17,4)*OPARR(5,2)
        SWARR(17,5)=SWARR(17,3)*SWARR(17,6)
        SWARR(18,6)=SWARR(18,4)*OPARR(3,2)
        SWARR(18,5)=SWARR(18,3)*SWARR(18,6)
        SWARR(19,6)=SWARR(19,4)*OPARR(2,2)
        SWARR(19,5)=SWARR(19,3)*SWARR(19,6)
        SWARR(20,6)=SWARR(20,4)
        SWARR(20,5)=SWARR(20,3)*SWARR(20,6)
        SWARR(21,6)=SWARR(21,4)
        SWARR(21,5)=SWARR(21,3)*SWARR(21,6)
        GO TO 1077
C
C  CIRCUIT GROUP 3
C
 1270   SWARR(1,4)=SWARR(1,4)*OPARR(3,2)/OPARR(3,1)
        SWARR(1,6)=SWARR(1,4)*OPARR(3,2)
        SWARR(1,5)=SWARR(1,3)*SWARR(1,6)*RTTWR
        SWARR(2,6)=SWARR(2,4)*OPARR(3,2)
        SWARR(2,5)=SWARR(2,3)*SWARR(2,6)*RTCTR
```

Figure 4-1. (continued)

```
SWARR(3,6)=SWARR(3,4)*OPARR(3,2)
SWARR(3,5)=SWARR(3,3)*SWARR(3,6)*RTCTR
SWARR(4,6)=SWARR(4,4)*OPARR(3,2)
SWARR(4,5)=SWARR(4,3)*SWARR(4,6)*RTTWR
SWARR(5,6)=      1.362*APTOPN
SWARR(5,5)=SWARR(5,3)*SWARR(5,6)
SWARR(6,6)=      0.695*APTOPN
SWARR(6,5)=SWARR(6,3)*SWARR(6,6)
SWARR(7,6)=SWARR(7,4)*OPARR(3,2)
SWARR(7,5)=SWARR(7,3)*SWARR(7,6)
SWARR(8,6)=SWARR(8,4)*OPARR(3,2)
SWARR(8,5)=SWARR(8,3)*SWARR(8,6)
SWARR(9,6)=SWARR(9,4)*OPARR(3,2)
SWARR(9,5)=SWARR(9,3)*SWARR(9,6)*RTTWR
SWARR(10,6)=SWARR(10,4)*OPARR(3,2)
SWARR(10,5)=SWARR(10,3)*SWARR(10,6)
SWARR(11,6)=SWARR(11,4)*OPARR(2,2)
SWARR(11,5)=SWARR(11,3)*SWARR(11,6)*RTCTR
SWARR(12,6)=SWARR(12,4)*OPARR(5,2)
SWARR(12,5)=SWARR(12,3)*SWARR(12,6)*RTCTR
SWARR(13,6)=SWARR(13,4)*OPARR(2,2)
SWARR(13,5)=SWARR(13,3)*SWARR(13,6)*RTCTR
SWARR(14,6)=SWARR(14,4)*ARRAY(48,1)+2.*(OPARR(1,2)-OPARR(1,1))
SWARR(14,5)=SWARR(14,3)*SWARR(14,6)
SWARR(15,6)=SWARR(15,4)*OPARR(2,2)
SWARR(15,5)=SWARR(15,3)*SWARR(15,6)
SWARR(16,6)=SWARR(16,4)*OPARR(4,2)
SWARR(16,5)=SWARR(16,3)*SWARR(16,6)*RTCTR
SWARR(17,6)=SWARR(17,4)*OPARR(1,2)
SWARR(17,5)=SWARR(17,3)*SWARR(17,6)*RTCTR
SWARR(18,6)=SWARR(18,4)*OPARR(2,2)
SWARR(18,5)=SWARR(18,3)*SWARR(18,6)*RTCTR
SWARR(19,6)=SWARR(19,4)*OPARR(2,2)
SWARR(19,5)=SWARR(19,3)*SWARR(19,6)*RTCTR
SWARR(20,4)=SWARR(20,4)*OPARR(5,2)/OPARR(5,1)
SWARR(20,6)=SWARR(20,4)*OPARR(5,2)
SWARR(20,5)=SWARR(20,3)*SWARR(20,6)*RTFSS
SWARR(21,6)=SWARR(21,4)*OPARR(5,2)
SWARR(21,5)=SWARR(21,3)*SWARR(21,6)*RTFSS
SWARR(22,6)=      15.81*(APTOPN-INSTOP)
SWARR(22,5)=SWARR(22,3)*SWARR(22,6)*RTFSS
SWARR(23,6)=OPARR(5,2)+7.22*FLTSVC
SWARR(23,5)=SWARR(23,3)*SWARR(23,6)*RTFSS
SWARR(24,6)=SWARR(24,4)*OPARR(5,2)
SWARR(24,5)=SWARR(24,3)*SWARR(24,6)*RTFSS
SWARR(25,6)=SWARR(25,4)*OPARR(5,2)
SWARR(25,5)=SWARR(25,3)*SWARR(25,6)*RTFSS
SWARR(26,6)=SWARR(26,4)*OPARR(5,2)
SWARR(26,5)=SWARR(26,3)*SWARR(26,6)*RTFSS
SWARR(27,6)=SWARR(27,4)*OPARR(5,2)
SWARR(27,5)=SWARR(27,3)*SWARR(27,6)*RTFSS
SWARR(28,6)=SWARR(28,4)
SWARR(28,5)=SWARR(28,3)*SWARR(28,6)
SWARR(29,6)=SWARR(29,4)
```

Figure 4-1. (continued)

```
      SWARR(29,5)=SWARR(29,3)*SWARR(29,6)
      GO TO 1077
C
C  CIRCUIT GROUP 4
C
1370  SWARR(1,6)=SWARR(1,4)*OPARR(5,2)
      SWARR(1,5)=SWARR(1,3)*SWARR(1,6)*RTFSS
      SWARR(2,6)=SWARR(2,4)*OPARR(3,2)
      SWARR(2,5)=SWARR(2,3)*SWARR(2,6)*RTTWR
      SWARR(3,6)=SWARR(3,4)*OPARR(2,2)
      SWARR(3,5)=SWARR(3,3)*SWARR(3,6)*RTCTR
      SWARR(4,6)=SWARR(4,4)
      SWARR(4,5)=SWARR(4,3)*SWARR(4,6)
      SWARR(5,6)=SWARR(5,4)
      SWARR(5,5)=SWARR(5,3)*SWARR(5,6)
      SWARR(6,6)=SWARR(6,4)*OPARR(3,2)
      SWARR(6,5)=SWARR(6,3)*SWARR(6,6)
      SWARR(7,6)=     10.065*APTOPN
      SWARR(7,5)=SWARR(7,3)*SWARR(7,6)
      SWARR(8,6)=SWARR(8,4)*OPARR(5,2)
      SWARR(8,5)=SWARR(8,3)*SWARR(8,6)*RTTWR
      SWARR(9,6)=SWARR(9,4)*OPARR(3,2)
      SWARR(9,5)=SWARR(9,3)*SWARR(9,6)*RTCTR
      SWARR(10,6)=SWARR(10,4)*OPARR(3,2)
      SWARR(10,5)=SWARR(10,3)*SWARR(10,6)*RTCTR
      SWARR(11,4)=SWARR(11,4)*OPARR(3,2)/OPARR(3,1)
      SWARR(11,6)=SWARR(11,4)*OPARR(3,2)
      SWARR(11,5)=SWARR(11,3)*SWARR(11,6)*RTTWR
      SWARR(12,6)=SWARR(12,4)*ARRAY(48,1)+2.*(OPARR(1,2)-OPARR(1,1))
