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THE AIRPORT PERFORMANCE MODEL

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16. Abstract

This report describes the development of a model and companion data base for evaluating levels and qualities of service provided to the public by Air Carrier Airports. The model is designed to translate changes in airport capabilities into public service via data describing the characteristics of demand at individual airports. The model is sensitive to airport saturation capacities, aircraft mix, time distribution of demand, airport weather, and data describing passenger movements such as load factor, through passenger, and transfer passenger descriptions.

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PREFACE

As part of the FAA's program to rationalize its investment decisions, the Transportation Systems Center (TSC) has examined the relationships between airport investments and the level of service provided to the public by the National System of Airports. This report documents the preliminary design of one of two models developed to translate airport capabilities and characteristics into levels of public service. The "Airport Performance Model" translates the impact of capability enhancements at individual airports into the level and quality of service delivered to the public. A companion report, The Airport Network Flow Simulator,* describes a model that projects the impacts of investments made at individual airports on the performance of the airport system as a whole.

Both models were developed under the sponsorship of the Federal Aviation Administration's Office of Aviation System Plans. In addition to the help provided by John Kal of the Planning Assistance Branch and by many people within the FAA, TSC would like to acknowledge the assistance of the FAA Air Traffic Control Tower personnel at Boston's Logan International Airport.

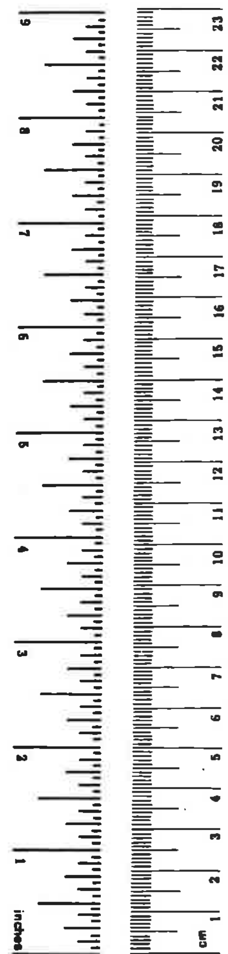
The bulk of the programming of the Airport Performance Model was done by John F. Dolan of Kentron Hawaii, Ltd. Other contributors to the project were Rita Folan, David Spiller, and Barbara Kolodjiez. The overall project was carried out under Dr. William J. Duffy in the Research Division of the Office of Systems Research and Analysis at the Transportation Systems Center.

*Steven Gordon, The Airport Network Flow Simulator, Federal Aviation Adminstration, Washington DC, FAA-ASP-75-6, May 1976.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

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



Approximate Conversions from Metric Measures

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

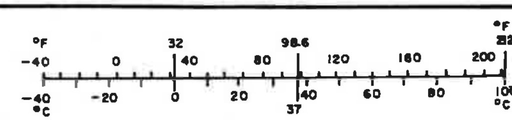


TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF ILLUSTRATIONS

LIST OF TABLES

1. INTRODUCTION

The Airport and Airway Development Act of 1970 (PL 91-258), as amended, authorizes a total $1.15 billion for development of the nation's air carrier airports. Both the duration and funding of this act are likely to be extended in the near future. In addition to these funds, a substantial portion of the more than $250 million allocated annually to Facility and Equipment (F&E) expenditures is devoted to airport investments. These funds are used for a spectrum of investments, ranging from land acquisition and paving to electronic approach aids. The magnitude of these funds, the importance of the nation's air transportation system, and the multitude of possible airport/investment combinations have led the FAA to strengthen its investment-decision process.

These decisions are difficult to make because they depend on complex technical knowledge and on ethical values. The required technical knowledge, such as the increase in annual passengers and the decrease in annual delay a new runway might produce at a specific airport, depends on a host of demand, operational, and environmental conditions unique to each airport. The ethical values must be used to judge competing, equally valid claims from adversary groups. This report addresses only the need for technical information — the need to assess the effects of a variety of investments at many different airports.

1.1 EFFECTS OF AN INVESTMENT

In order to determine the effects of an investment, it is necessary to state what types of effects are considered relevant. The effects are usually divided into costs and benefits.

This report will not deal with the cost of investments. The benefits of an airport investment are usually considered to fall into four main categories. First, an investment might reduce the delay incurred by aircraft and passengers. An aircraft might be delayed in landing or taking off because of runway congestion; an arriving aircraft might be delayed in docking because all gates are taken. Aircraft delay is wasteful since it runs up fuel and crew costs; passenger delay is undesirable since it keeps passengers from more preferred activities. A decision-maker should therefore know how much an investment (or a change in operating policies) will affect annual aircraft and passenger delay.

Second, an investment might reduce the amount of time that passengers are forced to use congested groundside facilities. Facilities subject to congestion include parking areas, curb space, ticket counters, waiting areas, baggage claim areas, and restrooms. Sometimes a congested facility will result in delay; e.g., a passenger is delayed while trying to reclaim his baggage in the middle of a throng. But often facility congestion results not in delay, but in discomfort and inconvenience; e.g., overcrowded departure lounges increase passenger discomfort without necessarily causing delay. Thus, a second consideration is the extent to which an investment in a groundside facility will affect annual congestion at that facility.

Third, an investment might increase the volume of serviceable demand that an airport can handle. The term "serviceable demand" needs to be carefully defined. For most airports, traffic is exceedingly light between 1:00 a.m. and 7:00 a.m. Therefore, the volume of passengers handled could easily be increased by 25% at any airport with no additional investments if the passengers would travel in the middle of the night. But the fact is that few passengers are willing to do this; if passenger volume is to increase by 25%, that increase will largely fall in the hours that are already busy. Passengers demand flights at certain popular hours and on certain popular days, and this must be recognized as an effective constraint when determining how many passengers an airport can serve. An airport's serviceable demand is defined to be the largest number of passengers (or operations) that it can serve in a year, subject to the constraints that the demand is spread across days and throughout each day in a realistic way and that the estimated delay per passenger not exceed some specified figure.

Fourth, an investment might affect the safety of a flight. This is an obvious and important effect of many airport investments. This report will not attempt to quantify the relationship between investments and safety. Safety is a difficult variable to measure; detailed, intensive studies are necessary in order to determine the effect of an investment upon safety. That this report omits further references to safety should not be interpreted as meaning that safety is unimportant or that investments do not affect safety.

1.2 PURPOSE

The purpose of this ongoing research effort is to provide a computer based model and data base that can be used to generate information about the effect of an airport investment on delay, congested facilities, and serviceable demand for air carrier airports. The model is named the Airport Performance Model since it predicts how well an airport will perform under different situations. The model has been constructed to provide the information that is most critical for decision-making. Marginal improvements in aircraft delay, passenger delay, groundside facility congestion, and annual serviceable demand can be projected as a function of changes in an airport's capabilities. Given this information, the planner can distinguish between efficient and inefficient investments. To facilite use by analysts, the model has been supplied in an easy-to-use, interactive computer package. The text of this report explains the main ideas behind the model; the details of the mathematics and the computer program are spelled out in the appendixes.

1.3 CAVEATS

A warning about this report is necessary. The main purpose of the FY75 effort has been to get the Airport Performance Model on the computer and running. The rationale for this was that it was better to have an imperfect model working by the end of FY75 rather than a finely-tuned model only half completed.

This strategy has led to three types of compromises. First, although the mathematical models and the computer programs are completed and apply to all airports, the data base contains data only for Logan Airport in Boston.

Second, some simplifying assumptions have been made about airports and demand. These assumptions will be spelled out in the course of the report and presented in Section 4.1.

Third, the model has not been validated; that is, the predictions made by the model have not been checked against actual operations to test the accuracy of the model. Therefore, it should be stressed that at this time one should not have blind confidence in the information generated by the model.

1.4 ORGANIZATION OF THIS REPORT

Section 2 describes the Airport Performance Model. This section presents the concept of an airport processing rate, tells how the model treats demand for airport services, and explains how the model calculates delay, facility congestion and serviceable demand. A discussion is presented relating how the user can utilize the interactive capability of the computer package to model the specific problem he is interested in. Section 3 describes the model inputs and outputs, and the manner in which these can be used to analyze varying alternatives. Section 4 discusses potential theoretical improvements that can be made to the model, potential ways of improving the data base, and additional phenomena that the model can be expanded to cover. The appendixes provide the technical details of the model.

2. DESCRIPTION OF THE AIRPORT PERFORMANCE MODEL

The label "Airport Performance Model" is given to the method used to estimate how much airside delay and groundside congestion occurs at an airport for specified investments, demand, and operating policies.

2.1 OVERVIEW

2.1.1 Outline of Airport Activity

Figure 2-1 is a schematic diagram of airport activity as envisioned by the Airport Performance Model. Starting with the groundside system, it includes the terminal and access facilities. Originating passengers, perhaps accompanied by well-wishers, arrive and are processed through the groundside system; i.e., they park, are ticketed, check their bags, and wait for boarding. The passengers enter the airside system when they board the aircraft. The aircraft takes off, perhaps after being delayed by congestion, and at that point leaves the system. Arriving aircraft enter the terminal airspace and, perhaps after being delayed by congestion, land and taxi to the gate. Some, and perhaps all, of the passengers deplane and are processed through the groundside complex. Some of the deplaning passengers are transfer passengers that trek to their next flight. Others are terminating passengers that get their bags and leave, perhaps accompanied by greeters. This is the flow of aircraft and people modeled in the Airport Performance Model.

2.1.2 Inputs and Outputs of the Airport Performance Model

There are four classes of inputs to the model. First, there are airport characteristics: the capability of the airside system to handle aircraft is summarized in a processing rate; the groundside complex is characterized by the dimensions of its facilities (e.g., parking lots, curbspace, ticket counters, etc.). Second, there are demand characteristics that state the volume of activity at the airport and the temporal peaking characteristics

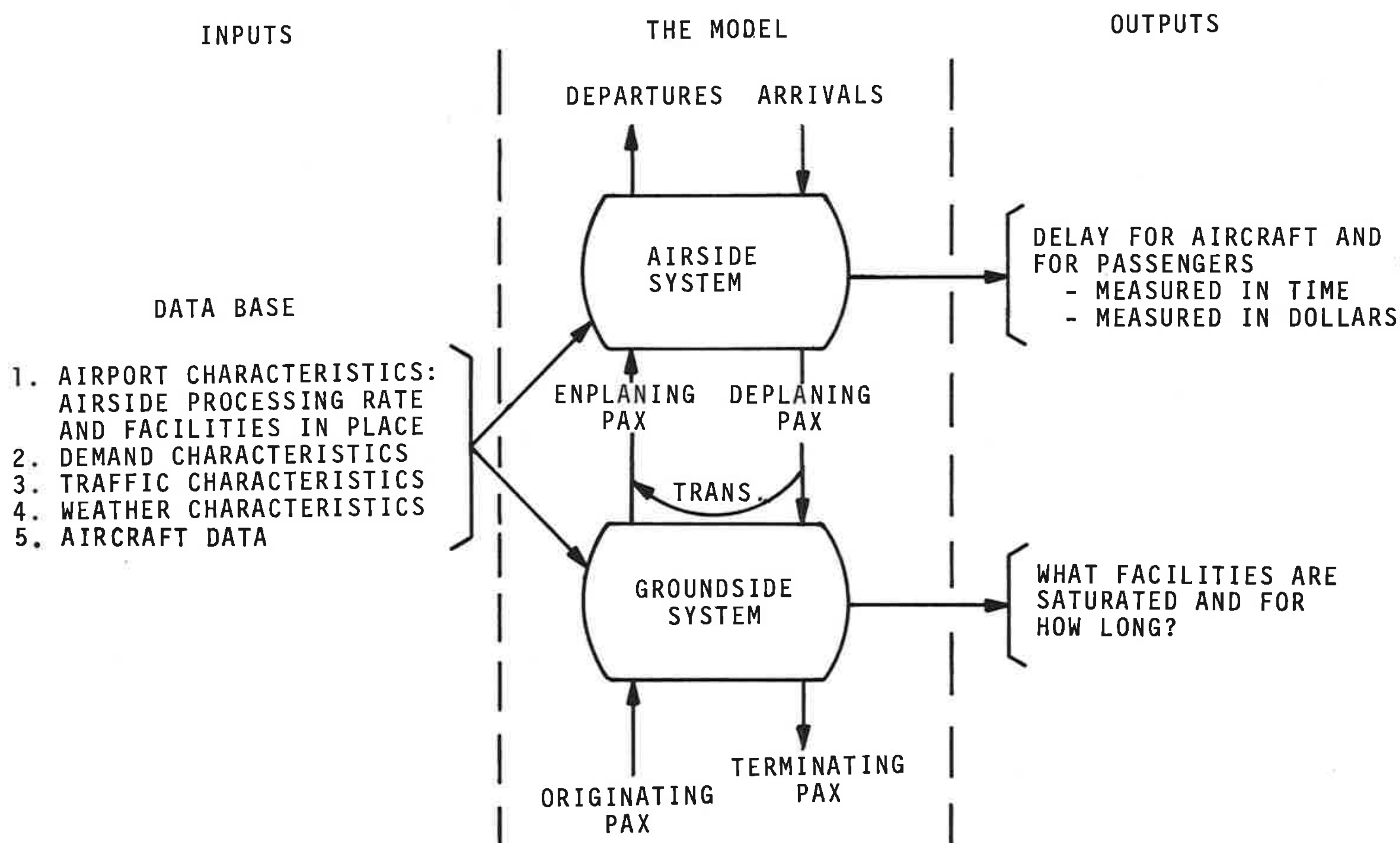


Figure 2-1. Overview of the Airport Performance Model

of that activity. Third, there are hourly traffic characteristics, such as the mix of aircraft types that use the airport (and the number of seats on each aircraft), the arrival-departure ratio, and the average load factor. Fourth, there are weather characteristics that describe the frequency and average duration of problem weather conditions.

The computer program listed in the appendixes uses these inputs to calculate two different types of outputs. First, delay for both aircraft and passengers is calculated in terms of both time and money. (To determine serviceable demand, delay is fixed at a constant, and the largest demand consistent with that delay is found.) Second, the amount of time that each groundside facility is congested is calculated.

2.1.3 Airport Performance Data Base

The input data described above constitue a substantial amount of information that must be developed for each airport to be analyzed by the model. The breadth and depth of this information permit the assessment of airport investments to be based on accurate and complete representation of the environment in which the investment will reside. The amount of this data and the difficulty in obtaining certain segments of it, however, also dictate the need for an ancillary data base that can maintain the information and provide it as input to the model with little or no assistance from the analyst. This extensive information base is one of the key features of the Airport Performance Model.