      SWARR(12,5)=SWARR(12,3)*SWARR(12,6)*RTCTR
      SWARR(13,6)=SWARR(13,4)*OPARR(3,2)
      SWARR(13,5)=SWARR(13,3)*SWARR(13,6)*RTTWR
      SWARR(14,6)=SWARR(14,4)*OPARR(2,2)
      SWARR(14,5)=SWARR(14,3)*SWARR(14,6)
      SWARR(15,6)=SWARR(15,4)*OPARR(5,2)
      SWARR(15,5)=SWARR(15,3)*SWARR(15,6)*RTFSS
      SWARR(16,6)=OPARR(5,2)+7.22*FLTSVC+26.09*OPARR(2,2)
      SWARR(16,5)=SWARR(16,3)*SWARR(16,6)*RTFSS
      SWARR(17,6)=SWARR(17,4)
      SWARR(17,5)=SWARR(17,3)*SWARR(17,6)
      SWARR(18,6)=SWARR(18,4)
      SWARR(18,5)=SWARR(18,3)*SWARR(18,6)
      SWARR(19,6)=SWARR(19,4)*(OPARR(3,2)+OPARR(5,2))
      SWARR(19,5)=SWARR(19,3)*SWARR(19,6)*RTTWR*RTFSS
      SWARR(20,6)=SWARR(20,4)*OPARR(4,2)
      SWARR(20,5)=SWARR(20,3)*SWARR(20,6)
      SWARR(21,6)=SWARR(21,4)
      SWARR(21,5)=SWARR(21,3)*SWARR(21,6)
C  ESTIMATE SWITCH REQUIREMENTS
1077  DO 1078 I=1,30
      SWARR(I,8) = SWARR(I,7)*SWARR(I,6)
C   1.5312 REPRESENTS GROWTH AND INFLATION SINCE 1976
      COSTAR(Y1,4)=COSTAR(Y1,4)+SWARR(I,6)*SWARR(I,9)*12.*1.5312
1078  CONTINUE
```

Figure 4-1. (continued)

```
      DO 1080 I=1,30
      IF(SWARR(I,1).NE.1.) GO TO 1080
      DO 1079 J=1,2
      K=SWINDX(I,J)
      IF(K.EQ.0) GO TO 1079
      SWARR(K,4) = SWARR(K,4)*(SWARR(K,6)+SWARR(I,6))/SWARR(K,6)
      SWARR(K,5) = SWARR(K,5)*(SWARR(K,6)+SWARR(I,6))/SWARR(K,6)
      SWARR(K,6) = SWARR(K,6)+SWARR(I,6)
      SWARR(K,8) = SWARR(K,8)+SWARR(I,8)
      SWARR(K,7) = SWARR(K,8)/SWARR(K,6)
      SWARR(K,10) = AMIN1(SWARR(K,10),SWARR(I,10))
      SWARR(I,2) = -1.
 1079 CONTINUE
 1080 CONTINUE
      ENDIST = 0.
      DO 1085 K=1,30
      IF(SWARR(K,2).LT.0.) GO TO 1086
      IF(SWARR(K,1).NE.1.) GO TO 1084
C
C  DETERMINE NUMBER OF CIRCUITS REQUIRED IN SWITCHED SYSTEM
C
      QQ = ALOG(AMAX1(SWARR(K,4)*SWARR(K,7),0.1))
      GG = ALOG(AMAX1(SWARR(K,10)*100000.,0.1))
      CKTS = EXP(1.506 + 0.39919*QQ + 0.08158*QQ*QQ
     2           + 0.11892*GG - 0.01709*GG*GG)
      CKTS = AMIN1(SWARR(K,4),CKTS)
      CKTS = AMAX1(SWARR(K,4)*SWARR(K,7),CKTS)
      SWARR(K,5) = SWARR(K,5)*CKTS/SWARR(K,4)
      SWARR(K,6) = SWARR(K,6)*CKTS/SWARR(K,4)
      SWARR(K,4) = CKTS
      ENDIST = ENDIST + SWARR(K,6)
C
C  ADD AVERAGE IXC COST PER CIRCUIT
C
 1084  DO 1095 I=1,9
      IF(IFIX(SWARR(K,2)).NE.I) GO TO 1095
      COSTAR(Y1,3)=COSTAR(Y1,3)+TRFARR(I,1)*SWARR(K,5)*12.
     2                         +TRFARR(I,2)*SWARR(K,6)*12.
 1095  CONTINUE
 1086 IF(SWARR(K,2).GT.0.) GO TO 1085
      DO 1088 L=3,9
 1088 SWARR(K,L) = 0.
 1085 CONTINUE
       IF(IFIX(YR).EQ.STRTYR) COSTAR(Y1,1)=COSTAR(Y1,1)+ENDIST*0.000500
       IF(IFIX(YR).GE.STRTYR) COSTAR(Y1,2)=COSTAR(Y1,2)+ENDIST*0.000030
       COSTAR(Y1,3) = COSTAR(Y1,3)/1.E6
       COSTAR(Y1,4) = COSTAR(Y1,4)/1.E6
C
C  SWITCH ARRAY REPORT
C
       IF(RPTYP(7).NE.1) GOTO 1099
       WRITE(5,1097)
 1097  FORMAT('1',50X,'SWITCH ARRAY',50X)
       WRITE(5,1098) ((SWARR(I,J),J=1,10),I=1,30)
```

Figure 4-1. (continued)

```
1098   FORMAT(10(3X,F10.2))
C
C  COMPUTE LEASED EQUIPMENT COSTS
C
1099  COSTAR(Y1,4)=COSTAR(Y1,4) + 5.467 + 0.6478*ARRAY(4,1)
    2            +0.0299*ARRAY(7,1) + 0.00797*ARRAY(25,1)
       COSTAR(Y1,5)=UASGN(Y1)
C
C  MAIN ARRAY REPORT
C
       IF(RPTYP(8).NE.1) GOTO 1104
       WRITE(5,1100)
1100   FORMAT('1',53X,'MAIN ARRAY'//)
       DO 1103 I=1,95
       WRITE(5,1101)I,NAMARR(I),(ARRAY(I,J),J=1,23)
1101   FORMAT('0',I2,2X,A4,12(2X,F7.2),/,9X,11(2X,F7.2))
1103   CONTINUE
1104   IF(YR.EQ.FLOAT(ENDYR)) GOTO 1130
       YR=YR+1.
       DO 1105 I=1,5
       OPARR(I,3)=OPARR(I,2)
1105   CONTINUE
       GOTO 999
1130   K=ENDYR-78
       DO 1140 I=1,K
       DO 1141 J=1,I
       COSTAR(I,1)=COSTAR(I,1)*(1.+IFE (J))
       COSTAR(I,2)=COSTAR(I,2)*(1.+IOM (J))
       COSTAR(I,3)=COSTAR(I,3)*(1.+ICKT(J))
       COSTAR(I,4)=COSTAR(I,4)*(1.+ICKT(J))
       COSTAR(I,5)=COSTAR(I,5)*(1.+IFE(J)/2.+IOM(J)/2.)
1141   CONTINUE
1140   CONTINUE
C
C  COST SUMMARY REPORT
C
175    IF(RPTYP(1).EQ.0) GOTO 188
       WRITE(5,183)
183    FORMAT('1',40X,'COSTS BY CATEGORY-ALL AMOUNTS IN MILLIONS OF DOLL
     2ARS',//,' ',9X,'FACILITIES',5X,'OPERATIONS',68X,'NET',8X,'CUMULATI
     3VE',/,' YEAR',9X,'AND',12X,'AND',25X,'LEASED',10X,'USER',10X,
     4 'TOTAL',9X,'PRESENT',5X,'NET PRESENT',/,11X,'EQUIPMENT',4X,
     5 'MAINTENANCE',5X,'CIRCUITS',7X,'EQUIPMENT',6X,'ASSIGNED',24X,
     6 'VALUE',9X,'VALUE',/,1X,66('- '))
188    SUM=0.
       Y=STRTYR+1900
       J=STRTYR-78
       K=ENDYR-78
189    DO 200 I=J,K
       TOT(I)=COSTAR(I,1)+COSTAR(I,2)+COSTAR(I,3)+COSTAR(I,4)+
     # COSTAR(I,5)
       NPV(I) = TOT(I)
       IF(I.EQ.1) SUM = TOT(I)
       IF(I.EQ.1) GO TO 190
```

Figure 4-1. (continued)

```
      DO 191 J=2,I
191   NPV(I) = NPV(I)/(1.+IDIS(J))
      SUM=SUM+NPV(I)
190   WRITE(5,195)Y,(COSTAR(I,J),J=1,5),TOT(I),NPV(I),SUM
195   FORMAT('0',1X,I4,2X,8('$',F8.1,6X))
197   Y=Y+1
200   CONTINUE
C
C  SHORT COST SUMMARY
C
398   IF(RPTYP(2).NE.1) GOTO 442
400   WRITE(5,415)
415   FORMAT('1',25X,'YEAR',24X,'TOTAL',20X,'NET PRESENT VALUE',/,82X,
     2 '(MILLIONS)',/,1X,66('- '))
      Y=STRTYR+1900
      J=STRTYR-78
      K=ENDYR-78
430   DO 440 I=J,K
      WRITE(5,435) Y,TOT(I),NPV(I)
435   FORMAT('0',25X,I4,22X,'$',F9.4,20X,'$',F9.4)
      Y=Y+1
440   CONTINUE
442   IF(RPTYP(5).NE.1) STOP
       WRITE(5,444)
444   FORMAT('1',64X,'TARIFF MATRIX',10X)
446   WRITE(5,448) (I,(TRFARR(I,J),J=1,2),I=1,9)
448   FORMAT(' ',I1,5X,'COST = $',F6.2,5X,'SERVICE = $',F6.2)
450   STOP
C
C     FORMAT STATEMENTS FOR THE DEFINITION OF INPUT CHANGES
C
700   FORMAT('0',5X,A4,10X,10A4,F16.2,F15.2,F9.0)
900   WRITE(5,905) CT
905   FORMAT(5X,'ERROR-CARD TYPE IS NOT EQUAL 1-9, PROGRAM
     # NOT EXECUTED  CT= ',I1)
      END


C    THIS SUBROUTINE STORES AND RETRIEVES ALL TRANSITION INFORMATION
      FUNCTION TNSARR(I,J,K,L)
      INTEGER TNINDX(1000)
      REAL    TNVALU(1000)
      COMMON NTN,TNINDX,TNVALU
      INDEX = 120*I + 60*J + 30*K + L
      TNSARR=0.
      IF (K.EQ.1) TNSARR=1.
      DO 10 N=1,NTN
      IF(TNINDX(N).NE.INDEX) GO TO 10
      TNSARR=TNVALU(N)
      RETURN
10    CONTINUE
      RETURN
      END
```

Figure 4-1. (continued)

Table 4-1. SUMMARY OF SOURCE LISTING FUNCTIONS (MAINPGM)	
Program Lines	Function
1-28	Variable definition and dimensioning; clear all array elements
29-31	F&E data base
32-56	O&M data base
57-63	Data for main array
64-67	Computed data for main array
68-70	Data for circuit array
71-73	Data for facility names and report labels
74-75	Tariff data base
76-92	Initialize portions of F&E, O&M and main arrays
93-106	Read first data card; error check and branch appropriately
107-118	F&E input
119-141	O&M input
142-144	Circuit parameters (not used)
145-184	Transition parameters
185-192	Tariff input
193-203	User assigned costs
204-252	Interest and automation factors
253-265	Circuit and switching data
266-278	Analysis period and reports
279-284	Update main array
285-297	Formats and definitions for F&E and O&M reports
298-325	Initialize report period and OPARR
326-358	Compute requirements due of traffic growth
359-384	Compute pre-transition F&E costs
385-424	Compute post-transition F&E costs
425-435	Compute pre-transition O&M costs
436-452	Compute post-transition O&M costs
453-469	Initialize parameters for circuit costs
470-504	Calculations for circuit type 1
505-549	Calculations for circuit type 2
550-610	Calculations for circuit type 3
611-653	Calculations for circuit type 4
654-684	Compute switch requirements
685-696	Compute IXC costs
697-701	Switch array report
702-703	Calculate leased equipment and user assigned costs
704-710	Main array report
711-716	Update arrays for next analysis year
717-726	Compute inflation
727-744	Cost summary report
745-755	Short cost summary report
756-761	Tariff report
762-765	Format statements and diagnostics

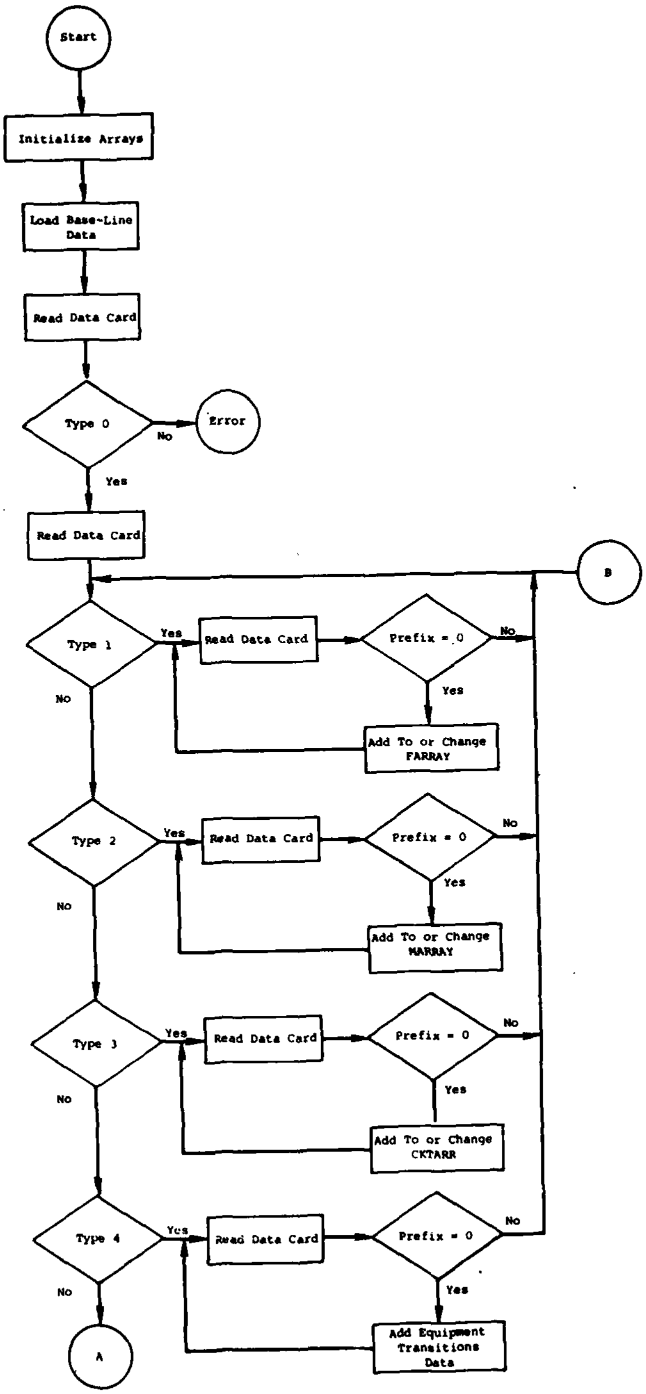


Figure 4-2. OVERALL FLOW CHART

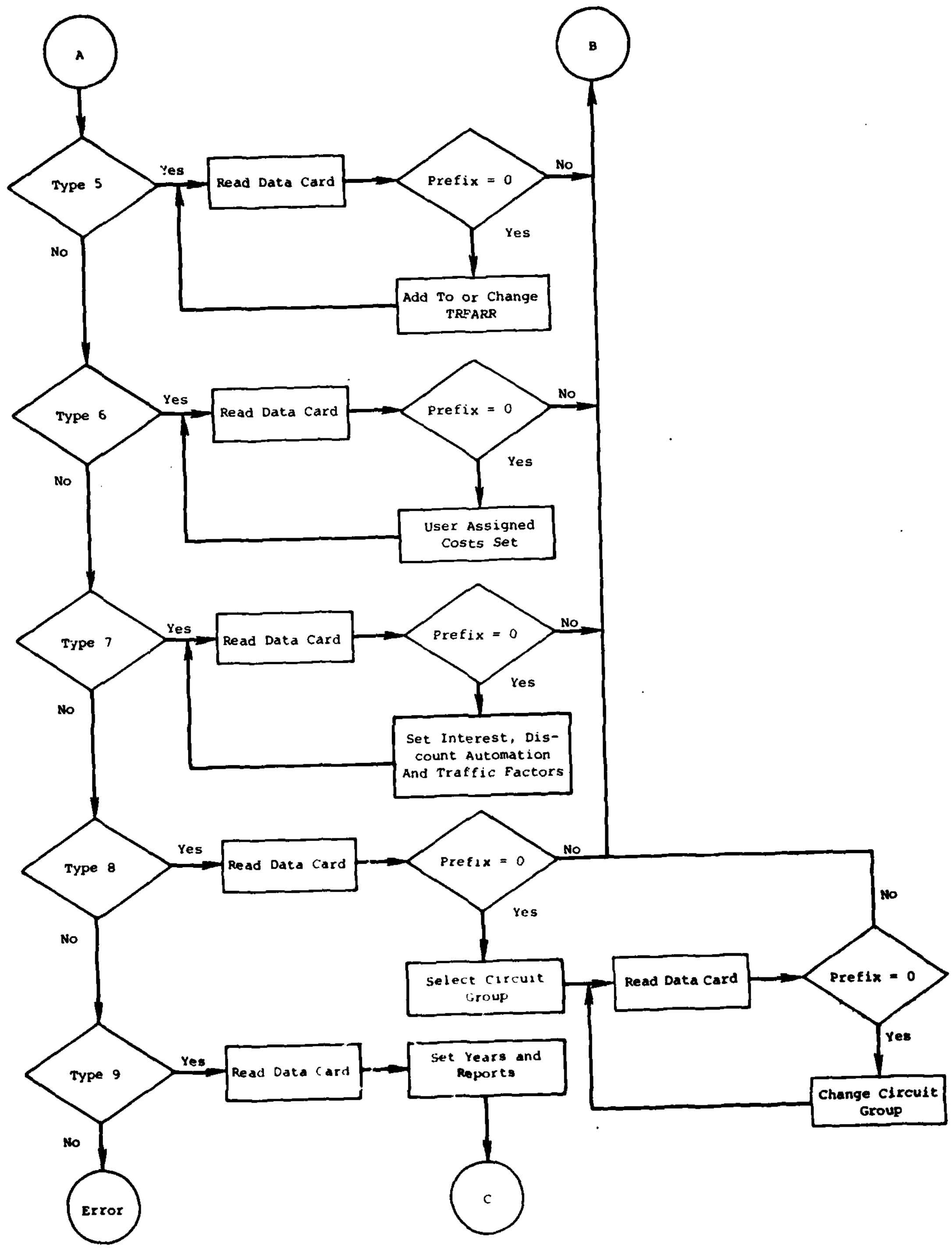


Figure 4-2. (continued)

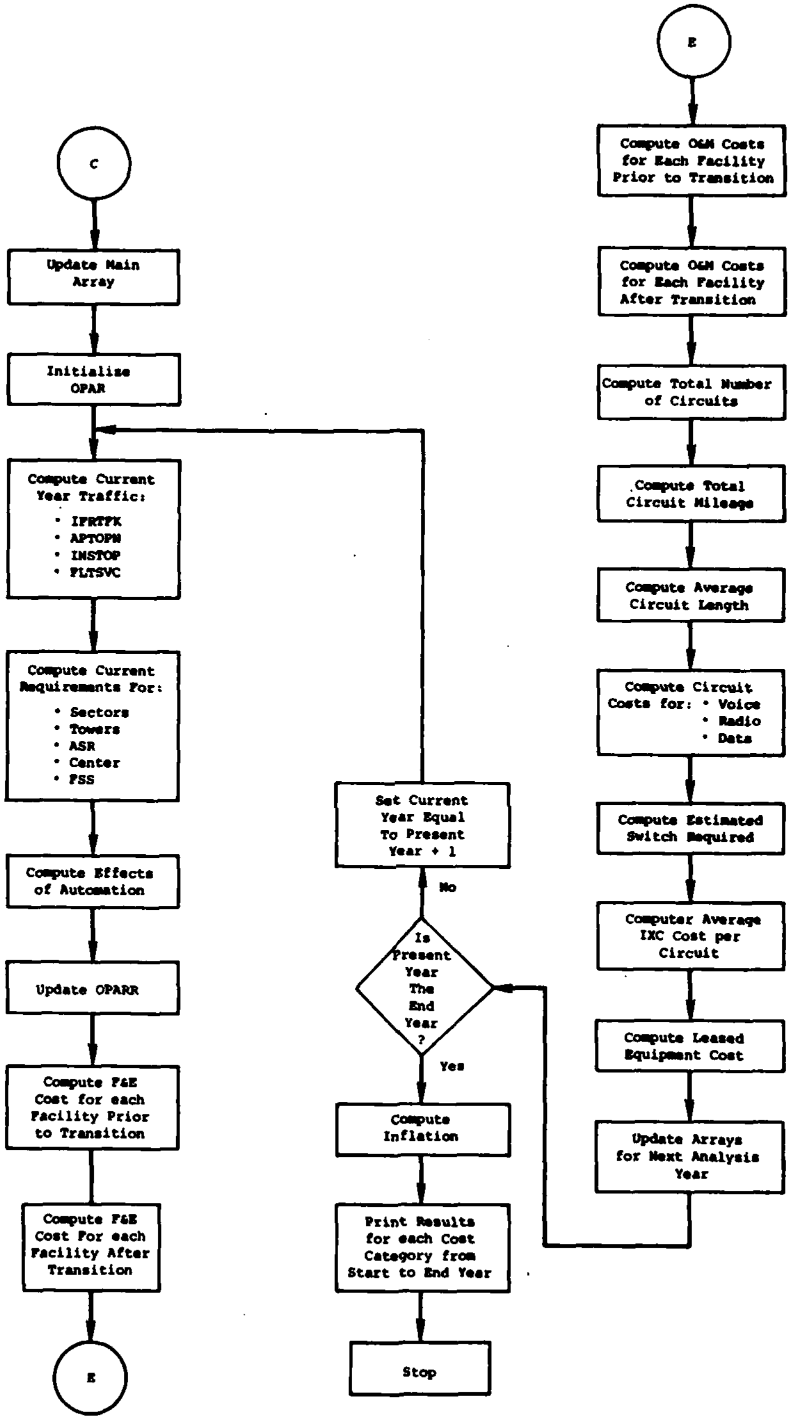


Figure 4-2. (continued)

Table 4-2. OPERATIONS AND MAINTENANCE DATA BASE							
Facility (I)	Cost Per Facility (In Thousands of Dollars)	Cost Increases (In Thousands of Dollars)					Percent of Communications
		Per Sector	Per Center	Per ATCT	Per ASR	Per FSS	
	MARRAY (I,1)	MARRAY (I,3)	MARRAY (I,4)	MARRAY (I,5)	MARRAY (I,6)	MARRAY (I,7)	MARRAY (I,13)
1. ADCOC	127.0	0.0	0.0	0.0	0.0	0.0	0.09