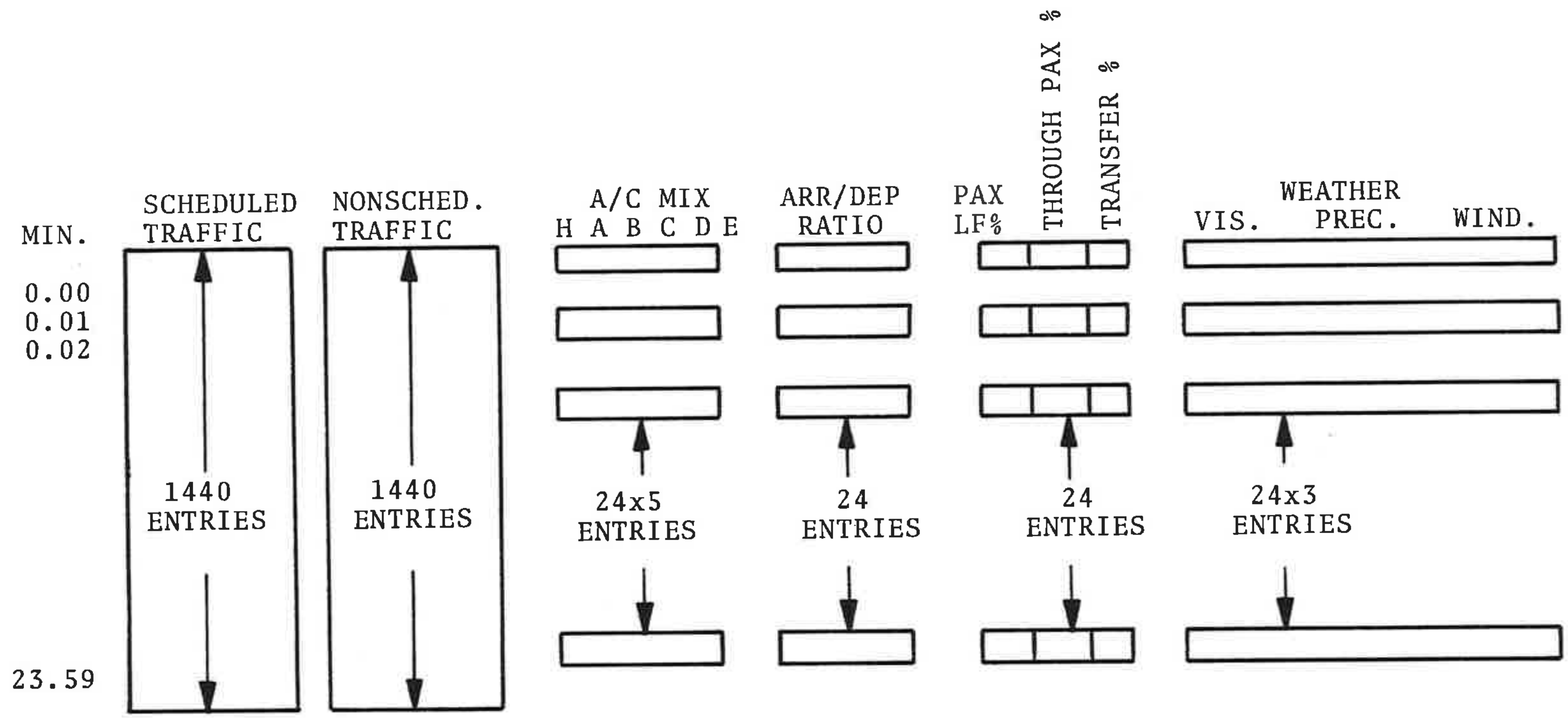
The information in the data base can be divided into airport-specific information and aircraft-specific information. For each airport, the data base contains two types of information — a single file describing the airport's capabilities, and a series of files containing the time-dependent information for a representative set of 24-hour demand periods. Table 2-1 shows the static airport characteristics file stored in the data base for each airport; Table 2-2 shows the contents of the time-dependent information files stored for each airport — the demand, traffic, and weather characteristics. Table 2-3 shows the characteristics stored in the

TABLE 2-1. AIRPORT DATA BASE — AIRPORT: BOS — CAPABILITY FILE

VISIBILITY	MAXIMUM PROCESSING RATE	NOMINAL MIX H	A	B	C	DE
GOOD	120 OPS/HR	.15	.10	.59	.10	.06
BAD	65 OPS/HR	.15	.10	.59	.10	.06

GROUNDSIDE FACILITY	DIMENSION	UNITS
ACCESS HIGHWAY	4	LANES
CIRCULATION ROADWAY	2	LANES
ARRIVAL CURB SPACE	300	FEET
DEPARTURE CURB SPACE	300	FEET
SHORT-TERM PARKING	150	SPACES
LONG-TERM PARKING	8,000	SPACES
TICKET LOBBY AREA	600	SQ. FT
PASSENGER SERVICE COUNTER	60	FEET
AIRLINE OPERATIONS SPACE	17,000	SQ. FT
BAGGAGE CLAIM AREA	10,000	SQ. FT
WAITING AREA	40,000	SQ. FT
WAITING AREA	1,000	SEATS
MEN'S REST ROOMS	60	FIXTURES
WOMEN'S REST ROOMS	60	FIXTURES

TABLE 2-2. AIRPORT DATA BASE — AIRPORT: BOS — TEMPORAL DATA FOR DAY 126



Scheduled Traffic Array:	From OAG
Nonsched. Traffic Array:	From tower daily traffic counts, FAA Form 7230-1; tower hourly traffic counts
Aircraft Mix:	Aircraft Type from OAG for Sched., assumed D&E for nonsched., classification from original AIL modeling study
Arrival/Departure Ratio:	OAG
Average PAX LF:	Congressional Airport Congestion Study
Weather:	National Weather Service (currently only visibility)

TABLE 2-3. AIRCRAFT DATA BASE

ITEM	CLASS				
	H	A	B	C	D+E
Aircraft Types	747, DC10, L1011, DC8S, 707F	707, DC8, 720, 88D, V10, CUL, Y62	727, 72S 737, 73S DC9,D9S, B11, F28, etc.	LJT, B18 B99, DC3, DTO, F27, etc.	A50, BTP, PAZ, PNV, TC4, BNI, CES, etc.
Average Available Seats	255	130	95	30	9
Average Airborne Costs/Min	$26.00	$16.33	$12.33	$4.17	$2.50
Average Ground Costs/Min	$22.08	$14.17	$10.08	$3.33	$2.08
Average Airborne Emissions/Min.	NA	NA	NA	NA	NA
Average Ground Emissions/Min.	NA	NA	NA	NA	NA

NA: Data not available at this time.

Source: Individual aircraft data from F. D'Alessandro et al., Airport Surface Traffic Concept Formulation Study, Computer Sciences Corp., Paramus NJ, Feb. 1975, CSC-TR-75-4421 and Aircraft Operating Cost and Performance Report, Civil Aeronautics Board, Bureau of Accounts and Statistics, Washington DC, June 1974. Class averages are weighted mean values based on aircraft utilization counts from the OAG.

data base for each class of aircraft (see Section 2.2.3 for a definition of the aircraft classes).

This data base is logically separate from the Airport Performance Model. The analyst may use the information stored in the data base to perform a baseline analysis for an airport, or he may specify alternate values for any of these data to perform a comparative analysis. The ability to selectively alter data from the data base before the input data set is passed to the model is discussed in Section 3.

The data from the data base are passed to different components of the model (referred to as modules) at different times during the model's execution. The source, derivation, and the use of the various data elements will be explained in the sections that describe the modules in which the data is used; it should be stressed, however, that all required information discussed in any of the later sections will be contained in the data base.

2.1.4 Logic of the Model

While Figure 2-1 exhibits the activities covered by the Airport Performance Model, it does not expose the logic on which the model rests. The logical flow of the model is sketched in Figure 2-2.

The model is broken down into four separate components or modules. Each of the next four sections will explain one module. The Airside Processing Rate Module takes as input a good weather and a bad weather processing rate (saturation capacity); it then calculates all relevant processing rates. The Activity Demand Module takes as input the number of daily operations and also information about weather, mix, and the arrival-departure pattern at the airport in question. It produces two outputs: (1) A minute-by-minute demand profile (i.e., a statement of how many aircraft request service during each minute of the day being studied) and (2) the weather, mix, and arrival-departure ratios for each hour. These first two modules provide the raw material used by the next two modules to calculate the statistics of interest.

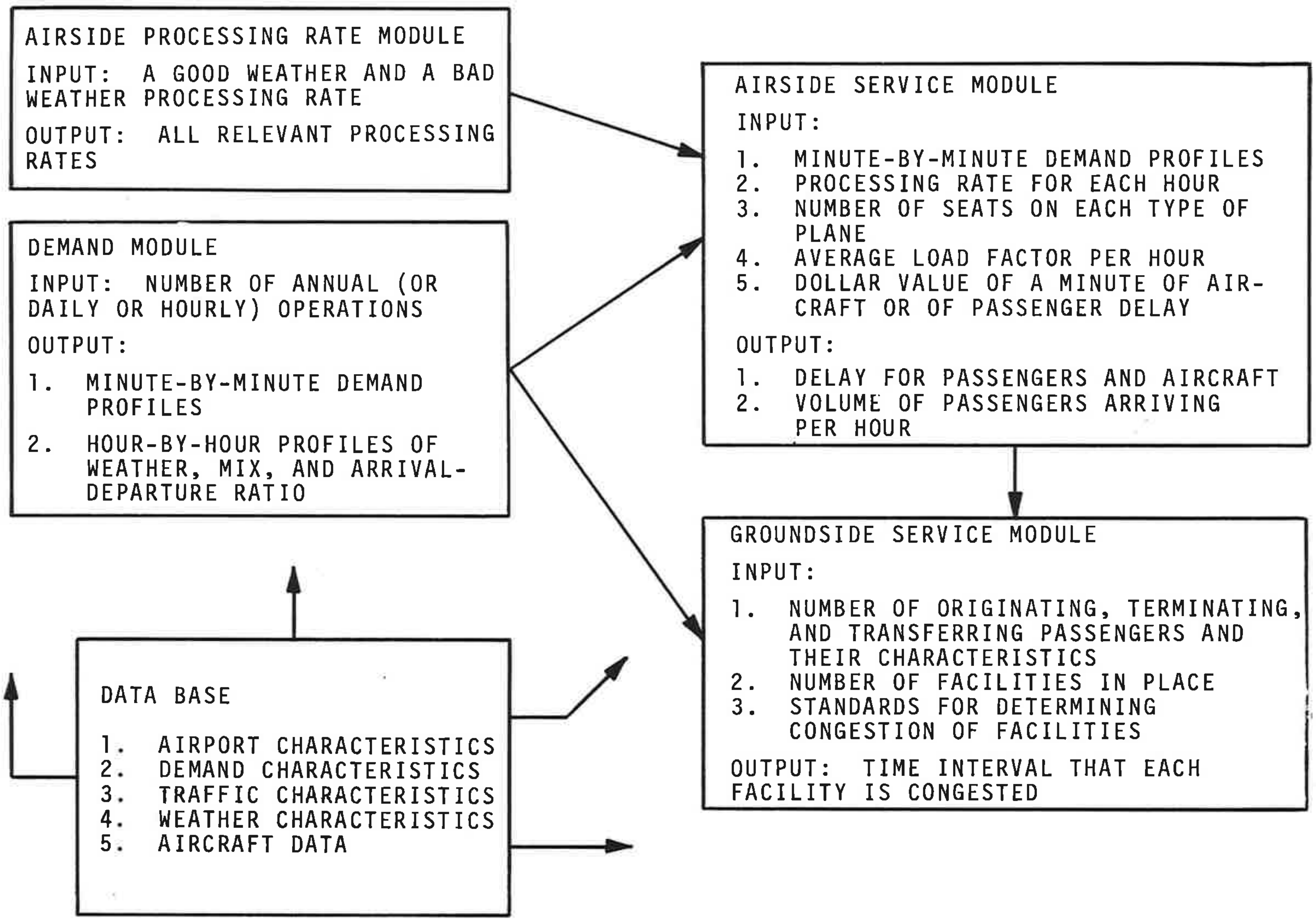


Figure 2-2. Logic of the Airport Performance Model

The Airside Service Module's first two inputs are (1) the minute-by-minute demand profiles, and (2) the processing rate for each hour (which is obtained by applying the Airside Processing Rate Module to the hourly information on weather, mix, and arrival-departure ratio). These inputs are sufficient to calculate the output of aircraft delay measured in time. Further inputs for the number of seats on each type of aircraft and the average load factor allow calculation of two more outputs: (1) passenger delay measured in time and (2) the volume of passengers that arrive in each hour (which is passed to the Groundside Service Module). Further inputs of dollar values per minute of aircraft and passenger delay allow calculation of the output of total dollar value of delay.

The Groundside Service Module has as inputs the number of originating, terminating, and transferring passengers and their characteristics, the groundside facilities that exist, and the standards used to determine when facilities are congested. The output is the time intervals during which each facility is congested.

The model is constructed to simulate an airport's activity for independent 24 hour periods. However, the model also has the ability to simulate a year's airport performance by modeling activity for an appropriate series of 24-hour periods. For a (user or default) specified value of annual demand, the demand module can distribute annual activity over individual days (based on historical data in the data base) and construct an appropriate series of 24-hour activity schedules (based on the information files represented in Table 2-2). The annual results are then computed from the selected 24-hour results (see Sections 2.4.3 and 2.4.4).

2.2 AIRSIDE PROCESSING RATE MODULE

2.2.1 Airside System

A distinction can be drawn between the airside system and the groundside system. The airside system consists of the airspace governed by approach and departure controllers, runways, runway exits, taxiways, and apron areas. The groundside system consists of waiting rooms and other terminal facilities, curb space, parking areas, and the access roads to the airport. The Airside Processing Rate Module deals only with a portion of the airside system; taxiways and gates are not modeled.

When aircraft are "processed through" the airside system, the following conventions are observed:

1. An arrival is in the system from the time it is handed off to the approach controller until it is off the runway. (If handoff to the approach controller is delayed by congestion, the aircraft is considered to be in the system at the time it would have been handed off had there been no congestion.)

2. A departure is in the system from the time of pushback (i.e., when the aircraft pulls away from the gate) until it is handed off to the departure controller. (If pushback is delayed by congestion, the aircraft is considered to be in the system at the time it would have pushed back had there been no congestion.)

An aircraft is said to "request service" when it enters the system and it is said to be "processed" when it leaves the system. This terminology is not only suggestive, but it allows us to speak simultaneously of both arrivals and departures.

2.2.2 Airside Processing Rate

Suppose that the airside system is saturated; that is, there are arrivals circling and ready to land and departures queued up and ready to take off. In this case the speed with which the airside system processes aircraft is not constrained by demand but by the capabilities of the airside system. We define the airside processing rate to be the number of aircraft that the airside system can process in an hour when the system is saturated. The maximum processing rate is equivalent to the "saturation capacity" used in queuing theory. The maximum processing rate, like the saturation capacity, is not a fixed number for any runway subsystem but a function of the existing weather conditions, the characteristics of the aircraft demanding service — including the type of aircraft and the relative number of arrivals and departures — and a host of intangible factors. Thus, an airport will have many maximum processing rates, each being the maximum number of aircraft that can be processed in an hour when the controllers are working normally and steadily under a specified set of conditions. For example, O'Hare airport in Chicago is considered to have a processing rate in good weather of 158 operations per hour. Logan Airport in Boston has a good weather processing rate of 120 operations per hour. The adjective "airside," which was employed to emphasize that the processing rate applied only to the airside system, will now be replaced by the term "processing rate."

(Note: It is sometimes convenient to divide the hourly processing rate by 60 to get a processing rate expressed in terms of operations per minute, which is then inverted to obtain a processing interval in terms of minutes per operation. It will always be made clear which is being used.)

2.2.3 Variables Affecting the Airside Processing Rate

We assume that the processing rate is a function of four variables:

1. weather
2. mix of aircraft types
3. arrival-departure ratio
4. light-heavy separation standards.

First, the processing rate depends on the weather. During bad weather, the processing rate typically drops for two reasons. First, runways that are not equipped with the appropriate electronic gear (e.g., ILS, ADF, NDB) cannot be used. Second, even for runways that are used, the aircraft are spaced further apart. We have made the simplifying assumption in the current model version that the weather takes on only two values — VFR and IFR. VFR weather is defined to be weather in which the visibility is at least 3 miles and the ceiling is at least 1200 feet.

Second, the processing rate depends on the mix of aircraft types. That is, the processing rate depends on the proportion of the aircraft requesting service that are heavy jets, large jets, medium jets and large props, etc. The processing rate is higher for smaller or slower aircraft because:

1. They have a smaller runway occupancy time, since their slow speeds allow them to brake more quickly and to get off the runway faster; and
2. They require a smaller time separation between aircraft, since they are more maneuverable and can be waved off more easily.

Moreover, the processing rate is lower when heavy aircraft are landing due to wake turbulence and the resulting greater separation requirements.

In computing the mix of aircraft the assumption is made that all aircraft can be divided into five classes. Table 2-4 defines these five classes and gives examples of aircraft in each of them.

Third, the processing rate depends on the arrival-departure ratio of the aircraft requesting service. Typically, arrivals are given priority and are allowed to land as they come in; departures are released in the gaps between arrivals. Thus, if the arrival-departure ratio is one, the local controller will try to send off a departure between every arrival; if he fails to get a departure off between two arrivals, he will then try to make up for it by releasing two departures between two subsequent arrivals. Now suppose that the arrival-departure ratio rises above one while the airside system is saturated. The maximum number of planes that could be processed in an hour is then expected to fall. Since arrivals were being landed at a maximum rate when the arrival-departure ratio was one, the additional arrivals must be delayed before landing; since there are fewer departures, some interarrival gaps that could have contained a departure go unused.