2. AID	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3. ARSR	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. ARTCC	457.0	5.0	405.0	0.0	0.0	0.0	0.74
5. ARTS	211.0	0.0	0.0	0.0	30.0	0.0	0.14
6. ASR	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7. ATCT	52.0	0.0	0.0	27.0	0.0	0.0	0.51
8. BDIS	54.0	0.0	0.0	0.0	0.0	0.0	1.00
9. BUEC	26.0	0.0	0.0	0.0	0.0	0.0	1.00
10. CCC	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11. CD	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12. CDC	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13. CERAP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14. CKT	22.0	0.0	0.0	0.0	0.0	0.0	1.00
15. CMLT	30.0	0.0	0.0	0.0	0.0	0.0	1.00
16. COMCO	99.0	0.0	0.0	0.0	0.0	0.0	0.98
17. CST	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18. CTRB	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19. DCC	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20. DF	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21. EDPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22. FAC	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23. FDEP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24. FM	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25. FSS	63.0	0.0	0.0	0.0	0.0	63.0	0.81
26. GS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27. H	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28. HH	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29. IATSC	488.0	0.0	0.0	0.0	0.0	0.0	1.00
30. IFSR	98.0	0.0	0.0	0.0	0.0	0.0	1.00
31. IFSS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32. IFST	249.0	0.0	0.0	0.0	0.0	0.0	0.32
33. IM	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34. LCOT	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35. LDA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36. LMM	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37. LNKR	5.0	0.0	0.0	0.0	0.0	0.0	1.00
38. LOC	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39. LOM	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40. LRCO	23.0	0.0	0.0	0.0	23.0	0.0	1.00
41. MM	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42. OAW	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43. OM	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44. ORES	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45. PAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46. RAPCO	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47. RBDE	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48. RCAG	36.0	0.0	0.0	0.0	0.0	0.0	1.00
49. RCO	31.0	0.0	0.0	0.0	0.0	0.0	1.00
50. RMLR	32.0	0.0	0.0	0.0	0.0	0.0	1.00
51. RMLT	37.0	0.0	0.0	0.0	0.0	0.0	1.00
52. RTR	20.0	0.0	0.0	20.0	20.0	20.0	1.00
53. SFO	11.0	0.0	0.0	0.0	0.0	0.0	1.00
54. SSO	7.0	0.0	0.0	0.0	0.0	0.0	1.00
55. TELEX	100.0	0.0	0.0	0.0	0.0	0.0	1.00
56. TOWB	0.0	0.0	0.0	0.0	0.0	0.0	0.0
57. TRACO	45.0	0.0	0.0	0.0	0.0	0.0	0.21
58. TRCAB	49.0	0.0	0.0	0.0	0.0	0.0	0.17
59. TROPO	49.0	0.0	0.0	0.0	0.0	0.0	1.00
60. TTS	218.0	0.0	0.0	0.0	0.0	0.0	1.00
61. TTY	14.0	0.0	14.0	14.0	14.0	14.0	1.00
62. VOR	0.0	0.0	0.0	0.0	0.0	0.0	0.0
63. VOT	0.0	0.0	0.0	0.0	0.0	0.0	0.0
64. WMSC	259.0	0.0	0.0	0.0	0.0	0.0	1.00

Table 4-3. FACILITIES AND EQUIPMENT DATA BASE

Facility (I)	Cost Per Facility (In Thousands of Dollars)	Cost Increases (In Thousands of Dollars)					Percent of Communications	Number of Facilities
		Per Sector	Per Center	Per ATCT	Per ASR	Per FSS		
	FARRAY (I,1)	FARRAY (I,3)	FARRAY (I,4)	FARRAY (I,5)	FARRAY (I,6)	FARRAY (I,7)	FARRAY (I,13)	FARRAY (I,14)
1. ADCOC	0.0	0.0	0.0	0.0	0.0	0.0	1.00	11.0
2. AID	0.0	0.0	0.0	0.0	0.0	0.0	1.00	8.0
3. AMSR	3298.0	0.0	0.0	0.0	0.0	0.0	0.25	102.0
4. ARTCC	20599.0	100.0	0.0	0.0	0.0	0.0	0.60	23.0
5. ARTS	989.0	0.0	0.0	0.0	0.0	0.0	0.60	93.0
6. ASR	975.0	0.0	0.0	0.0	0.0	0.0	0.25	181.0
7. ATCT	620.0	0.0	0.0	0.0	0.0	0.0	0.85	428.0
8. BDIS	0.0	0.0	0.0	0.0	0.0	0.0	1.00	2.0
9. BUEC	80.0	0.0	0.0	0.0	0.0	0.0	1.00	204.0
10. CCC	11345.0	0.0	0.0	0.0	0.0	0.0	0.25	20.0
11. CD	201.0	0.0	0.0	0.0	0.0	0.0	1.00	107.0
12. CDC	0.0	0.0	0.0	0.0	0.0	0.0	0.80	15.0
13. CERAP	0.0	0.0	0.0	0.0	0.0	0.0	0.60	3.0
14. CKT	76.0	0.0	0.0	0.0	0.0	0.0	1.00	5.0
15. CMLT	70.0	0.0	0.0	0.0	0.0	0.0	1.00	13.0
16. COMCO	42.0	0.0	0.0	0.0	0.0	0.0	1.00	18.0
17. CST	1039.0	0.0	0.0	0.0	0.0	0.0	0.85	5.0
18. CTMB	1664.0	0.0	0.0	0.0	0.0	0.0	0.60	25.0
19. DCC	0.0	0.0	0.0	0.0	0.0	0.0	0.60	5.0
20. DF	54.0	0.0	0.0	0.0	0.0	0.0	1.00	205.0
21. EDPS	49372.0	0.0	0.0	0.0	0.0	0.0	0.25	1.0
22. FAC	22.0	0.0	0.0	0.0	0.0	0.0	0.03	21.0
23. FDEP	30.0	5.0	150.0	10.0	10.0	0.0	1.00	230.0
24. FM	18.0	0.0	0.0	0.0	0.0	0.0	0.25	36.0