TABLE 2-4. AIRCRAFT BY TYPE AND CLASS

CLASS	DESCRIPTION	TYPE
H	All jet aircraft having normal loaded weights in excess of 300,000 pounds	Boeing 747 McDonald-Douglas, DC-10 Lockheed L-1011 Douglas DC-8 Super Series Boeing 707-320 Fan Jet
A	All jet aircraft not included in Class H but normally requiring runway lengths in excess of 6000 feet for take-off and/or landing (corrected to sea level).	Boeing 707 and 720 series Douglas DC-8 series Convair 880 and 990 Sud-Aviation Caravelle DeHavilland Comet BAC VC 10
B	(1) Piston and turboprop aircraft having a normal loaded weight of >36,000 pounds (2) Jet aircraft not included in Class A but having a normal loaded weight >25,000 pounds	BAC 111 Boeing 727 Lockheed Jetstar Lockheed Electra BAC Vanguard Vickers Viscount Douglas DC-6 and DC-7 series Lockheed Constellation Bristol Brittannia Convair 240, 340, and 440 Martin 202 and 404
C	(1) Piston and turboprop aircraft having a normal loaded weight of >8000 pounds but <36,000 pounds. (2) Jet aircraft having a normal loaded weight of >8000 pounds but <25,000 pounds	Fairchild F-27 Grumman Gulfstream Douglas B-26 Lockheed Lodestar and Learstar series Douglas DC-3 Beech 18 series North American T-39 Potez 840 Aero Jet Commander DeHavilland 125
D	All light twin-engine piston/turboprop aircraft with <8000 pounds normal loaded weight and some high-performance single-engine light aircraft	Beech 500 Twin Bonanza Aero Commander Beech Queen Air Beech Travelair Piper Aztec Piper Apache Cessna 310 Cessna Skyknight Beech Bonanza and Debonair DeHavilland Dove

TABLE 2-4. AIRCRAFT BY TYPE AND CLASS (CONTINUED)

CLASS	DESCRIPTION	TYPE
E	All single-engine light aircraft other than those included in Class D	Piper Cub, Tripacer, Pacer, etc. Cessna 140, 150, 170, 180, and 210 series Piper Cherokee Piper Comanche Beech Musketeer DeHavilland Beaver (L-20) Mooney M20 Aeronica Champion

Sources: Classes A-E as defined in Reference 1; Class H as defined in Reference 2.

Fourth, the processing rate depends on the separation standards employed. Currently the 3-5 separation standard is used; i.e., a 5 mile separation is required following all heavy aircraft and a 3 mile separation is required following all other aircraft. Adoption of a 3-7 standard that would require a 7 mile separation following heavy aircraft has been discussed. The processing rate for many airports would be lowered if this 3-7 standard were used since interarrival times would increase whenever heavy aircraft were present in the arrival stream.

Since the separation standard is a variable established by administrators and does not change during a day, it will be suppressed throughout most of this report. It is discussed here to illustrate how the model can cover a change in operating policies.

2.2.4 Logic of the Module

The building blocks of the Airside Processing Rate Module have now been described. To facilitate further discussion, the following abbreviations will be used:

r the airside processing rate

W the weather (either VFR or IFR)

M the mix

AD the arrival-departure ratio

We assume that r is a function of W, M, and AD (and separation standards, which are suppressed), so we write r (W,M,AD). We assume that r depends only on these variables. This assumption could be relaxed in future work. For example, the processing rate could be made to depend on the length of the queue of planes waiting for service if further study indicates that controller performance increases during the busiest periods.

In order to calculate the delay that will be incurred at an airport on any day, it is necessary to have the processing rate for each hour. If a day is being studied, this means that as many as 24 different processing rates – one for each hour – must be known; if a year is being studied, the number of different processing rates might be staggering. The motivation behind the Airside Processing Rate Module is that it is not reasonable to require the user to input the dozens of needed processing rates. Therefore, this module gives the user the following shortcut: provide one good weather processing rate and one bad weather processing rate and the module will calculate all of the other processing rates needed.

More specifically, recall the processing rate can be written as r (W,M,AD). Let $\overline{M}$ be a typical mix at the airport being studied. The input to this module is r (VFR,$\overline{M}$,1) and r (IFR,$\overline{M}$,1) – i.e., a processing rate for good weather, the typical mix, and an arrival departure ratio of unity, and another processing rate for bad weather, the typical mix, and an arrival departure ratio of unity. The computer then calculates from these two values all additional needed values for the function r (W,M,AD). That is, the computer uses these two processing rates to calculate all the other processing rates for the different values of M and AD expected to occur. These calculations are approximations derived from information in References 3 and 4. The details of these calculations are fully spelled out in Appendix A.

In summary, the inputs and output of this module are shown in Figure 2-3.

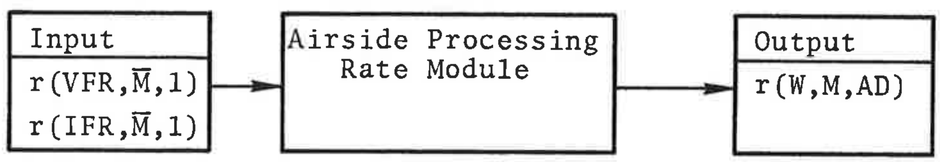


Figure 2-3. Module Inputs and Output

This module is useful because it relieves the user from the burden of specifying many different processing rates. The user may select the standard default values stored in the data base for the subject airport, or he may elect to override one or both of these values. This module then calculates all other needed values.

2.2.5 Importance of the Module

Section 1 emphasized the importance of knowing the effect that an airport investment will have on delay, facility, congestion, and serviceable demand. However, since there are dozens of different investments that might be made at an airport, it is not practical to allow specific investments to serve as inputs to the model. Therefore, the approach taken is to assume that the impact on airside capacity of an investment in the airside system can be summarized by how it affects the processing rate.

The data base stored in the computer contains the current values for processing rates; if the user wants to use the current values, he does not need to input anything to this module. However, in many applications the user will want to input new processing rates that will be relevant when a new investment is made.

It should be emphasized that the calculation of the airport performance that results when a new investment is made is sensitive to the processing rates input by the user. It is therefore necessary for the user to think carefully about the processing rates when he specifies them. Some investments will affect both the good and bad weather processing rates; e.g., improved runway exits. Some investments will only improve the good weather processing rates; e.g., installing a runway not equipped with ILS. Some investments will only improve the bad weather processing rates; e.g., installing an ILS on an existing runway. Other investments — such as strengthened runways — do not directly affect capacity and must be incorporated in other ways (see Section 3.3).

2.3 DEMAND MODULE

Many different characteristics of airport traffic are relevant when calculating airside delay or groundside congestion. One is the degree to which operations are peaked rather than spread evenly over a year, a day, or an hour. The mix of different aircraft types and the arrival-departure ratio are characteristics that vary over the course of a day. Finally, the weather is variable. There are variations in all these airport characteristics, and calculations of airside delay, groundside congestion, or serviceable demand are sensitive to them. It is basic to the approach taken in this report that all calculations should recognize these variations and take them into account.

The purpose of the Demand Module is to put daily volume, minute-by-minute volume, weather, mix, and arrival-departure ratios into a realistic form. Therefore, the calculations of airside delay, groundside congestion, and serviceable demand reflect as closely as possible the actual conditions under which the airport is anticipated to operate.

An inconsistency in this section should be pointed out. The capabilities outlined below can be divided into three classes. First, there are capabilities that are included in the present computerized version of the Airport Performance Model. Second, there are capabilities that should be included, but are not currently in the model. The reason for the exclusion is that we did not have enough time to program these capabilities into this year's model; they will be included in future versions. Third, there are proposed capabilities that might be included in future versions of the model, but on which no definitive decision has yet been made. Thus, the exposition will alternate between these three stages.

2.3.1 Data Sources

Three main data sources have been used to construct the temporal components of the data base for Logan Airport. First, information on the number of daily and annual operations comes from FAA Form 7230-1. This form gives the number of daily air carrier, air taxi, general aviation, and total operations. This form is compiled from the flight strips that are filled out in the tower whenever an aircraft is processed. Data from this form were utilized for four years: 1 January 1970 – 31 December 1972 and 1 May 1974 – 30 April 1975. Data in the middle of this period were omitted to prevent the unusual conditions during the energy crisis from biasing the results.

Second, information on the number of operations for each hour of the day was taken from an unnumbered FAA form. Hourly traffic counts, also based on tower flight strips, are entered on this form at the end of each hour, and the 24-hour total is entered on

Form 7230-1 at the end of each day. Data from this form were only available for the period 1 January 1975 — 30 April 1975. These first two data sources are referred to collectively as the Logan Tower data. Third, information was taken from tapes that contained data from the Official Airline Guide (OAG). The OAG provided the number of scheduled arrivals and departures for each minute and the type of aircraft used for each operation. The OAG tapes used were for September 1974, December 1974, and January 1975.

2.3.2 Decomposing Annual Operations into Daily Operations

One question that the Airport Performance Model can be used to study is how much airside delay and groundside congestion will occur at an airport in the course of a year. To answer this question it is necessary to know how much traffic there will be at the airport during the year and how this traffic will spread over 365 days. The position taken in the development of the Airport Performance Model is that it is unreasonable to require the user to input the volume of traffic for all 365 days; not only would this be laborious, but it would require data that the user could not easily gather. Therefore, the user is only asked to input a single number — the total operations volume for the year. The demand module then uses the historical patterns of demand which are contained in the data base to break down this annual volume into volumes for each day.

Before describing how annual volume is broken up into daily volumes, two remarks are necessary. First, it is possible to express volume in terms of either operations (i.e., landings and takeoffs) or passengers. The model as currently written only allows the user to express volume in terms of operations; the capability to deal with passengers will be added next year. Second, the technique for dealing with different annual volumes has been completely designed (and will be explained below), but the time constraint under which this work was done prevented this capability from being built into the current model. Third, weekends and holidays are considered separately from nonholiday weekdays. This is because the mix of aircraft types is systematically and significantly different on these two types of days, since many more of the smaller, general aviation aircraft fly on weekdays (see Section 2.4.5).

The method used to divide the total number of annual operations into the number of operations for each day is based on the assumption that the demand patterns that have held in the past will continue to hold in the future. The historical pattern of daily demand for Boston Logan, derived from four years of data from Form 7230-1, is exhibited in Table 2-5. This table shows a frequency distribution for the daily volume, with each day's volume expressed as a percentage of the year's average daily volume. The left hand column shows the percentage of average daily volume. The second column shows the average number of non-weekdays (Saturdays, Sundays, and holidays) that will have that volume during a year. The third column shows the number of weekdays that will have each volume during an average year. For example, if annual volume is 300,000 operations, then average daily volume is 300,000 ÷ 365 = 822 operations. Looking at the 100% interval, we then anticipate that, on average, during a year there will be 1.75 weekend days and 8.25 weekdays with about 822 operations. For another example, examine row 119. Since 822 x 1.19 = 978, we expect that, on average, a year will contain four weekdays and no weekend days with about 978 operations. The frequency distributions in Table 2-5 are displayed graphically in Figures 2-4 and 2-5.

This method allows the planner to input any number for the total number of annual operations. The model then divides this number by 365 to obtain the average number of daily operations. The average number of daily operations is then combined with the historical frequency distributions stored in the data base to project the distribution of the user-specified annual volume across the 365 days of a typical year.

TABLE 2-5. AVERAGE ANNUAL VOLUME FREQUENCY DISTRIBUTION FOR BOSTON LOGAN AIRPORT[1]

DAILY VOLUME[2]	AVERAGE NUMBER[3] OF NONWEEKDAYS PER YEAR	AVERAGE NUMBER OF WEEKDAYS PER YEAR
17	0.25	0.00
18	0.00	0.00
19	0.00	0.00
20	0.00	0.00
21	0.00	0.00
22	0.00	0.00
23	0.00	0.00
24	0.00	0.00
25	0.00	0.00
26	0.00	0.00
27	0.00	0.00
28	0.00	0.00
29	0.00	0.00
30	0.00	0.00
31	0.00	0.00
32	0.00	0.00
33	0.25	0.00
34	0.00	0.00
35	0.25	0.00
36	0.00	0.00
37	0.00	0.00
38	0.00	0.00
39	0.00	0.00
40	0.00	0.00
41	0.00	0.00
42	0.25	0.00
43	0.00	0.00
44	0.00	0.00
45	0.00	0.00
46	0.00	0.00
47	0.50	0.00
48	0.00	0.25
49	0.75	0.25
50	0.00	0.00
51	0.00	0.00
52	0.25	0.00
53	0.00	0.00
54	0.00	0.00
55	0.25	0.00
56	0.25	0.75
57	0.50	0.25
58	0.00	0.00
59	0.25	0.00
60	0.00	0.00
61	0.25	0.00
62	0.25	0.50
63	0.75	0.25
64	0.75	0.00
65	0.50	0.25
66	0.00	0.50
67	0.50	0.00
68	1.50	0.00
69	1.25	0.75
70	0.25	0.25
71	2.25	0.25
72	1.50	0.25
73	1.50	0.75
74	2.75	0.50
75	3.25	0.00
76	2.75	0.50
77	2.75	1.50
78	4.25	0.25
79	5.00	0.50
80	3.50	0.75
81	3.50	0.75
82	5.75	1.25
83	4.50	1.50
84	3.25	0.25
85	1.50	1.50
86	3.75	1.00
87	4.00	3.00
88	3.50	1.00
89	2.25	2.75
90	2.25	3.25

[1] Data from FAA Form 7230-1.

[2] Daily volume is expressed as a percentage of the appropriate year's average daily volume.

[3] Nonweekdays include all Saturdays, Sundays, and holidays

TABLE 2-5. AVERAGE ANNUAL VOLUME FREQUENCY DISTRIBUTION FOR BOSTON LOGAN AIRPORT[1] (CONTINUED)

DAILY VOLUME[2]	AVERAGE NUMBER[3] OF NONWEEKDAYS PER YEAR	AVERAGE NUMBER OF WEEKDAYS PER YEAR	DAILY VOLUME[2]	AVERAGE NUMBER[3] OF NONWEEKDAYS PER YEAR	AVERAGE NUMBER OF WEEKDAYS PER YEAR
91	3.50	2.50	116	0.00	5.50
92	4.00	3.25	117	0.00	4.75
93	4.00	5.00	118	0.00	5.50
94	2.00	5.75	119	0.00	4.00
95	2.00	4.00	120	0.00	4.75
96	2.50	4.00	121	0.25	3.50
97	3.25	6.50	122	0.00	5.50
98	2.50	8.50	123	0.00	4.25
99	1.75	4.25	124	0.00	3.75
100	1.75	8.25	125	0.00	1.75
101	2.00	8.00	126	0.00	2.75
102	1.25	5.00	127	0.00	2.75
103	0.50	5.25	128	0.00	1.75
104	2.00	10.75	129	0.00	1.75
105	1.00	10.00	130	0.00	2.00
106	1.00	9.00	131	0.00	0.25
107	1.00	10.00	132	0.00	0.75
108	0.50	7.50	133	0.00	0.00
109	1.75	7.75	134	0.00	2.50
110	0.25	8.50	135	0.00	0.25
111	0.50	8.00	136	0.00	0.50
112	0.25	7.50	137	0.00	0.50
113	0.00	5.75	138	0.00	0.25
114	0.25	6.75	139	0.00	0.00
115	0.00	7.25	140	0.00	0.25

[1]Data from FAA Form 7230-1

[2]Daily volume is expressed as a percentage of the appropriate year's average daily volume.

[3]Nonweekdays include all Saturdays, Sundays, and holidays.