25. FSS	116.0	0.0	0.0	0.0	0.0	0.0	0.85	318.0
26. GS	120.0	0.0	0.0	0.0	0 0	0.0	0.25	599.0
27. H	699.0	0.0	0.0	0.0	0.0	0.0	0.25	207.0
28. HH	130.0	0.0	00.0	0.0	0.0	0.0	0.25	9.0
29. IATSC	3403.0	0.0	0.0	0.0	0.0	0.0	1.00	1.0
30. IFSR	1203.0	0.0	0.0	0.0	0.0	0.0	1.00	6.0
31. IFSS	2405.0	0.0	0.0	0.0	0.0	0.0	1.00	6.0
32. IFST	794.0	0.0	0.0	0.0	0.0	0.0	0.25	9.0
33. IM	11.0	0.0	0.0	0.0	0.0	0.0	1.00	65.0
34. LCOT	50.0	0.0	0.0	0.0	0.0	0.0	1.00	84.0
35. LDA	17.0	0.0	0.0	0.0	0.0	0.0	0.25	10.0
36. LMM	28.0	0.0	0.0	0.0	0.0	0.0	0.25	18.0
37. LMKR	50.0	0.0	00.0	0.0	0.0	0.0	1.00	8.0
38. LOC	186.0	0.0	0.0	0.0	0.0	0.0	0.25	667.0
39. LOM	28.0	0.0	0.0	0.0	0.0	0.0	0.25	360.0
40. LRCO	18.0	0.0	0.0	0.0	0.0	0.0	1.00	0.0
41. MM	18.0	0.0	0.0	0.0	0.0	0.0	0.25	577.0
42. OAW	30.0	0.0	0.0	0.0	0.0	0.0	1.00	23.0
43. OM	18.0	0.0	0.0	0.0	0.0	0.0	0.25	612.0
44. ORES	241.0	00.0	0.0	0.0	0.0	0.0	1.00	1.0
45. PAR	1189.0	0.0	0.0	0.0	0.0	0.0	0.25	8.0
46. RAPCO	182.0	0.0	0.0	0.0	0.0	0.0	0.85	6.0
47. RBDE	151.0	0.0	00.0	0.0	0.0	0.0	0.25	101.0
48. RCAG	244.0	20.0	0.0	0.0	0.0	0.0	1.00	[illegible]
49. RCO	239.0	0.0	0.0	0.0	0.0	0.0	1.00	904.0
50. RMLR	166.0	0.0	0.0	0.0	0.0	0.0	1.00	518.0
51. RMLT	163.0	0.0	0.0	0.0	0.0	0.0	1.00	213.0
52. RTR	132.0	0.0	0.0	0.0	0.0	0.0	1.00	791.0
53. SFO	41.0	0.0	0.0	0.0	0.0	0.0	1.00	128.0
54. SSO	76.0	0.0	0.0	0.0	0.0	0.0	1.00	3.0
55. TELEX	151.0	0.0	0.0	0.0	0.0	0.0	1.00	5.0
56. TOMB	142.0	0.0	0.0	0.0	0.0	0.0	0.60	303.0
57. TRACO	999.0	0.0	0.0	0.0	0.0	0.0	0.60	40.0
58. TRCAB	749.0	0.0	0.0	0.0	0.0	0.0	0.60	36.0
59. TROPO	613.0	0.0	0.0	0.0	0.0	0.0	1.00	3.0
60. TTS	0.0	0.0	0.0	0.0	0.0	0.0	1.00	1.0
61. TTY	0.0	0.0	0.0	0.0	0.0	0.0	1.00	398.0
62. VOR	374.0	0.0	0.0	0.0	0.0	0.0	0.25	931.0
63. VOT	12.0	0.0	0.0	0.0	0.0	0.0	0.25	66.0
64. WMSC	7551.0	0.0	0.0	0.0	0.0	0.0	1.00	1.0

CHAPTER FIVE

SYMBOLS

All symbols, variables, and arrays appearing in the model equations (Chapter Three) and in the program listing (Section 4.3) are summarized and described in this section

Table 5-1 defines scalar variables; Table 5-2 is a summary of all subscripted variables used in the program listing and equation definition.

Tables 5-3 through 5-10 define the parameters used in each of the major arrays.

	Table 5-1. SCALAR QUANTITIES
APOGRO	Airport operations growth rate
APTIN	Total airport operations (if user input)
APTOPN	Total operations at airports forecast
AT	Transition factor F&E or O&M
AUTOAS	Terminal radar productivity factor
AUTOCN	Center productivity factor
AUTOFS	FSS productivity factor
AUTOSE	Sector productivity factor
AUTOTW	Tower productivity factor
AVNEW	New technology equipment in place
B	Local variable
CKTP	Circuit type
CKTS	Used to compute total circuits
CST	Average cost per mile per month
CT	Card type
CTFE	Literal "FE"
ENDIST	Used to compute local distribution requirements
ENDYR	Last year of analysis period
FENEW	F&E expenditures on new technology equipment
FEOLD	F&E expenditures on old technology equipment
FLTIN	Flight services in millions (if user input)
FLTSVC	Total flight services forecast
FRSTYR	Year transition will begin
FSVGRO	Flight services growth
FT	Facility type
GG	Local variable
I	Local variable
IFRGRO	IFR operating growth
IFRIN	IFR traffic volume (if user input)
IFRTFK	IFR traffic forecast
INDEX	Subscript for transition data
INOGRO	Instrument operations growth
INSIN	Instrument operations at airports (if user input)
INSTOP	Instrument operations at airport forecast
I1	Local variable

Table 5-1. (continued)	
J	Local variable
JJ	Local variable
K	Local variable
KK	Local variable
L	Local variable
LENGTH	Total length of circuits
LIFE	Equipment life
MODE	Transition mode
N	Local variable
NEWONM	O&M cost for new technology equipment
NSTAR	Indicates command continuation on second card
NTN	Number of transition parameters stored
OLDONM	O&M cost for old technology equipment
PERCOM	Percent communication
QQ	Local variable
RTCTR	Average length factor of center circuits
RTFSS	Average length factor of FSS circuits
RTTWR	Average length factor of tower circuits
RT2	Local variable
RT3	Local variable
RT4	Local variable
SECTOR	Number of radar sectors in 1978 if different from the default value of 740
STRTYR	First year of analysis period
SUM	Local variable
SVC	Average cost per month for termination of both circuit ends
TSUM	Local variable
TT	One-digit number representing a tariff schedule
U	Local variable
V	Percent or percent change during transition
W	Initially set to 0
Y	Local variable
YR	Current year
Y1	Array index for current year
Y2	Array index for previous year