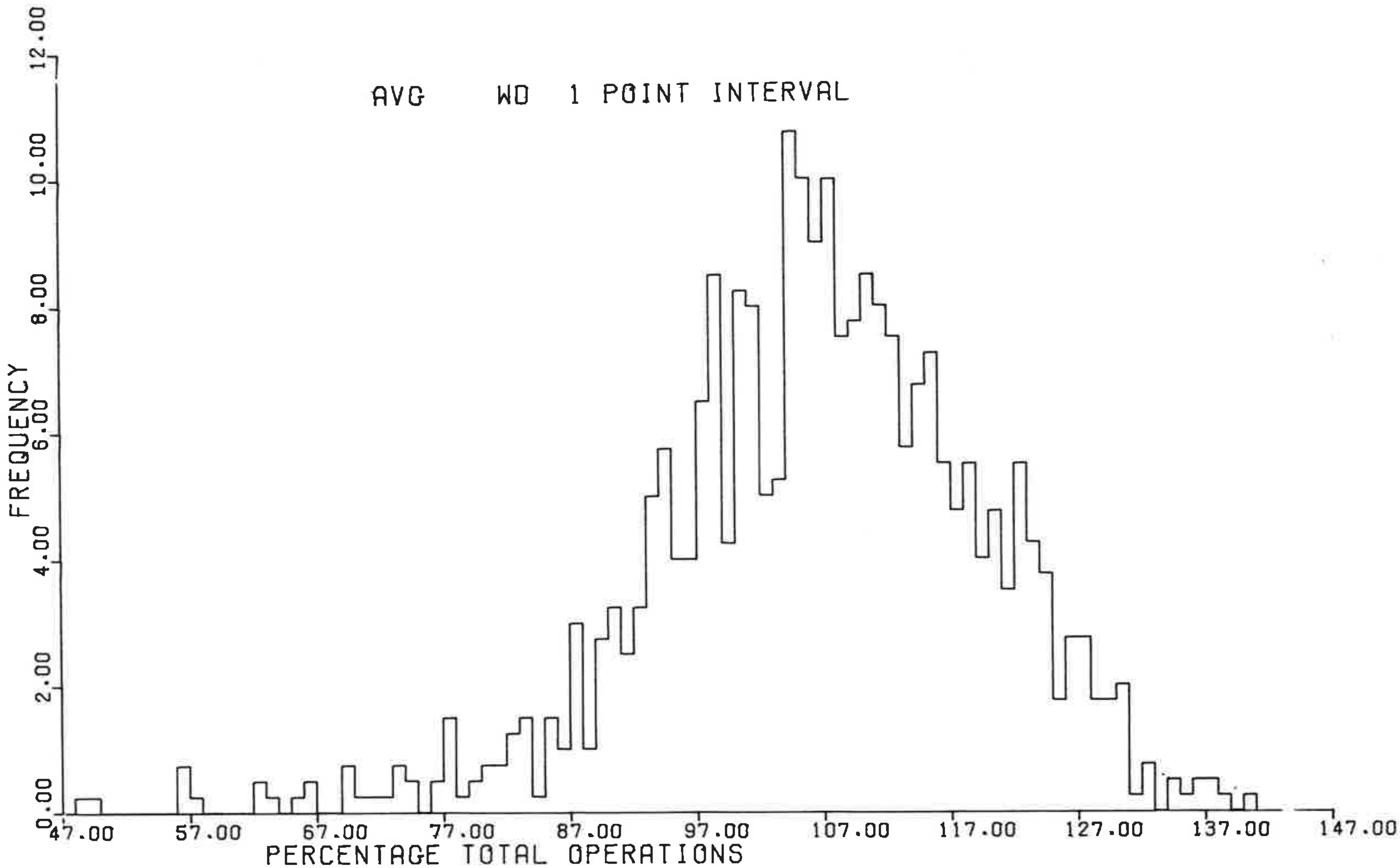


Figure 2-4. Frequency Distribution, Boston Logan — Weekdays

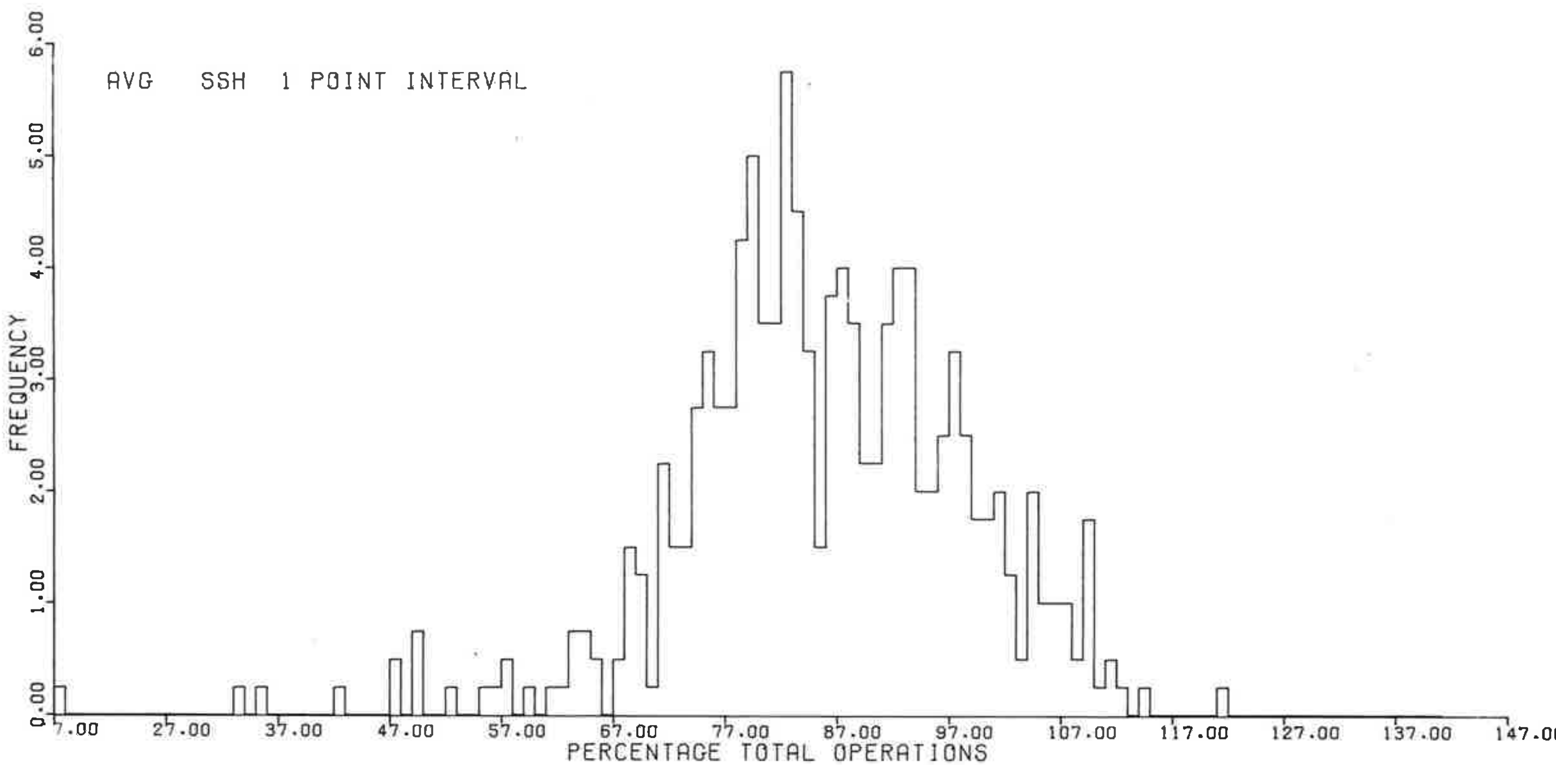


Figure 2-5. Frequency Distribution, Boston Logan – Saturdays, Sundays, Holidays

Three points should be noted. First, the computer does <u>not</u> calculate how many operations there are on, say, July 21. Instead it calculates 365 volumes; it is not known on which calendar day a particular volume occurs. This is not a drawback of the model since presumably only the amount of delay, and not the exact date, is important. Second, the method described above has been carefully chosen to preserve realistic peaking characteristics of demand. Third, the data base does not contain information for all 365 days of a year; the computer time required to simulate each day's operations forced a compromise between computational accuracy and model running time. As described in Section 2.4.4, the nature of the delay function and Boston's demand characteristics led to the selection of eight representative 24-hour demand profiles (each profile includes a scheduled traffic array, a nonscheduled traffic array, an aircraft mix array, and an arrival/departure ratio array; see Table 2-2) that collectively represent the annual variations in Boston's daily traffic characteristics.

The choice of this method was guided by the findings of the theory of portfolio selection on the effects of diversification. An example of an inappropriate technique would be to take the percentage of average daily volume occuring on July 21 for each of four years and then to average these four percentages to get the percentage of average daily volume that obtains, on average, on July 21. This technique would make the frequency distribution flatter than it should be.

2.3.3 Transforming Daily Operations into a Minute-by-Minute Demand Profile and into Hourly Mix and Arrival-Departure Ratio Profiles

In order to calculate a day's airside performance, the model must have a service request schedule, and information describing the hourly variations in aircraft mix and arrival/departure ratio. This section explains the method used to generate the scheduled traffic, unscheduled traffic, aircraft mix, and arrival/departure ratio arrays for a user or data base specified 24-hour aircraft volume.

One of the standard problems encountered in evaluating airport performance is accurately representing the time pattern in which aircraft request service. If aircraft happened to request service just as the runway was released by each previous aircraft, a number of aircraft equal to the saturation capacity could be processed during the specified period of time with no delay. This rarely, if ever, happens. If, on the other hand, all aircraft arrive simultaneously at the beginning of the time period, the accumulated delay will be very large.

Two approaches have been used to model the pattern of aircraft service requests. The first is based on the observation that aircraft activity appears to be randomly distributed over time and is motivated by the extensive development of queuing theory. This approach characterizes the service-request stream as a Poisson process. The Poisson process is characterized by an average arrival rate (for some period of time). The important property of the Poisson process is that the probability that an aircraft will request service in the next time interval (t) is a function of only the average arrival rate. Thus it is independent of events in the previous interval, and the probability that an aircraft will request service in the next (t) is the same for all (t).

Once the stream of demands are assumed to conform to a Poisson process, queuing theory can be used to express the performance of the system as a function of the ratio of the average request rate to the maximum service rate (saturation capacity). This is the approach behind the Airborne Instrumentation Laboratory's Airport Capacity Handbook.

The second approach to modeling the pattern of aircraft service requests is based on actual schedules for the airport being studied. The scheduled service requests can also be modified to incorporate the expected variations between scheduled and actual request times. This could be done by assuming that each service request is randomly distributed about its scheduled time. This is the approach used by Maddison (Reference 5).

Theoretically, the schedule-based service-request pattern is considerably superior to the pattern based on the Poisson distribution. Aircraft operations do not exhibit the time independence inherent to a Poisson distribution, particularly during peak hours when an inordinate percentage of total hourly operations will be scheduled on only three or four individual minutes. Delay reduction due to changes in the "concentration" of activity through the appropriate time interval cannot be modeled with the Poisson distribution. The difficulty with the schedule-based service-request pattern is the substantial amount of data that must be generated for each airport and the need to simulate each aircraft's activity at the airport.

A six-step method was used to generate the 24-hour demand profiles, which comprise a scheduled traffic array, a nonscheduled traffic array, an aircraft mix array, and an arrival/departure ratio array. The scheduled and nonscheduled traffic arrays, which are minute-by-minute schedules, are combined to produce the aircraft service-request schedule discussed above. (Section 2.4 discusses the method used to simulate airside activity.) The six steps involved are:

Step 1 - Determine the Volume for the Day. If the user inputs a volume for a year, the volume for each day is obtained from the procedure outlined above. If the user is studying the delay and congestion for a day and thus inputs the volume for a day, that figure is then used. Otherwise the standard day stored in the data base is used.

Step 2 - Break Down the Total Daily Volume into Scheduled and Unscheduled Traffic. Comparing information in the OAG with the Logan tower data indicates that scheduled traffic is, on average, 80 percent of the total on weekdays and 90 percent on weekends. (See Table 2-6.) Multiplying the total daily volume times the appropriate percentage yields the scheduled volume for that day. Total volume minus this scheduled volume gives the unscheduled volume for the day.

TABLE 2-6. COMPARISON OF SCHEDULED AND ACTUAL OPERATIONS

MONTH	WEEKDAYS			WEEKENDS		
	SCHEDULED OPS.	ACTUAL OPS	SCHEDULED OPS. AS A PERCENTAGE OF ACTUAL OPS.	SCHEDULED OPS.	ACTUAL OPS.	SCHEDULED OPS. AS A PERCENTAGE OF ACTUAL OPS.
September 1974	13,603	17,542	77.5	6,054	7149	84.7
December 1974	13,559	16,842	80.5	5,684	6198	91.7
January 1975	14,062	17,158	82.5	5,069	5422	93.5

Source: Computed from information in the Logan tower data and the OAG.

Step 3 - Construct a Minute-by-Minute Demand Profile for the Scheduled Flights. This is done by taking information from the OAG; the details are spelled out in Appendix B.

Step 4 - Construct a Minute-by-Minute Demand Profile for the Unscheduled Flights. The Logan Tower data indicate that 90 percent of the unscheduled flights (which are mainly general aviation with some air taxi) are spread evenly from 8:00 a.m. to 10:00 p.m. and that 10 percent are spread evenly from 10:00 p.m. until 8:00 a.m. For example, suppose that on a hypothetical weekday there were 467 total operations. Since 80 percent of the flights are scheduled, this means that 374 (=467 x 80%) flights are scheduled; i.e., 93 (=467-374) are unscheduled. Since 90 percent of the unscheduled flights are assumed to fall between 8:00 a.m. and 10:00 p.m., the number of unscheduled flights in this interval is 84 (=93 X 90%). Since there are 840 minutes in this interval, and the flights are assumed to be spaced evenly, it follows that an unscheduled flight requests service every 10 minutes. This is an example of how unscheduled aircraft are treated in this year's model. One might object that this fails to capture the randomness and irregularity of unscheduled activity. This point is well taken, but it can be dealt with in a future version of the model; moreover, the scheduled traffic in the model does exhibit the desired irregular behavior.

Step 5 - Construct the Minute-by-Minute Demand Profile for All Flights. This is done by simply adding together the minute-by-minute profiles for scheduled and unscheduled flights constructed in the two preceding steps. This demand profile comprises the number of aircraft that request service during each minute of the day. This is the major output of the Demand

Module. It is passed to the Airside Service Module, which uses it to place time-specific demands on the airside complex.

Step 6 - Construct the Hourly Mix and Arrival/Departure Ratio Profiles. When a scheduled demand profile is taken from the OAG, information is also obtained on the number of arrivals and departures in each hour and on the number of each type of aircraft that request service during each hour. It is assumed that the arrival-departure ratio for unscheduled aircraft during an hour is the same as for scheduled, so the OAG gives the arrival-departure ratio for each hour of the day; we will call this the hourly arrival-departure profile. It is assumed that all of the unscheduled flights are of classes D and E (see Table 2-3). This information, combined with the information on aircraft types for the OAG is used to compute the mix of different aircraft types that request service during each hour of the day. This is called the hourly mix profile. Both the hourly arrival-departure profile and the hourly mix profile are outputs of the Demand Module that are passed to the Airside Service Module.

2.3.4 Weather Profiles

In order to calculate delay for a day, it is necessary to know the existing weather conditions during each hour of the day. The following procedure was used to construct daily weather profiles. It was assumed that, for this year, only two types of weather would be distinguished — good weather and bad weather — and that weather conditions changed only on the hour. Good weather is defined to exist when visibility is at least 3 miles and the ceiling is at least 1200 feet. All other weather is bad weather. To keep down the cost of using the model, it was decided that only two daily weather profiles, each comprising 24 consecutive hours of weather conditions, would be used. One obvious profile is good weather all day; this profile is used for 75 percent of the days during annual analyses. Appendix C contains an analysis of data that concludes that a suitable second profile is bad weather from 6:00 p.m. until 11:00 p.m. and good weather during the other 20 hours of the day. This profile is used for 25 percent of the days. It should be emphasized that it is not possible to summarize a year's weather accurately in only two profiles with only two weather conditions. The assumptions made here should be thought of as a first attempt at incorporating the impact of annual weather variations on airport operations.

2.3.5 Conclusions

The Demand Module does essentially two things: first, it takes an annual number of operations and uses historical patterns stored in the data base to divide this into the number of operations on each day; second, it takes from the data base information about minute-by-minute demand profiles, aircraft mix, arrival-departure ratios, and weather and characterizes these factors for each day. This, then, is the output of this module: a minute-by-minute profile of demand and hourly profiles of weather, mix, and arrival-departure ratio for a single day or for all appropriate days of a year. This output is used by the Airside Service Module to calculate airside delay, groundside congestion, and serviceable demand.

2.4 AIRSIDE SERVICE MODULE

As described in Section 2.1.4, the Airport Performance Model is constructed to simulate airport activity for independent 24-hour periods. For each 24-hour period, the Demand Module provides the minute-by-minute demand profile and the hour-by-hour profiles of weather, mix, and arrival-departure ratios. These hour-by-hour profiles are fed into the airside processing rate module in order to calculate the processing rate for each hour.

2.4.1 Calculating Individual Aircraft Delay

Only the principal ideas behind the determination of individual aircraft delay will be considered here; the derivation of the delay algorithm and the computer program that calculates delay are described in the appendixes. Recall that, at this stage of the model, the relevant processing rates and the time that each plane requests service are known.

Figure 2-6 shows a hypothetical minute-by-minute demand profile for the 1440 minutes in a day and a processing rate in operations per minute. (The processing rate is shown to be constant throughout the day only for diagrammatic clarity; the model allows the processing rate to change every hour.) At the beginning of the day the demand profile is completely beneath the processing rate, so no queue builds up and no delay develops. When the demand profile climbs above the processing rate, however, a queue does build up. The queue is worked off when the demand profile falls back below the processing rate. The length of time aircraft

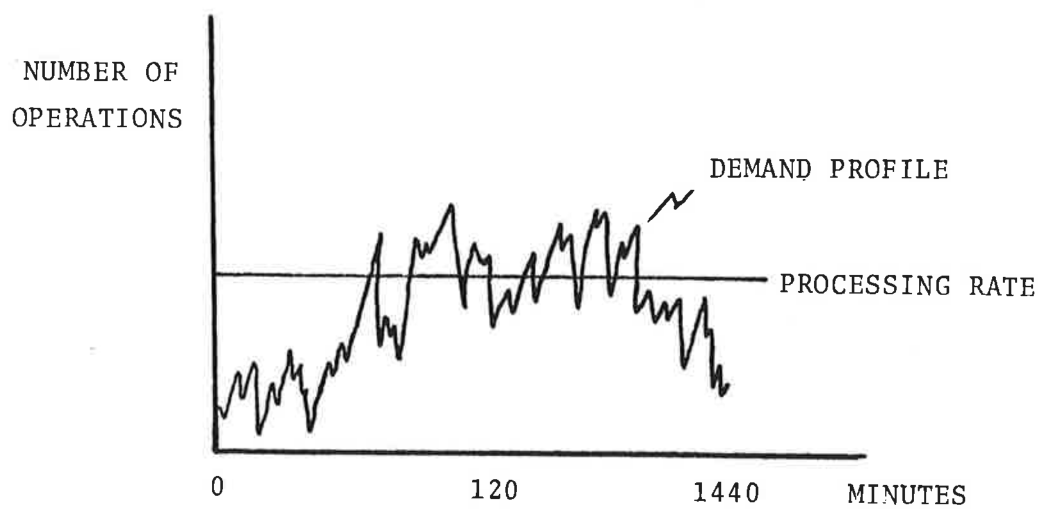


Figure 2-6. Hypothetical Minute-by-Minute Demand Profile

and passengers spend waiting in the queue, which is calculated by the Airside Service Module, is the aircraft and passenger delay.

In order to explain how the model calculates delay, it will be convenient to invert the processing rate, and speak in terms of minutes per operation. The "acceptance interval" equals, when the system is saturated, the minimum time that must elapse between successive aircraft entering the system. For example, if the maximum processing rate in operations per hour is 120, then the minimum acceptance interval in minutes per operation is 1/2; i.e., an aircraft may enter the system, at the earliest, 30 seconds after the preceding aircraft. It might be noted that this "processing interval" or "minimum acceptance interval" is <u>not</u> the time it takes an aircraft to be processed through the system; rather, this interval reflects the fact that more than one aircraft are being simultaneously processed. While one aircraft is landing, perhaps another arrival is 3 miles behind, one departure is ready to go, and others are taxiing to the runway. To return to the numerical example, suppose it takes 10 minutes for an aircraft to be processed through the system. Since the acceptance interval is 1/2 minute per aircraft, this implies that 20 aircraft are being simultaneously processed when the system is saturated.

If there is no congestion, an aircraft is not delayed. In cases where there is congestion we can conceive of the aircraft in the airside system as being divided into two categories: those waiting in a queue and those being processed (see Figure 2-7).

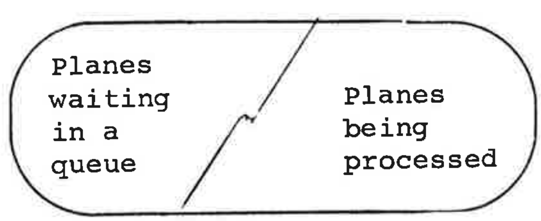


Figure 2-7. Division of Aircraft in the Airside System

As aircraft are processed and leave the system, the waiting aircraft are taken from the queue and processed.

More specifically, let T be the minimum acceptance interval in minutes per aircraft. Recall that it is known when an aircraft enters the system and thus when it first requests service. If the aircraft requests service less than T minutes after the preceding aircraft is accepted for service, it must then wait in the queue. For example, the first aircraft to enter the system is accepted for service immediately. If the second aircraft enters within T minutes after the first aircraft, it will not be accepted for service until T minutes after the first aircraft is accepted; if the second aircraft enters more than T minutes after the first aircraft, it will not be delayed and will be accepted at the time of its request. Aircraft delay is thus the difference between the service request time and the service acceptance time, and the variable limiting the acceptance process is the minimum acceptance interval.

One aspect of the preceding explanation requires elaboration. The phrase "relevant processing rate" has been used without specifying exactly which processing rate is the relevant one. Recall that the weather, mix, and arrival-departure ratio are allowed to change on the hour and that the processing rate r(W,M,AD) depends on these three variables. If an aircraft enters and leaves the system in the same hour, it is clear that the relevant processing rate is the one determined by the values taken on by W, M, and AD during that hour. A complication arises, however, if an aircraft enters the system in one hour but, because it is forced by congestion to wait in a queue, leaves the system in the next hour. What are the relevant values of W, M, and AD? Should the values for the old hour or the new hour be used?

The appropriate values for W, M, and AD are those that affect the processing rate at the time the aircraft is accepted for service. Since the aircraft in question is embedded in a queue formed in the previous hour, the relevant mix is that of the previous hour. Since arrivals and departures are both delayed, the relevant arrival-departure ratio is also that of the previous hour.

But the relevant weather is that which holds in the new hour, when the aircraft is accepted for service. Therefore, in general, in calculating the processing rate r (W, M, AD) one should use:

1. The weather of the hour in which the aircraft is accepted for service
2. The mix and arrival-departure ratio of the hour in which the aircraft requested service.

The computer program is written to guarantee that the relevant processing rate is always used to calculate delay. As described above, this processing rate is inverted to produce the minimum acceptance interval that must elapse between successive airside operations. This acceptance interval is an average value for the specified hour's aircraft mix and arrival/departure ratio. The aircraft that request service during an hour will be a mixture of types, ranging from 747's to Twin Otters. As the number of 747's increases, the average acceptance interval will <u>also</u> increase, reflecting the loss in saturation capacity produced by heavy aircraft separation standards. If the number of Twin Otters increases, other things held equal, the average acceptance interval will decrease. In this manner, the minimum average acceptance interval is adjusted to account for each hour's aircraft mix. Similarly, the minimum acceptance interval is adjusted for each hour's arrival/departure ratio to account for the different intervals required for arrivals and departures.

In modeling airside activity, the model implicitly assumes that all aircraft during an hour are identical. This "homogenous aircraft," or average operation, is somewhere between a 747 and a Twin Otter; the maximum number of 747's and Twin Otters that can be processed during an hour is equal to the maximum number of these homogenous operations that can be processed. The model does not distinguish between arrivals and departures or among equipment types at the time the aircraft are actually processed through the airside system. Although this treatment might slightly overestimate or underestimate delay for an individual operation, it will not systematically overestimate or underestimate total airside delay.

The cost of aircraft delay is based on the total delay time for each hour, the hour's mix, and the hour's arrival/departure ratio. Total delay time is first divided between arrivals and departures using the arrival departure ratio. Delay time attributed to arrivals is multiplied by a weighted average airborne operating cost, computed as the product of the average airborne operating cost for each of the five aircraft classes and the fraction of the hour's operations in each class. Delay time attributed to departures is multiplied by a weighted average ground operating cost, computed as the product of the average ground operating cost for each class and the fraction of the hour's operations in each class. The aircraft delay cost is the sum of the arrival delay costs and departure delay costs. Current values for both the weighted average ground operating cost and the weighted average airborne operating cost are stored in the aircraft section of the data base; these values will be used in the cost calculation unless other values are specified by the user.

2.4.2 Calculating Passenger Delay

Information about load factors and the number of seats on an aircraft type can be used to calculate the amount of delay suffered by passengers. The number of seats on each hour's homogenous aircraft is calculated by multiplying the average number of seats currently found on aircraft in each aircraft class – information that is contained in the aircraft section of the data base – by the fraction of the hour's total operations in each aircraft class (the mix). Next, the number of seats is multiplied by the average load factor for the hour, taken from historical airport data; the result is the number of passengers on the homogenous aircraft. It is assumed that each aircraft that requests service during an hour has the same number of passengers. Since the total amount of aircraft delay is known (see

Section 2.4.1), we multiply this by the number of passengers on the average aircraft to get the total passenger delay. The cost of passenger delay is determined by multiplying the hours of passenger delay by the value of passenger time. As with aircraft time costs, the value of passenger time stored in the data base will be used in the calculation unless a different value is specified by the user.

2.4.3 Output of the Module

A discussion of the different statistics that the Airside Service Module can calculate and the different ways they can be displayed for the user will be given in Section 3.2. This section indicates the nature of these statistics.

Section 2.4.1 showed how daily aircraft delay is calculated. The delay can be given separately for arrivals and departures. From an assumed dollar value for a minute's cost of crew and fuel consumption a dollar value of aircraft delay is calculated. Average delay is calculated both for all aircraft and also for only those aircraft that were delayed. Maximum delay for an aircraft is calculated. The length of the queue at selected points in time is calculated.

Section 2.4.2 described how total daily passenger delay is calculated. Assuming a value of passenger time, the dollar value of passenger delay is calculated. This can be added to the dollar value of aircraft delay to derive the total dollar value of delay.

The number of passengers serviced is then calculated. This output is necessary in determing how an investment affects the maximum amount of demand an airport can realistically service. Finally, the number of passengers that arrive, transfer, and depart per hour is calculated and passed to the Groundside Module.

Sections 2.4.4 and 2.4.5 describe the selection of 16 representative days that can be used to estimate a full year's performance.

2.4.4 Delay Function

The above discussion has dealt with calculating delay for a single day. We now turn to the issue of how the delay for individual days is aggregated to arrive at the delay for an entire year.

A central concept in calculating delay for a year is the delay function. This function expresses daily delay as a function of the number of operations for that day, with weather, mix, and arrival-departure profiles held parametrically constant. A hypothetical delay function is sketched in Figure 2-8.

In principle, the delay function is completely known. To get a point on the function, select a daily volume on the horizontal axis and use the methods described in preceding paragraphs to calculate the delay for the day. This gives one point of the function. Repeat this for all appropriate daily volumes, (a finite quantity), and the delay function for the specified weather, mix, and arrival-departure profiles has been found. Repeating the

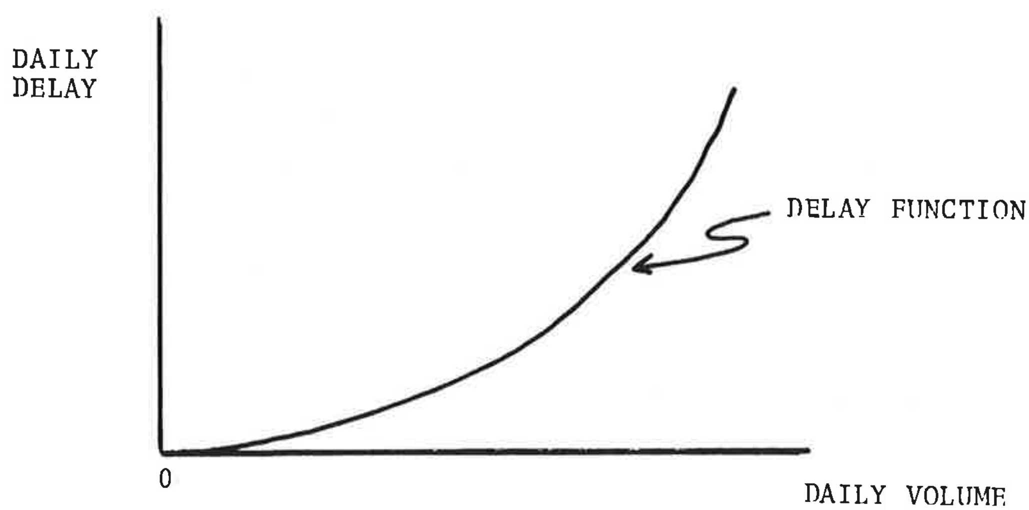


Figure 2-8. Hypothetical Delay Function

process for all daily volumes with other mixes, or other weather conditions, produces a series of daily functions that completely characterize the relationship between volume and delay. Delay for the year is simply the delay for each volume times the number of days in the year having that volume (which can be determined from Table 2-5), summed over all volumes (for Logan, summing over volumes from 0 to 1500 would be sufficient since larger volumes do not occur).

This method is very time consuming since it requires calculating delay for a large number of volumes. It is worthwhile investigating ways in which the delay function can be approximated using fewer calculations; a small degree of accuracy can perhaps be given up in return for a large decrease in computational cost. The next section describes one way of doing this.

2.4.5 Approximating the Delay Function

The simplest way to approximate the delay function is to use a step function. We will demonstrate this by applying it to the data in Table 2-5. The manipulations described below are exactly those used in this year's model.

Assume that the average daily volume for the year being studied is anticipated to be 822 operations. It will be convenient to think not in terms of daily operation counts, but in daily operations as a percentage of the annual average daily volume. That is, if the number of daily operations is 822, this is expressed as 100, since 822 is 100 percent of average daily volume; or 411 operations expressed as 50 since 411 operations is 50 percent of the average daily volume of 822. Table 2-7 shows annual operations at Boston Logan segregated first by mix and second by volume. Examination of the four years of daily operations data for Logan (FAA Form 7230-1) indicated that daily aircraft mix varied substantially between weekends (and holidays) and weekdays, due to general aviation activity on weekdays (probably private business use); it varied little within each group.

TABLE 2-7. REPRESENTATIVE DAYS

PERCENT OF AVERAGE DAY OPERATIONS: INTERVALS	NUMBER OF DAYS IN INTERVAL	REPRESENTATIVE DAY VOLUME: IN PERCENT OF AVERAGE DAY OPERATIONS
	WEEKDAYS	
0- 84	13	78
85-101	72	96
102-111	82	107
112-120	52	117
121-140	33	126
Total	252	
	WEEKENDS	
0- 84	56	79
85- 96	35	91
97-114	22	104
Total	113	
Grand Total	365	

Source: FAA Form 7230-1; data for the 48 months January 1970 – December 1972 and May 1974 – April 1975.

Weekdays are divided into five groups. The first group contains days with a volume from 0 to 84 percent of the annual, average daily volume; the second group contains days with a volume from 85 to 101 percent of average daily volume; etc. The five groups contain, respectively, 13, 72, 82, 52, and 33 days. It is assumed that the delay is the same for each day in an interval. For example, it is assumed that each day in the interval 0-84 has the same delay as a representative day with volume 78. This is reflected in the step function shown in Figure 2-9.

The estimated total delay for the weekdays in the interval 0-84 is 13 times the delay for a day with volume 78 and the average weekday mix, since, as Table 2-5 shows, 13 days are in

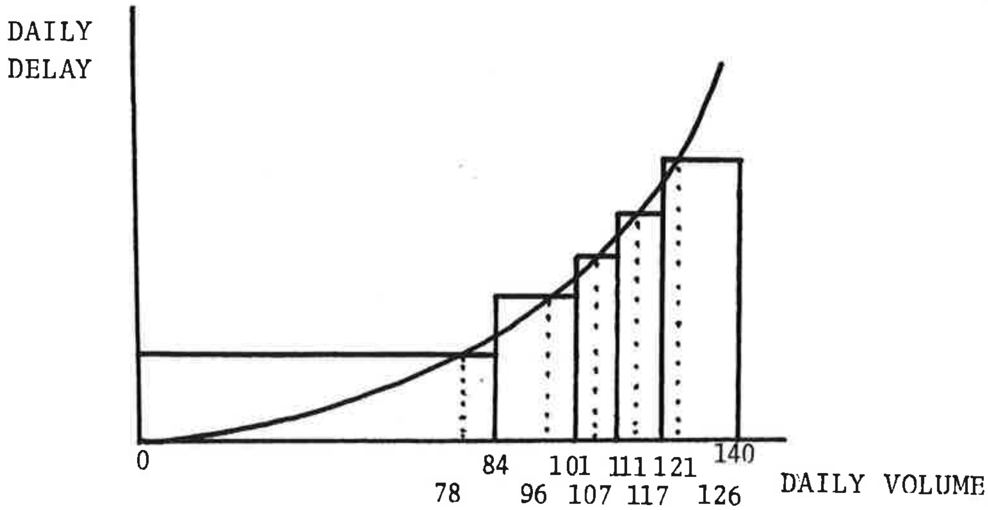


Figure 2-9. Step Function Approximation to the Delay Function

this interval. More generally, the total delay for any interval is the product of the number of days in the interval and the delay for the representative day in that interval. The total delay for the year is then the sum of the total delays for the intervals. Stated differently, total delay for the year is a weighted sum of delay for the representative days, where the weights are the number of days in each interval. This is the method used to approximate the delay function and the total delay for the year.