Table 5-2. SUMMARY OF SUBSCRIPTED VARIABLES	
A	Percentage of transition applicable each year (up to 10)
ARRAY	Main program array of facility types and parameters (see Table 5-3)
CH	New value for special category
CKTARR	Circuit array
CKT1	Extension of CKTARR
CL	Category number to be changed (up to 14)
CNPV	Cumulative net present value
COL	Dummy array used for reading cards
COSTAR	Cost output array (see Table 5-4)
ELIFE	Equipment life
FARRAY	F&E parameter array (see Table 5-5)
FELBL	F&E label matrix
ICKT	Inflation rates applied to all leased costs including circuits
IDIS	Discounting factors
IFE	Inflation rates applied to all F&E costs
IOM	O&M inflation
MARRAY	O&M parameter array (see Table 5-6)
NAMARR	Name array contains translation for facility types
NPV	Net present value
OLDFAC	Old technology facilities required to meet demand
OMLBL	O&M label matrix
OPARR	Operational units array (see Table 5-7)
REP	Local array reads in reports to be generated
RPTYP	Selects one of eight types of report for output
SWARR	Switching array (see Table 5-8)
SWMAP	Switch map -- indicates circuit groups effected by switching
SWINDX	Subset of SWMAP
TNINDX	Average transition index
TNVALU	Average transition value
TOT	Total cost
TRFARR	Traffic tariff array (see Table 5-10)
UASGN	User assigned costs, by year
WGRATE	Wage rate

Table 5-3. ARRAY PARAMETERS*

ARRAY (I**,1)	Facility requirements in current year (quantity)
ARRAY (I,2)	Increase in number of facilities per additional sector (current year)
ARRAY (I,3)	Increase in number of facilities per additional center (current year)
ARRAY (I,4)	Increase in number of facilities per additional tower (current year)
ARRAY (I,5)	Increase in number of facilities per additional terminal radar (current year)
ARRAY (I,6)	Increase in number of facilities per additional FSS (current year)
ARRAY (I,7)	Facility requirements for previous year
ARRAY (I,8)	Increase in number of facilities per additional sector (previous year)
ARRAY (I,9)	Increase in number of facilities per additional center (previous year)
ARRAY (I,10)	Increase in number of facilities per additional tower (previous year)
ARRAY (I,11)	Increase in number of facilities per additional terminal radar (previous year)
ARRAY (I,12)	Increase in number of facilities per additional FSS (previous year)
ARRAY (I,13)	Transition year (last two digits). Set to 100 unless there is a transition
ARRAY (I,14)	Number of facilities in baseline system (1978)
ARRAY (I,15)	Number of facilities required in current year
ARRAY (I,16)	Number of facilities required in previous year
ARRAY (I,17)	Number of facilities required prior to transition
ARRAY (I,18)	Number of sectors prior to transition
ARRAY (I,19)	Number of centers prior to transition
ARRAY (I,20)	Number of towers prior to transition
ARRAY (I,21)	Number of terminal radars prior to transition
ARRAY (I,22)	Number of FSSs prior to transition
ARRAY (I,23)	Year of transition (set to 100 unless there is a transition

*This array provides for 95 facility types with 23 parameters for each facility type.
**I = facility type code, 1-95.

Table 5-4. COSTAR PARAMETERS*	
COSTAR (Y,1)	Total F&E cost with inflation
COSTAR (Y,2)	Total O&M cost with inflation
COSTAR (Y,3)	Total circuit cost with inflation
COSTAR (Y,4)	Total leased equipment cost with inflation
COSTAR (Y,5)	Grand total

*This array contains the cost outputs of the model for each analysis year.

Table 5-5. FARRAY PARAMETERS*	
FARRAY (I**,1)	Total cost of an old facility
FARRAY (I,2)	Total cost of a new facility
FARRAY (I,3)	Old facility cost increase per sector
FARRAY (I,4)	Old facility cost increase per center
FARRAY (I,5)	Old facility cost increase per tower
FARRAY (I,6)	Old facility cost increase per terminal radar
FARRAY (I,7)	Old facility cost increase per FSS
FARRAY (I,8)	New facility cost increase per sector
FARRAY (I,9)	New facility cost increase per center
FARRAY (I,10)	New facility cost increase per tower
FARRAY (I,11)	New facility cost increase per terminal radar
FARRAY (I,12)	New facility cost increase per FSS
FARRAY (I,13)	Percent of cost due to communications
FARRAY (I,14)	Total number of facilities

*FARRAY lists all of the F&E parameters used in the model.
**I = facility type code, 1-95.

Table 5-6. MARRAY PARAMETERS*	
MARRAY (I**,1)	Maintenance cost of old facility
MARRAY (I,2)	Maintenance cost of new facility
MARRAY (I,3)	Old maintenance cost increase per sector
MARRAY (I,4)	Old maintenance cost increase per center
MARRAY (I,5)	Old maintenance cost increase per tower