When there are, as assumed in this example, 300,000 operations in a year, the average daily volume is 822 = 300,000 ÷ 365. Then 822 x .78 = 641 operations for the representative day that has 78 percent of average daily operations. Note that this number is the first volume given for weekdays in Appendix B. The other numbers in Appendix B can be similarly derived. This explains why these particular numbers are chosen.

The remaining questions are: (1) How were the intervals chosen? and (2) How was the representative day in each interval chosen? These two choices were made based on inspection of Table 2-5. Four criteria were used. First, the width of each interval should be as small as possible to keep the approximation to the delay function from becoming too inaccurate. Second, the intervals should be narrower in the part of the horizontal axis where days are denser in order to improve the approximation to yearly delay. Third, the intervals should be narrower in the part of the horizontal axis where the delay function exhibits the most curvature in order to improve the approximation to the delay function. (This last criterion was not used since the curvature of the delay function was not known.) Fourth, to hold down computational cost, the number of intervals should be as small as possible.

The choices of intervals were made by trying to strike a suitable compromise between these conflicting criteria. The representative day in an interval was chosen to be slightly above the average day in an interval, since an increase in volume has a more than proportional effect on delay. It will perhaps be possible to apply the principles of statistical decision theory to derive a method of picking intervals and representative days that is in some sense optimal, but such an effort was beyond the scope of this year's work.

As described above, the delays calculated for each of the eight representative days (five weekdays and three weekend days) are multiplied by the number of days in the interval, and the sum of these weighted delays is taken to produce annual delay. As actually used, this process is somewhat more involved because of the inclusion of the weather profile. As described in Section 2.3.4, two weather profiles have been developed on the basis of historic data — one, a day with all good weather, and the second, a day with a representative time interval of bad weather. Thus, calculation of annual delay actually involves modeling airport activity for 16 unique days. Eight of these days are the representative days described with activity modeled for a day with good weather conditions; the delay for each of these days is weighted (multiplied) by the number of days in the interval it represents, less the number of those days expected to have bad weather. The second eight are the same representative days, but with activity modeled over a day during which a period of bad weather occurs; the delay for each of these days is multiplied by the number of days in each appropriate interval expected to experience bad weather conditions.

This process implies that, at least for Logan International Airport, there are four separate delay functions: One each for weekdays with good weather, weekdays with bad weather, weekends and holidays with good weather, and weekends and holidays with bad weather. For any one of these functions, the delay is a function only of the volume of traffic.

This completes the discussion of the method by which knowledge of daily delay for certain selected days is used to calculate yearly delay. This is the method used in this year's model. An alternate method that might be used in future versions of the model is explained in Appendix E.

2.5 GROUNDSIDE SERVICE MODULE

The groundside service module estimates the hours during which airport groundside facilities are insufficient to handle the airport and airport-related traffic. Fourteen facilities were investigated for adequacy:

1. Access Highway Lanes
2. Circulation Roadway Lanes
3. Arrival Curb Space
4. Departure Curb Space
5. Short-term Parking
6. Long-term Parking
7. Ticket Lobby Area
8. Passenger Service Counter Length

9. Airline Operations Space
10. Baggage Claim Area
11. Waiting Area Space
12. Waiting Area Seats
13. Men's Restroom Fixtures
14. Women's Restroom Fixtures

Estimates of facility use are computed from enplaned and deplaned passengers generated by the Demand Module and the Airside Service Module, respectively.

2.5.1 Assumptions of the Module

This section outlines the assumptions implicit in the Groundside Service Module. Each qualitative assumption is followed in parenthesis by the associated quantitative assumption for Boston's Logan Airport.

The number of originating passengers and the number of their well-wishers are set equal to some fraction (originating passengers - .897; well-wishers - .5) of the number of departing passengers. They arrive at the airport several (45) minutes before their scheduled departure. Their mode of access to the airport is split among private auto, taxi, bus, and limousine in a ratio (.67:.19:.10:.04) constant throughout the day and year. The number of airport-destined passengers per arriving vehicle (auto, .7; taxi, .7, bus, 20; limousine, 6) is also constant throughout the day and year.

Originating passengers and their well-wishers arrive at the terminal via the access highway and the terminal-bound lanes of the circulation roadway. Taxis, buses, limousines, and some (.5) fraction of private autos deposit their passengers at the departure curb, occupying curb space for a short time (auto, 2, taxi, 2, bus 10, limousine, 10; in minutes). Taxis then exit via the exit lanes of the circulation roadway and the access highway. Buses and limousines proceed to the arrival curb, picking up passengers before they depart. Some fraction (.8) of the private autos that dropped passengers at the departure curb leaves immediately; those automobiles not departing immediately and those not using the departure curb park in one of the airport lots. Some fraction (.5) seeks short-term parking; the remainder, long-term parking. When short-term parking is full, the overflow uses long-term parking. The current version of the model assumes that even when long-term spaces are completely full, the overflow is somehow accommodated in the long-term parking facility. The average duration of parking is airport specific (36 hours long-term, 1 hour short-term).

Once inside the terminal originating passengers wait in line in the ticket lobby area before being served at the passenger ticket counter. During this time, accompanying well-wishers wait elsewhere in the ticket lobby area.

After being ticketed (if necessary) and having baggage checked, originating passengers and their well-wishers join the inter- and intra-airline transfer passengers, who comprise some fraction of the arriving passengers (.064), in the waiting areas.

The number of terminating passengers and the number of their greeters is computed as some fraction (terminating passengers - .897: well-wishers - .5) of arriving passengers (always equal to the fraction that originating passengers and well-wishers comprise of departing passengers). The greeters arrive at the airport several minutes (45) before the scheduled arrival time of the flight they are to meet (equal to the number of minutes departing passengers arrive before their scheduled flight), and park in short-term facilities if possible, and long-term facilities otherwise. The terminating passengers, with their greeters, pick up their baggage at the baggage claim area, and then depart the terminal several minutes (15) after their arrival for their egress from the airport. Their egress mode of transportation is split among private auto, taxi, bus and limousine in the same ratio as the access mode of originating passengers. Taxi, bus, and limousine users are picked up at the arrival curb and exit the airport via the airport exit lanes of the circulation roadway and the access highway. Some fraction (.5) of the auto users also stop at the arrival curb, after some member of the arriving party and its greaters picks up the parked car. Time spent at the arrival curbside depends on the vehicle mode (auto, 3; taxi, 2; bus, 10; limousine, 10; in minutes). Auto users not returning to the arrival curbside exit via the departing lanes of the circulation roadway directly from the parking lot.

Airport and airline employees are a constant fraction of annual departing passengers (600 employees per one million enplaned passengers). They are assumed to work in three shifts — 8:00-4:00, 4:00-12:00, and 12:00-8:00 — with the employees split evenly between the shifts. They are also assumed to arrive in the hour preceding their shift and to depart in the hour their shift ends.

All departing passengers are assumed to perform their activities outside the terminal in an hour determined as follows: A specified time (45 minutes) is subtracted from their scheduled departure time. Their activities are assumed to occur in the hour containing this resulting time. Similarly, all arriving passengers perform their activities inside the terminal in their hour of arrival and their activities outside the terminal in the hour containing the minute occuring a specified time (15 minutes) after their arrival.

2.5.2 Operation of the Module

The Groundside Service Module receives the hourly scheduled enplaned passenger volume from the Demand Module and the hourly arriving passenger volume from the Airside Service Module. Based on these data and the assumptions detailed in Section 2.5.1, passenger and vehicle passage through the various parts of the on-airport groundside system can be computed for each hour.

Non-airport-related traffic on the access highway is passed to the groundside module from the data base. This is added to the airport-generated traffic to compute the load on the off-airport access highway. Based on the standards shown in Table 2-8

TABLE 2-8. GROUNDSIDE FACILITY STANDARDS

1.	Hourly auto-equivalents *(AE's) per roadway or highway lane	1200
2.	Car-lengths **(CL's) per foot of curb space	0.075
3.	Ticket lobby area (sq. ft/hourly passengers)	12.0
4.	Passenger service counter (ft/hourly passengers)	0.5
5.	Airline operations space (sq. ft/hourly passengers)	0.5
6.	Baggage claim area (sq. ft/hourly passengers)	5.0
7.	Waiting area (sq. ft/hourly passengers)	20.0
8.	Waiting area (seats/hourly passengers)	0.7
9.	Men's restrooms (fixtures/hourly interminal passengers)	0.02
10.	Women's restrooms (fixtures/hourly interminal passengers)	0.02

*Auto = 1AE, Taxi = 1AE, Bus = 2.1AE, Limousine = 1.2AE
**Auto = 1CL, Taxi = 1CL, Bus = 2.1CL, Limousine = 1.2CL

Source: Standards based on data in Reference 6.

requirements for each of the 14 facilities listed in Section 2.5 above can be derived for each hour. These requirements are compared to existing facilities as input by the user or retrieved from the data base. When requirements exceed availability, the facility is flagged as being saturated during the hour. The list of saturated facilities and the hours they are saturated constitute the output of the Groundside Service Module.

Annual performance of the groundside system is estimated in the same manner as that of the airside system (Section 2.4.5). The hours of congestion for each facility during representative 24-hour demand periods are weighted and summed to produce expected annual saturation. The annual results are reported as total hours saturated rather than as the specific times during a day a facility is reported saturated for individual 24-hour periods.

2.6 USER INTERACTION

Any large-scale computer system intended to aid analysts in their work must be accessible to someone other than the experienced programmer. Many sophisticated systems are poorly used, not because of technical failings, but because their operation is inscrutable to the intended user. The Airport Performance Model provides an extensive set of interactive capabilities that enable the airport planning analyst to control its operation effectively; the model communicates those capabilities through commands and interrogations in a format and language familiar to the analyst.

Figure 2-10 illustrates the model's user-interactive capabilities. The model is self-instructive; the user need only know how to start the interactive process (the LOG ON procedure; see Model User's Guide, Appendix F). Once the process has been started successfully, the executive program asks the user for the information needed to run the model, informs the user of the availability of optional user requests, and instructs the user on the proper way to implement options and to input data.

```
   .RUN NAS

   HELLO. WHAT AIRPORT ARE YOU INTERESTED IN ?PLEASE USE A 3 LETTER CODE
   FOR: ATL,BOS,DCA,JFK,LAX,LGA,MIA,ORD OR SFO                          .
U: BOS

   THANKS FOR SELECTING BOSTON

   TYPE OF ANALYSIS DESIRED - HOURLY OR DAILY?
U: DAILY

   STANDARD VFR RATE = 120 OPS/HR
   STANDARD IFR RATE =  65 OPS/HR
   DO YOU WISH TO CHANGE THESE RATES ? YES OR NO
U: NO

    SPACING IS SET FOR 3MILE/5MILE - 35

    DO YOU WANT TO CHANGE IT TO 37, YES OR NO?
U: NO

   DO YOU WANT TO CHANGE THE WEATHER ARRAY - YES OR NO ?
U: NO

.  DO YOU WANT TO SEE INPUT FIGURES - YES OR NO ?
U: YES
```

Figure 2-10. Sample User/Model Interaction

The major user options are his ability to examine and to modify the data base, and to determine the time period to be modeled. Currently, the user can only examine those elements of the data base shown in Appendix F (the Model User's Guide). When the system is fully developed, the user will have the option of examining any element in the data base as well as certain aggregates, sums, and averages. The user can currently modify only those elements of the data base shown in Appendix F. When the system is fully developed, the user will be able to modify any element individually and alter certain groups of elements by a constant factor or product.

The user must specify the airport to be modeled and whether the model is to simulate activity for several hours, for a single day, or for a year. If the model is run for a day, the user must also specify what day's data, of all those stored in the data base, applies.

Currently, the user receives a standard output report (illustrated in Section F.4 of Appendix F) after the model is run. When the system is fully implemented, the user will have the option of asking for more information or for a finer breakdown of several of the output statistics.

3. MODEL OPERATION AND APPLICATION

The Airport Performance Model is designed to translate activity at air carrier airports into measures of public use. This process requires a substantial amount of both input parameters and output data for each airport to be modeled. To be an effective analytic tool, such a model must allow the analyst to vary or experiment with different values of a wide range of these parameters, and it must provide a range of output data broad enough to capture performance changes in all major airport subsystems.

3.1 USER SPECIFIED INPUT PARAMETERS

There are only two parameters that the analyst must specify to run the Airport Performance Model – the airport and the time period to be modeled. The data base contains historical values for all other parameters that it needs; if the analyst does not specify alternate values for these parameters, the historical or default values will be used. The set of default values that the analyst may alter depends on the second mandatory input – the time period to be modeled. One set of default values is used for model runs covering one day or several hours of airport operations. A second, extended set is used to model a full year's operations.

If the analyst elects to model a day's operations, and specifies no other parameters except the airport, the model will simulate one full day of operations for VFR conditions; the current VFR aircraft processing rate (airside saturation capacity); existing ground-side facility dimensions; and the aircraft mix, arrival-departure ratio, passenger load factor, and minute-by-minute aircraft activity schedule for a recent weekday having 107 percent of this year's anticipated average daily aircraft volume. The enplaning and deplaning passenger flow through the terminal is determined by the aircraft activity schedule, seats per aircraft type, and average hourly load factor. Tables 2-1, 2-2, and 2-3 show the complete set of input data that the data base transfers to the model for a single day's analysis.

The analyst may vary any of these parameters; he might choose to increase the VFR aircraft processing rate, change the weather conditions to IFR for certain hours during the day, increase the total aircraft volume for the day, increase the percentage of heavy aircraft in the mix, increase the average load factor, shift the concentration of scheduled aircraft activity during certain hours, etc. Note that the passenger flow would be changed by any change to mix (through the number of seats per aircraft type), load factor, or aircraft traffic volume.

Since annual results are determined by computing the weighted sum of the daily results for 16 representative days (see Section 2.4.5), the default-valued parameters that may be modified for modeling a year's activity are basically the same that may be modified in modeling a day's activity. In the case of a year's activity, these changes may be applied to all days during the year, or they may be applied to a specific representative day or days (and thus to all the days the specified day represents). For example, the aircraft mix might be altered to exclude small aircraft or unscheduled traffic throughout the year; or this exclusion might only be applied to the 33 days a year on which traffic exceeds 120% of the average daily aircraft volume (represented by the weekday traffic profile having an operations count equal to 126% of the average daily volume – see Section 2.4.5).

Additional existing parameters that may be altered when modeling annual operations are those affecting the magnitude of total annual operations. These include the values for total annual passengers, total annual aircraft operations, total scheduled aircraft operations, and total unscheduled aircraft operations.

3.2 MODEL OUTPUT DATA

The output data provided by the Airport Performance Model are also a function of the time period being modeled; one set of results is produced for model runs covering one day or several hours of activity, and a second set is produced for runs modeling a year's activity. In both cases, the model will first produce a standard result report. The analyst can then request more detail for one of the parameters reported, or request information not shown in the standard report. A complete list of output variables and report options appears in Appendix F.

The results reported for a day's activity can be grouped into two categories — airside results and groundside results. The airside results comprise the day's total scheduled aircraft operations, total nonscheduled aircraft operations, total airside passenger delay time (in minutes), total airside passenger delay costs, total aircraft delay time, total number of aircraft delayed, the dollar cost of aircraft delay, and other information on the delayed aircraft. The groundside results comprise total passenger movements for through passengers, transfer passengers, originating passengers, and terminating passengers, and the hours during which groundside facilities — such as ticket counters, the circulation roadway, and short-term parking — are overloaded. Figure 3-1 shows a sample output for a single day's activity.

The analyst may require more detailed information for one or more of these results. For example, he may be interested in hour-by-hour analysis of aircraft delay, including each hour's total delay, maximum delay, the number of aircraft (arrival or departure or both) actually delayed, etc. Or he may wish to see the number of people using a groundside facility during each hour it was overloaded. The capability to request more detail on specified results provides the analyst with the ability to examine more deeply changes in subsystem performance measures, enabling him to understand the nature of and reasons for projected performance improvements.

The results reported for annual activity are the same as those for daily activity. The aircraft activity counts, the airside delay time and cost figures for aircraft and passengers, and the through, transfer, originating, and terminating passenger movements are, in this case, all annual totals. The report on groundside facilities congestion comprises the number of days during the year on which each facility was overloaded at any time.

```
DAILY STATISTICS


 MAX Q LENGTH          MAX AC DELAY          TOTAL # AC DELAYED

      10                   7.83                   398.


TOTAL AC-MIN DELAY     TOTAL # AC DELAYED    AVERAGE MIN DELAY PER
                        30 MINS. OR MORE          DELAYED AC

      769.                 0.00                   1.93


AVERAGE MIN DELAY PER    TOTAL PAX DELAY     PASSENGER DELAY COST
   AC SERVICED

      1.18                  37602.           $   9400.59


TOTAL AC DELAY COST

   $   492775.

DO YOU WANT TO SEE GROUNDSIDE STATISTICS - YES OR NO?
YES
```

Figure 3-1. Sample Output – 24-Hour Run

PASSENGER MOVEMENTS

HOUR	THROUGH	TRANSFERS	ORIGINATING	TERMINATING	ENPLANED
1	40.	65.	914.	914.	1019.
2	25.	42.	585.	585.	652.
3	32.	53.	740.	740.	825.
4	27.	45.	628.	628.	700.
5	2.	3.	41.	41.	46.
6	2.	3.	41.	41.	46.
7	11.	19.	264.	264.	294.
8	112.	184.	2573.	2573.	2869.
9	135.	222.	3116.	3116.	3474.
10	198.	325.	4554.	4554.	5077.
11	165.	271.	3794.	3794.	4230.
12	100.	165.	2308.	2308.	2573.
13	171.	281.	3935.	3935.	4387.
14	101.	166.	2331.	2331.	2599.
15	141.	231.	3237.	3237.	3609.
16	122.	200.	2802.	2802.	3124.
17	166.	273.	3827.	3827.	4266.
18	193.	317.	4437.	4437.	4947.
19	163.	267.	3740.	3740.	4170.
20	157.	258.	3621.	3621.	4037.
21	151.	248.	3472.	3472.	3871.
22	107.	175.	2453.	2453.	2735.
23	76.	125.	1747.	1747.	1948.
24	41.	68.	950.	950.	1059.

SATURATED GROUNDSIDE FACILITIES

	FACILITY	HOURS
1	ACCESS HWY LANES	5
2	CIRCULATION RDWY LANES	6
3	ARRIVAL CURB SPACE	10
4	DEPARTURE CURB SPACE	6
5	SHORT TERM PRKG SPACE	24
6	LONG TERM PRKG SPACE	24
7	TICKET LOBBY AREA	4
8	PAX SERVICE COUNTER	11
9	AIRLINE OPERATIONS SPACE	9
10	BAGGAGE CLAIM AREA	11
11	WAITING AREA(SQUARE FEET)	7
12	WAITING AREA (SEATS)	4
13	MENS REST ROOM (FIXTURES)	4
14	WOMENS REST ROOM (FIXTURES)	4

Figure 3-1. Sample Output — 24-Hour Run (Continued)

3.3 MODEL APPLICATIONS

To describe the applications for which the Airport Performance Model is intended, it is important to distinguish between two types of airport analysis. The first type is concerned with the physical or engineering impact of new equipment or new construction; an example is the determination of the processing rate increase that a wake vortex avoidance system will produce at airports serving heavy jet aircraft. This type of analysis deals with the efficiency of a particular subsystem under a set of assumed demand conditions.

The second type of analysis deals with the change in the quality or volume of public use that subsystem efficiency changes will produce; an example is estimation of the reduction in busy-day passenger delay that a wake vortex avoidance system would produce at an airport. This type of analysis translates estimated efficiency gains into public benefits based on actual demand volumes and characteristics.

The Airport Performance Model is designed for the second type of analysis. It translates efficiency gains from airport facility modifications or operational modifications into public benefit. The input parameters discussed in Section 3.1 can be altered to represent a wide variety of facility and operational changes. The output parameters described in Section 3.2 measure the change in performance these modifications will deliver.

The model can be used in two ways. First, one of the following changes can be made to the input parameters for an airport:

1. Change in airside processing rate (VFR or IFR) resulting from new investment.
2. Change in aircraft separation standards.
3. Change in aircraft mix.
4. Change in demand peaking.
5. Change in schedule concentration (the number of aircraft operations scheduled on the same minute in an hour).

6. Change in hourly load factors.

7. Transfer of GA traffic to reliever airport.

The model will then estimate values for the following performance measures keeping all other parameters — aircraft volume, passenger volume, time distribution of demand, etc. — unchanged:

1. Delay time — passengers and aircraft

2. Delay costs — passengers and aircraft

3. Serviceable passenger volume (for constant delay)

4. Groundside facility congestion

By comparing these results to those from a base-case run (in which all default values are used), the effect of the parameter change on airport performance can be determined. This type of analysis can be used to examine the effects of a specific investment at an airport. Alternatively, annual passenger volumes or aircraft volumes can first be changed (perhaps increased to forecast levels for some future time) and one of the above parameters can then be changed incrementally for a series of model runs. Plotting the results or recording them in a table would then produce a function expressing the successive percentage increases in airport performance achievable by successive percentage changes in airport capabilities or procedures. Functions developed in this way can be used to assess the marginal increase in airport capabilities that airport investments must produce in order to provide specified levels of performance under future demand volumes. By specifying appropriate future demand volumes and levels of performance, these functions can be used to develop minimum standards or criteria for airport investments.

Table 3-1 shows two examples of the functions that might be developed through this."incremental" analysis. In the first case, the analyst has increased Boston annual operations volume to its forecast 1986 level and made an initialization run using the existing (1975) airside good visibility processing rate (Rg). By making successive runs, each with an incremental increase in airside capacity of 3%, the analyst has produced a tabular function showing

TABLE 3-1. AIRPORT CRITERIA ANALYSIS

AIRPORT: BOS

DEMAND: 575,000 OPS (1986)

PARAMETER: ΔRG/RG	CHANGE IN DELAY COSTS ($000)	
	AIRCRAFT	PAX
+.03	-082	-178
+.06	-156	-378
+.09	-257	-652
+.12	-301	-702
+.15	-327	-746

AIRPORT: BOS

DEMAND: 9,976,000 PAX (1986)

PARAMETER: ΔD&E/D&E	CHANGE IN DELAY COSTS($000)	
	AIRCRAFT	PAX
-.10	-36	-84
-.20	-54	-102
.	.	.
.	.	.
.	.	.
-1.00	-257	-652

the change in annual delay cost produced by changes in the airside hourly capacity. This function could be used to establish the minimum percentage increase in airside capacity that a proposed new runway (or other investment) would have to produce to justify its construction.

The second example in Table 3-1 shows the changes in annual delay cost produced by reductions in the member of general aviation aircraft (classes D and E) at Boston's Logan Airport. In this case, the level of activity is defined by the 1984 forecast passenger demand, since the member of aircraft operations will decrease with reductions in general aviation use. This second function could be used to establish the minimum fraction (or increase to that fraction) of general aviation activity expected to be diverted to a reliever airport before the reliever airport's development (or improvement) is warranted.

4. EXTENSIONS AND REFINEMENTS

This year's version of the Airport Performance Model calculates the airside delay and groundside congestion implied by a particular pattern of demand and by airport capabilities. This model could be improved by gathering better data, refining the modeling techniques, and by extending it to other airports. Extending the model to other airports is straightforward (although time consuming) since the modeling techniques explained in Section 2 are general and apply to all airports; all that is necessary to apply the model to an airport is to assemble the data base for that airport. Therefore, the possible improvements to the model that merit discussion are those concerned with gathering better data or refining the techniques.

4.1 ASSUMPTIONS OF THE MODEL

The Airport Performance Model makes a number of assumptions about demand patterns and airport operations. These assumptions, which illustrate the proper application and limitations of the model, include:

1. The processing rate (saturation capacity) is a deterministic function of weather, mix, and arrival-departure ratio.
2. Weather, mix, and arrival-departure ratios change only on the hour.
3. Aircraft can be divided into five classes; all aircraft in a class are assumed to be identical (i.e., to have the same number of seats, same cost of delay, etc.).
4. Annual demand can be expected to demonstrate similar peaking characteristics from year to year.
5. The scheduled flight times are a suitable approximation of actual flight times.
6. A day's general aviation activity volume can be divided

into two blocks — the fraction during daylight hours and that during night hours. The traffic distribution between these two blocks is assumed to be the same for any day.

7. Only two types of weather — good and bad — need be distinguished.
8. A year's weather can be suitably represented by two weather profiles.
9. Aircraft request service at the beginning of a minute.
10. The groundside facilities requirements are a suitable indicator of groundside congestion.

4.2 IMPROVEMENTS TO THE PROCESSING RATE MODULE

There are three areas in which the Processing Rate Module might be improved. First, the processing rate is assumed to be a deterministic function of weather, mix, and arrival-departure ratio. The processing rate could be made stochastic, and it could be made a function of other variables, such as the length of the queue.

Second, the processing rate is now averaged over arrivals and departures. Different rates could be used, and arrivals and departures could be kept in separate queues.

Third, the AIL modeling work (References 1 and 7) is the basis for varying the processing rate with changing mix and arrival/departure ratio. Other studies of the functional relationship between the processing rate and mix, arrival/departure ratio, separation standards, and the like might be used (References 8, 9 and 10).

4.3 IMPROVEMENTS TO THE DEMAND MODULE

There are five areas in which the Demand Module might be improved. First, the minute-by-minute demand profiles, which are critical to the delay calculation, deserve attention. Scheduled flight times could continue to be used to approximate actual times, but with a stochastic factor included. Perhaps the flight times could be generated by a stochastic process centered around scheduled times and with a deviation based on flight stage length, or perhaps analysis of flight strips from airport towers might lead to a method of suitably approximating actual flight times.

Second, the modeling of general aviation activity could be carried out in more detail. Instead of evenly distributing 90 percent of the daily GA traffic between 8 a.m. and 10 p.m., as was done for Boston Logan, a more appropriate time-dependent scheme might be devised.

Third, the weather descriptor could be expanded. Perhaps it would be desirable to distinguish between more than two types of weather, adding categories for high winds, low visibility, precipitation, and the like. Also, since the approach used to construct the weather profiles was ad hoc (see Appendix C), it would be worthwhile to analyze the data more carefully and to pay more attention to the relationships among weather, traffic, volume, and delay.

Fourth, volume in this year's model is stated in terms of operations, but it should also be possible to state it in terms of passengers. This would allow the user to input either a forecast volume of operations or of passengers.

Fifth, the method used to disaggregate annual demand into daily demand should be re-examined. The method for selecting the representative days used to estimate the annual delay function should be based on a more thorough knowledge of the relationship between traffic volume and delay.

4.4 IMPROVEMENTS TO THE AIRSIDE SERVICE MODULE

There are three areas in which the Airside Service Module might be improved. First, taxiway and gates could be modeled. This would fill a gap in the current model.

Second, the method by which daily delay is aggregated into annual delay could be improved. It is necessary to decide whether the delay function can best be approximated by a step function (see Section 2.4.5) or by a piecewise linear function (see Appendix E).

Third, the current model does not allow diversions and cancellations; these might be modeled in future versions.

4.5 IMPROVEMENTS TO THE GROUNDSIDE MODULE

The groundside module measures the quality of groundside service by comparing passenger flow volumes and the physical dimensions of the groundside facilities to accepted standards for those facilities. Currently, it judges a facility to be either congested or uncongested during each hour.

This module could be modified to assess varying degrees of congestion. For certain facilities, passenger delays could be computed in addition to facility saturation. The module could also be modified to eliminate many macroscopic treatments incorporated to put the module in operation as quickly as possible. For example, each of the facilities not shared among airlines could be modeled at the airline level so that one airline's slack facility would not be used to satisfy another's excess demand. Also, airline and airport employee traffic flows can be modeled more exactly by allowing more detailed input, such as whether they park in the same lots and use the same on-airport access roads as the passenger. More detailed input might also specify whether buses, limousines, and taxis use the same curb areas as automobiles, different but shared curb areas, or mode-dedicated curb areas.

The groundside module could be extended to address congestion in other facilities, such as corridor, escalator, baggage-handling areas, and concessions. Although such modifications are minor conceptually, every facility examined increases the amount of data that must be maintained in the airport data base.

The groundside module could also be modified to incorporate one of the groundside simulations being investigated as part of TSC's Airport Landside Capacity Program (FA632).

4.6 CONCLUSIONS

This year's version of the Airport Performance Model can be used to estimate how a change in demand, an airport's processing rate, or operating policies affect the amount of airside delay and groundside congestion that occur at that airport. The model has not yet been validated; therefore, one should not have blind confidence in the estimates generated by the model. Thus, in addition to the refinements and extensions described for each module above, the entire model must be calibrated and validated for several airports that represent the airport types to be analyzed by the FAA.

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APPENDIX A — THE PROCESSING RATE MODULE

A.1 INTRODUCTION

The airside processing rate is defined to be the maximum number of aircraft that the airside can handle in a hour using normal operating practices. The input to the Processing Rate Model consists of two processing rates: a good weather processing rate for a typical mix and an arrival-departure ratio of unity, and a bad weather processing rate for that mix and arrival-departure ratio. The purpose of the Processing Rate Module is to adjust these processing rates in order to obtain the rates that are appropriate when the mix differs from the typical mix or when the arrival-departure ratio is not unity. The purpose of this appendix is to explain how these adjustments are made.

The method used to adjust for mix and arrival-departure ratio is the AIL approach (References 1 and 7). However, the AIL approach differs from the approach used in this report in two respects. First, the AIL results are expressed in terms of a practical capacity instead of in terms of a processing rate. Second, the AIL work does not recognize the effect of heavy jets on airport operation.

The organization of this appendix is as follows. We start with a good weather processing rate and a bad weather processing rate, where mix is assumed to be at a typical value and the arrival-departure ratio is unity. If the typical mix contains any heavy jets, the effect of these heavy jets must be taken out of the processing rate in order to achieve comparability with the AIL framework. Section A.4 does this. Then Section A.5 transforms the processing rate into a practical capacity. The AIL work is then used in Sections A.6 to A.8 to adjust this practical capacity for changes in mix and arrival-departure ratio. Finally, Section A.9 indicates how this adjusted practical capacity is transformed back into the processing rate required by the Airport Performance Model. This organization is depicted in Figure A-1, and the symbols are defined in Section A.3.

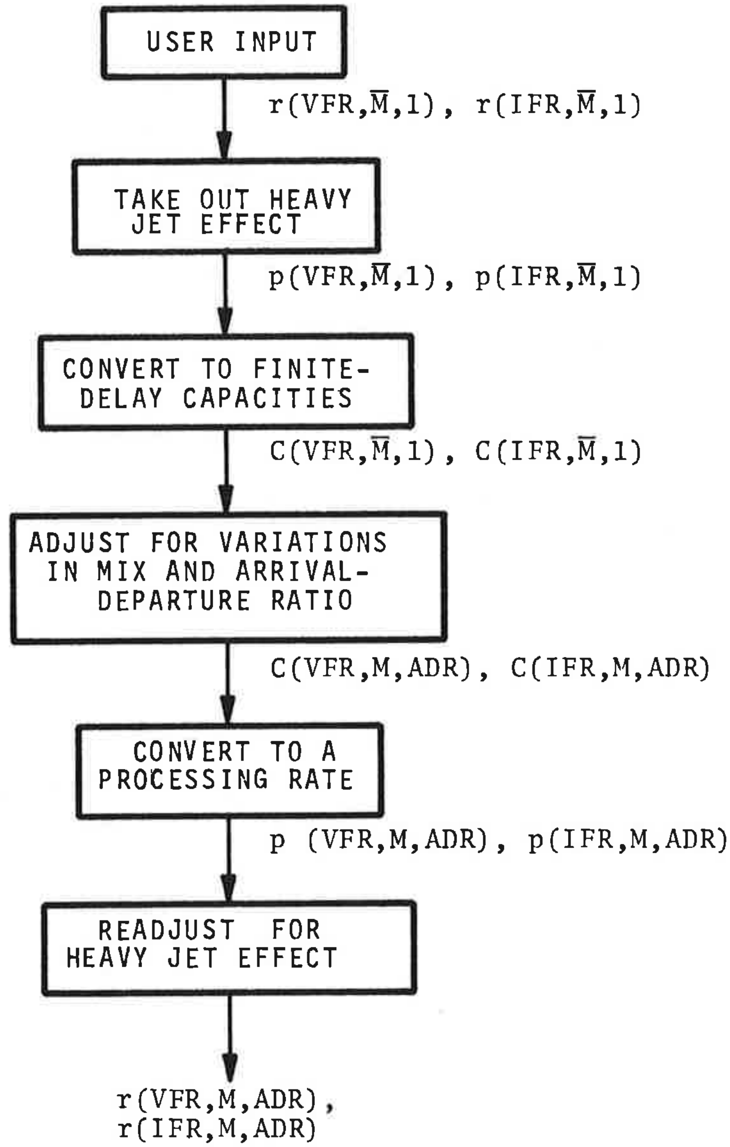

Figure A-1. Simplified Flow Diagram of the Processing Ratio Module

A.2 SOURCES

The adjustments described in this appendix are based primarily on FAA publication, AC 150/5060-IA, "Airport Capacity Criteria Used in Preparing the National Airport Plan," July 1968 (abbreviated AC). The reader should be familiar with this publication. AC is based on the AIL model described in the "Airport Capacity" handbook, FAA/BRD-136, June 1963 and in "Operational Evaluation of Airport Runway Design and Capacity," Report 7601-6, FAA/BRD-136, January 1963. Information on the effect of heavy jets is taken from "FAA Report on Airport Capacity — Vol. I — National Summary," FAA-EM-74-5, 1, January 1974.