MARRAY (I,6)	Old maintenance cost increase per terminal radar
MARRAY (I,7)	Old maintenance cost increase per FSS
MARRAY (I,8)	New maintenance cost increase per sector
MARRAY (I,9)	New maintenance cost increase per center
MARRAY (I,10)	New maintenance cost increase per tower
MARRAY (I,11)	New maintenance cost increase per terminal radar
MARRAY (I,12)	New maintenance cost increase per FSS
MARRAY (I,13)	Percent of cost due to communications

*This array gives all of the O&M parameters used in the model.
**I = facility type code, 1-95.

Table 5-7. OPARR PARAMETERS

Type of Units	Number of Units in Baseline System (1978)	Number of Units Required in Current Year	Number of Units Required in Previous Year
Sectors	OPARR (1,1)	OPARR (1,2)	OPARR (1,3)
Centers	OPARR (2,1)	OPARR (2,2)	OPARR (2,3)
Towers	OPARR (3,1)	OPARR (3,2)	OPARR (3,3)
Terminal Radars	OPARR (4,1)	OPARR (4,2)	OPARR (4,3)
FSSs	OPARR (5,1)	OPARR (5,2)	OPARR (5,3)

Table 5-8. SWARR PARAMETERS

Rows

SWARR (J,1)	Zero if circuit is not switched, one otherwise
SWARR (J,2)	Tariff used to price this circuit
SWARR (J,3)	Average circuit length
SWARR (J,4)	Average number of circuits required per facility
SWARR (J,5)	Total length
SWARR (J,6)	Total quantity required
SWARR (J,7)	Busy hour average utilization per circuit
SWARR (J,8)	Total utilization of all circuits
SWARR (J,9)	Equipment cost per circuit
SWARR (J,10)	Required grade of service

Columns

Circuit Group 1 Circuits According to Type	Circuit Group 2 Circuits According to Type (Emphasis on Voice, Data)
1. Miscellaneous voice circuits	1. FSS-to-tower voice circuits
2. FSS-to-tower voice circuits	2. FSS-to-center voice circuits
3. FSS-to-center voice circuits	3. Tower-to-center voice circuits
4. Tower-to-center voice circuits	4. Center-to-center voice circuits
5. Center-to-center voice circuits	5. FSS-to-public voice circuits
6. FSS-to-public voice circuits	6. FSS-to-FSS voice circuits
7. Misscellaneous data circuits	7. Tower-to-tower voice circuits
8. FSS-to-tower data circuits	8. Miscellaneous voice circuits
9. FSS-to-center data circuits	9. FSS-to-center low-speed data circuits
10. Tower-to-center data circuits	10. Miscellaneous low-speed data circuits
11. Center-to-center data circuits	11. Tower-to-center FDEP circuits
12. Miscellaneous radio circuits	12. Tower-to-center ARTS circuits
13. RCAG radio circuits	13. Center-to-center high-speed data circuits
14. FSS radio circuits	14. Miscellaneous high-speed data circuits
15. Tower radio circuits	15. WMSC circuits
16. BUEC radio circuits	16. RCAG radio circuits
17. Miscellaneous circuits	17. FSS radio circuits
	18. Tower radio circuits
	19. BUEC radio circuits
	20. Miscellaneous radio circuits
	21. Other circuits

Circuit Group 3 Circuits According to Terminating Facilities	Circuit Group 4 Circuits According to Function or Use
1. Tower-to-tower circuits	1. Military-to-FSS circuits
2. Tower-to-FSS circuits	2. Military-to-tower circuits
3. Tower-to-center circuits	3. Military-to-center circuits
4. Tower-to-military circuits	4. Autovon circuits
5. Tower-to-VOR circuits	5. Miscellaneous military circuits
6. Tower-to-Foreign exchange	6. ILS circuits
7. Tower-to-RCO circuits	7. VORTAC circuits
8. Tower-to-ILS circuits	8. DF circuits
9. Tower-to-weather circuits	9. Tower-to-center circuits
10. Miscellaneous tower circuits	10. FSS-to-center circuits
11. Center-to-center circuits	11. FSS-to-tower circuits
12. Center-to-FSS circuits	12. Center-to-RCAG circuits
13. Center-to-military circuits	13. Tower-to-RTR circuits
14. Center-to-RCAG circuits	14. Center-to-BUEC circuits
15. Center-to-BUEC circuits	15. FSS-to-RCO circuits
16. Center-to-ARSR circuits	16. Foreign exchange circuits
17. Center-to-RTR circuits	17. Miscellaneous communications circuits
18. Center foreign exchange	18. Special circuits
19. Center miscellaneous circuits	19. Weather circuits
20. FSS-to-FSS circuits	20. ARSR circuits
21. FSS-to-military circuits	21. Other circuits
22. FSS-to-VOR circuits	
23. FSS foreign exchange circuits	
24. FSS-to-RCO circuits	
25. FSS-to-RTR circuits	
26. FSS-to-weather circuits	
27. Miscellaneous FSS circuits	
28. Special circuits	
29. Other circuits	

Table 5-9. TNSARR FUNCTION PARAMETERS
TNSARR (I,J,K,L) (as a percent, $0 \le$ TNSARR ≤ 1) I = Facility type code, 1-95. J = Flag to indicate whether percentages are applicable to F&E or O&M costs. $J_{FE} = 1$ $J_{OM} = 2$ K = Flag to indicate whether percentages apply to old or new equipment. $K_{Old} = 1$ $K_{New} = 2$ L = Year (1-30). This index represents the years 1979 through 1999.

Table 5-10. TRFARR PARAMETERS
TRFARR (i,j) i = tariff type j = 1 represents the mileage charge in ¢/mi/month j = 2 represents the charge in ¢/month

APPENDIX A

UPDATING THE COMMUNICATIONS COST MODEL

The Communications Cost Model must be continually updated as new data become available to maintain its timeliness. Table A-1 indicates specific arrays to be updated and their location in the program listing.

Table A-1. PROGRAM UPDATE PROCEDURE	
Type of New Data	Modify Lines
Facility Data	
F&E cost per facility	29-1 to 29-7
F&E communications percentage	29-7 to 29-C
Number of facilities	29-C to 29-H
F&E Interfacility Cost Increases	30 to 31
O&M cost per facility	32 to 41
O&M interfacility cost increases	41 to 46
O&M communications percentage	47 to 56
Interfacility increase in number of facilities	57 to 63
Facility identifier	71-1 to 71-B
Circuit Data	
Switch indicator, all circuit group	68-1
Tariff indicator, circuit groups 1,2,3	68-1
Tariff indicator, circuit group 4	68-1 to 68-2
Average circuit length, circuit group 1	68-2
Average circuit length, circuit group 2	68-3 to 68-5
Average circuit length, circuit group 3	68-5 to 68-8
Average circuit length, circuit group 4	68-8 to 68-A
Average circuits per facility, group 1	68-A to 68-B
Average circuits per facility, group 2	68-B to 68-D
Average circuits per facility, group 3	68-D to 68-F
Average circuits per facility, group 4	68-F to 68-H
Utilization per circuit, group 1	69-1 to 69-2
Utilization per circuit, group 2	69-2 to 69-3
Utilization per circuit, group 3	69-3 to 69-5
Utilization per circuit, group 4	69-5 to 69-6
Equipment cost per circuit, group 1	69-6 to 69-8
Equipment cost per circuit, group 2	69-8 to 69-A
Equipment cost per circuit, group 3	69-A to 69-D
Equipment cost per circuit, group 4	69-D to 69-F
Required grade of service, all group	69-G
Tariff Data	74 to 75
Model Equations	
IFR traffic	327 to 330
Sectors	332 to 333
Center	334 to 335
Airport operations	336 to 339
Towers	340 to 341
Instrument operations	342 to 345
Radars (ASR)	346 to 347
Flight services	348 to 351
Circuit group 1	470 to 503
Circuit group 2	505 to 548
Circuit group 3	550 to 609
Circuit group 4	611 to 653

APPENDIX B

FACILITY ALPHA CODES AND DESCRIPTIONS

Table B-1 contains the alpha codes and descriptions.

Table B-1. FACILITY ALPHA CODES AND DESCRIPTIONS	
Alpha Code	Description
ADCOC	Air Defense Command Operation Control
AID	Airport Information Desk
ARSR	Air Route Surveillance Radar -- FAA and Military
ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Terminal System
ASR	Airport Surveillance Radar -- FAA and Military
ATCT	Airport Traffic Control Tower
BDIS	Automatic Data Interchange System, Service "B"
BRITE	Bright Radar Indicator Terminal Equipment
BUEC	Backup Emergency Communications
CCC	Central Computer Complex -- IBM 9020 System
CD	Common Digitizer
CDC	Computer Display Channel
CERAP	Combined Center/RAPCO
CKT	Control Circuit Equipment
CMLT	Communications Microwave Link Terminal
COMCO	Command Communications Outlet
CST	Combined Station/Tower
CTRB	Center Building Maintenance
DCC	Display Channel Complex
EDPS	Electronic Data Processing System
FDEP	Flight Data Entry and Printout
FSS	Flight Service Station
GS	Glide Slope
H	Homing Radio Beacon
HH	Homing Radio Beacon -- High Power
IATSC	International Aeronautical Telecommunications Switching Center
IFSR	International Flight Service Receiving Station
IFSS	International Flight Service Station
IFST	International Flight Service Transmitter Station
IM	Inner Marker

(continued)

Table B-1. (continued)

Alpha Code	Description
LCOT	VHF/UHF Link Terminal
LDA	Localizer-Type Directional Aid
LMM	Compass Locator at the ILS Middle Marker
LNKR	Link Repeater
LOC	ILS Localizer
LOM	Compass Locator at the ILS Outer Marker
LRCO	Limited Remote Communication Outlet
MM	Middle Marker
OAW	Off-Airways Weather Station
OM	Outer Marker
ORES	IFSS Residual Facility
PAR	Precision Approach Radar -- FAA and Military
RBDE	Radar Bright Display Equipment
RCAG	Remote Center Air/Ground Communications Facility
RCO	Remote Communications Outlet
RMLR	Radar Microwave Link Repeater
RMLT	Radar Microwave Link Terminal
RTR	Remote Transmitter/Receiver Facility
SFO	Single Frequency Outlet
SSO	Self-Sustained Outlet
TELEX	Telephone Exchange
TOWB	Tower Building Maintenance
TRACO	Terminal Radar Approach Control
TRCAB	Terminal Radar Approach Control in Tower Cab
TROPO	Tropospheric Scatter Station
TTS	Teletype Switching Facilities
TTY	Teletypewriter Station
VOR	VHF Omnidirectional Range
VOT	VHF Omnidirectional Range Test
WMSC	Weather Message Switching Center

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