A.3 NOTATION

The following notation is used:

W	the weather, which takes on the values of VFR and IFR
$M=(m_1,m_2,m_3,m_4,m_5)$	the mix of aircraft types during the hour in question; m_i is the number of aircraft of type i that request service during the hour as a percentage of the total number of aircraft for that hour
$\bar{M}$	the typical mix at the airport
ADR	the arrival-departure ratio during the hour
r(W,M,ADR)	the processing rate in terms of planes per hour when the weather, mix, and arrival-departure ratio take on the values W,M, and ADR, respectively
p(W,M,ADR)	the processing rate after the effect of heavy jets has been taken out
c(W,M,ADR)	the practical capacity at an airport in terms of planes per hour
SPN	the spacing standards; SPN takes on values 35 for 3 mile/5 mile spacing and 37 for 3 mile/7 mile spacing.

The aircraft classes are defined as follows:

k=1	heavy jets (i.e., B747, L1011, DC10, stretched B707, stretched DC8, and Concorde)
k=2	class A aircraft
k=3	class B aircraft
k=4	class C aircraft
k=5	class D and E aircraft

The definitions of the different aircraft classes are shown in Table 2-3.

A.4 ADJUSTING FOR HEAVY JETS

We start with $r(\text{VFR},\bar{M},1)$ and $r(\text{IFR},\bar{M},1)$, good and bad weather processing rates for a typical mix and an arrival-departure ratio of one. The "typical mix" might include some heavy jets. However, the work in AC was done before the effect of heavy jet wake vortexes was fully appreciated and does not allow for the effect of heavies on capacity. Therefore, in order to use the results reported in AC, we must remove the effect of heavies from $r(\text{VFR},\bar{M},1)$ and $r(\text{IFR},\bar{M},1)$ by ajusting the processing rates upward. That is, since heavies take longer to process than other planes, by removing heavies from the mix the number of planes that can be processed increases. Let $p(\text{VFR},\bar{M},1)$ and $p(\text{IFR},\bar{M},1)$ be the processing rates for good and bad weather where the effect of heavies has been removed.

Based on the "FAA Report on Airport Capacity, Vol. 1 — National Summary," FAA-EM-74-5, January 1974, Appendix A, Figure A-4, it was found that the processing rate fell 32 percent as the proportion H of heavy jets increased from 0.0 to 1.0, for 3 mile/5 mile separation standards (i.e., separation is 3 miles following a light and 5 miles following a heavy). A quadratic was fit to the data in the referenced table for both 3/5 and 3/7 spacing. The results are:

$$p(W,M,ADR) = \frac{r(W,M,ADR)}{.997-.426H + .109H^2}$$

for 3/5 spacing and

$$p(W,M,ADR) = \frac{r(W,M,ADR)}{.987 - .640H + .184H^2}$$

for 3/7 spacing. These formulas allow us to convert $r(VFR,\bar{M},1)$ to $p(VFR,\bar{M},1)$ and $r(IFR,\bar{M},1)$ to $p(IFR,\bar{M},1)$.

A.5 CONVERTING A PROCESSING RATE TO A PRACTICAL CAPACITY

The next step is to convert the processing rate $p(W,\bar{M},1)$ to a practical capacity. A practical capacity is defined to be the largest average rate at which aircraft request service is consistent with exponentally distributed interarrival times, subject to the constraint that the average delay per aircraft be less than or equal to some specified figure. In other words, practical capacity is the largest number of aircraft an airport can handle, given realistic bunching of flights, if the average delay per plane is to be less than, say, 4 minutes. The conversion of processing rate to practical capacity is done via Figures 15 and 16 of AC, Appendix 2. (Throughout this appendix it is assumed that 1 is the appropriate exit rating. Also, the figure numbers from AC have been preserved.) The asymptotes of these curves correspond to the processing rate (in planes per hour) since these give the maximum number of planes that can be processed. The practical capacity is found by choosing an average delay on the vertical axis and then reading a practical capacity on the horizontal axis. The particular value of average delay that is chosen depends on whether the weather is IFR or VFR.

IFR: As stated in AC, Appendix 2, page 1, Section 1.a(3), practical capacity is based on a four minute average delay. From Figure 16, one may obtain the practical capacity on the horizontal axis that corresponds to a 4 minute average delay on the vertical axis if he knows which curve to use. The appropriate curve is the one for which the asymptote equals the $p(IFR,\bar{M},1)$. The asymptote is approximated for each curve of Figure 16 as 1.10 times the practical capacity for that curve when a 4 minute average daily is assumed. Hence, for the IFR case, the practical capacity $c(IFR,\bar{M},1) = .91\ p(IFR,\bar{M},1)$.

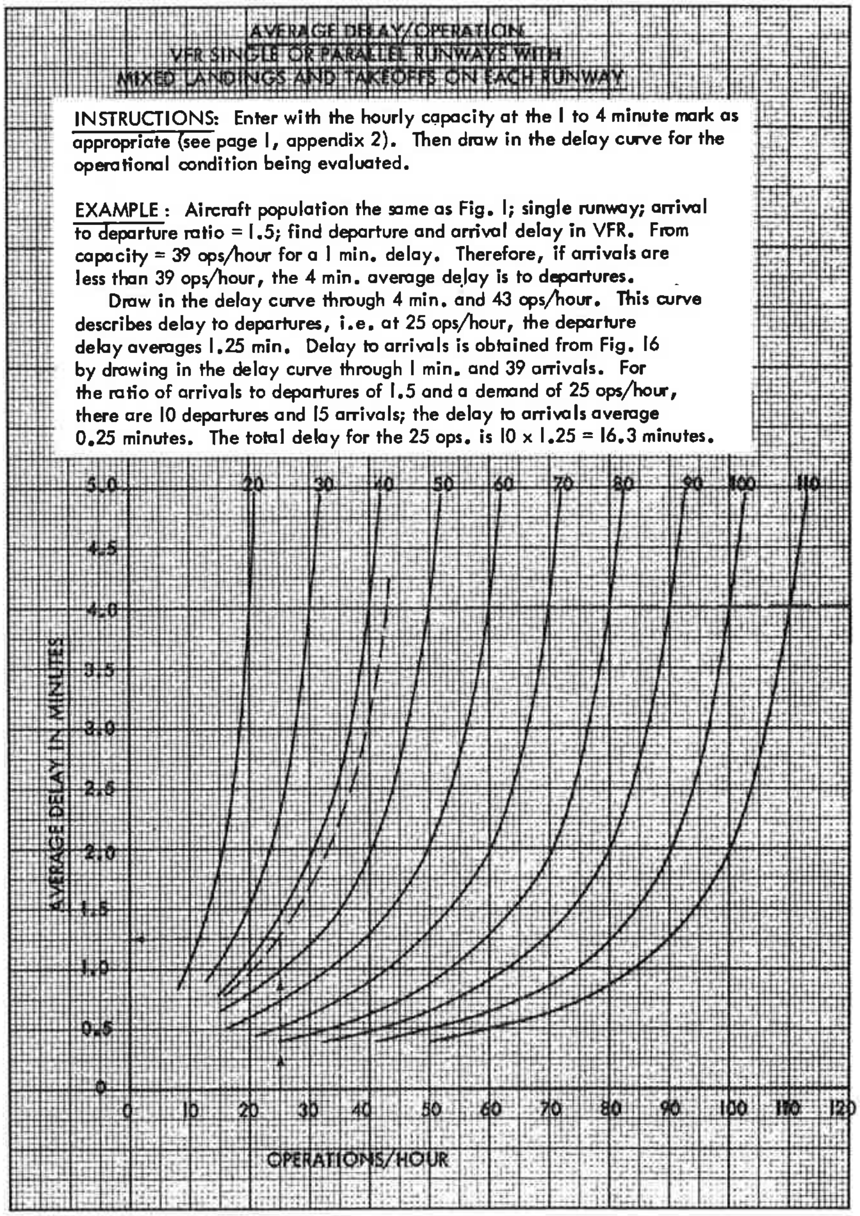

FIGURE 15. AVERAGE DELAY/OPERATION - VFR SINGLE OR PARALLEL RUNWAYS WITH MIXED LANDINGS AND TAKEOFFS ON EACH RUNWAY

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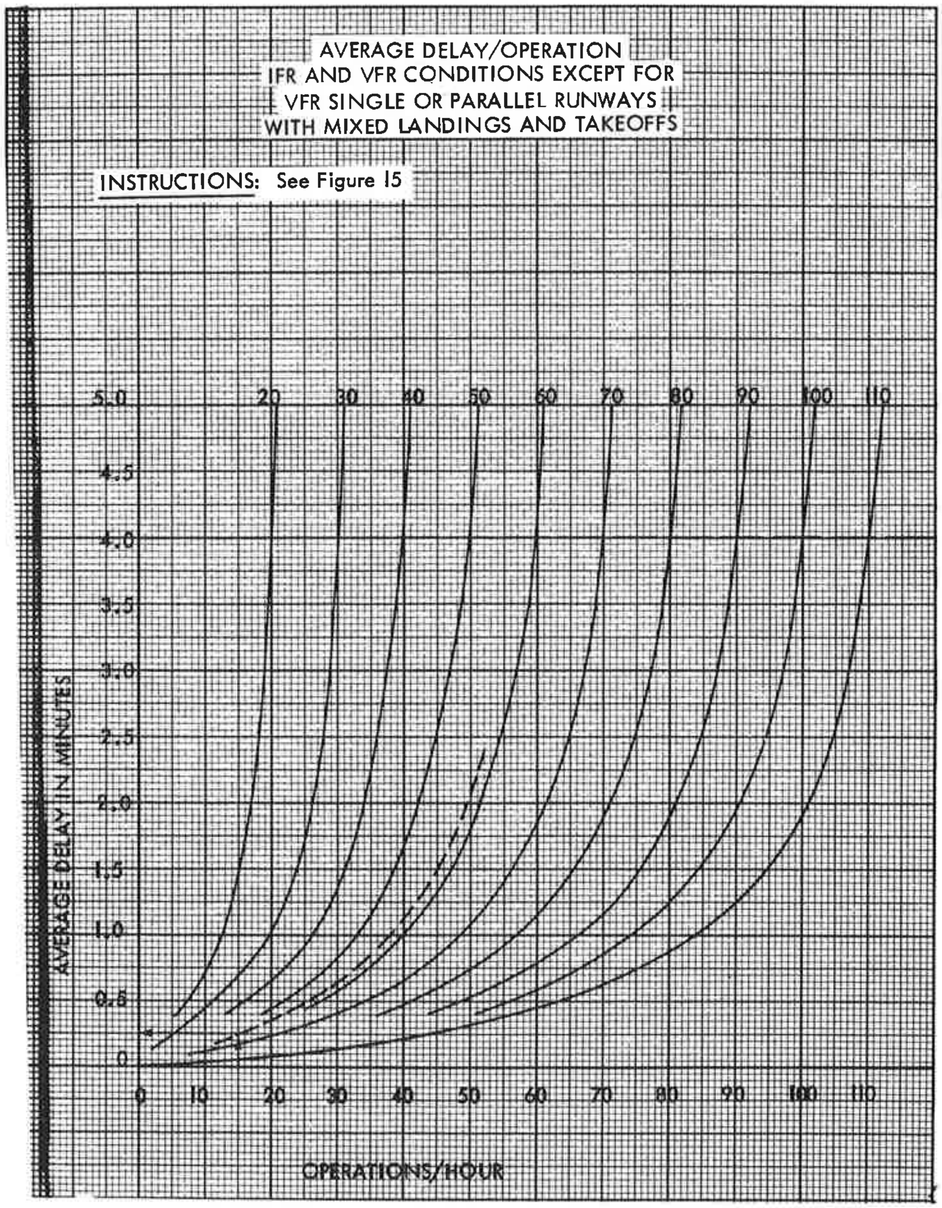

FIGURE 16. AVERAGE DELAY/OPERATION - VFR & IFR
FOR CONDITIONS NOT COVERED BY FIGURE 15

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VFR: As stated in AC, Appendix 2, Page 1, Sections 1.a.(1) and (2), the practical capacity is based either on a 1 minute average delay to arrivals or on a 4, 3, or 2 minute delay to departures. Hence, it is necessary first to determine if delay is to arrivals or to departures. The test for arrival-limited capacity is described in AC, Appendix 2, Section 2.d, page 11. For the assumed value of ADR (=1.0) the test will fail, since $0.6 \leq ADR \leq 1.1$. Thus, the VFR case reduces to determining the departure delay. This is a function of mix, as given in AC, Appendix 2, Section 1.a. (1), Page 1. If the percentage of A and B aircraft is greater than 10, the delay is 4 minutes; if the percentage is between 1 and 10, the delay is 3 minutes; if the percentage is less than 1, the delay is 2 minutes. (Heavies are counted as part of class A for this calculation).

Having determined the appropriate departure delay, Figure 16 gives the practical capacity by the same means as described for IFR above. It is seen from this figure that the 3-minute VFR practical capacity is roughly 87 percent of the processing rate and that 2-minute VFR capacity is about 80 percent of the processing rate. Hence, the approximations used are

$$c(VFR,\bar{M},1) = \begin{cases} .91.p(VFR,\bar{M},1) & \text{if } A+B \geq 10 \\ .87.p(VFR,\bar{M},1) & \text{if } 1<A+B<10 \\ .80.p(VFR,\bar{M},1) & \text{if } A+B \leq 1. \end{cases}$$

A.6 CALCULATING THE MIX NUMBER

Thus far the processing rates input by the user have been adjusted to take out the effect of heavy jets and have been converted into practical capacities. The next task is to adjust the practical capacities to allow for variations in mix and the arrival departure ratio.

The mix for the hour consists of five numbers $M = (m_1,m_2,m_3,m_4,m_5)$ which give the percentage of planes requesting service during the hour that are of each type. It will be handy to condense these five numbers into a single "mix number that will describe the mix. (Heavy jets are added to class A in arriving at a mix number.)

VFR: The VFR capacity curves in AC, Appendix 2, Figure 1–6, reproduced here, have mixes listed along the X-axis. The interval of interest is from X=0 to X=7, in the arbitrary units of the graph paper employed. There are 3 cases:

(1) If any Class A aircraft are in the mix, then the lowest abscissa scale in Figures 1–6 is employed. Interpolation is done by Figure 10 on the basis of the percentage of Class B aircraft.

(2) If no Class A aircraft are in the mix, but some Class B aircraft are, then the next to the bottom abscissa scale is used. Interpolation is done by Figure 11 on the basis of the percentage of Class C aircraft; Classes D and E are ignored.

(3) If no Class A and no Class B aircraft are present, but some Class C aircraft are, then X is assumed to increase linearly from X=0 to X=2.0 as the percentage of Class C aircraft increases from 0 to 30, and to remain at X=2.0 for Class C greater than 30 percent. The rationale for limiting X is that the continued capacity drop shown on the curves of Figures 1–6 is due to increased proportions of Class A and B assumed in the abscissa scales. Since, in the present case, we are assuming Class A = Class B=0, capacity drops below Class C = 30% would not occur.

The interpolation formulas for cases (1) and (2) above are taken directly from Figures 10 and 11, except that the small kinks near the origin of Figure 11 were ignored for simplicity. The formulas are:

$$X = 4.0 + \frac{1}{20}\left[\frac{B}{2} + \frac{5}{4}\,(H+A-20)\right], \text{ Figure 10}$$

$$X = 2.0 + \frac{1}{30}\left[\frac{C}{2} + \frac{10}{9}\,(B-15)\right], \text{ Figure 11}$$

where H + A is the total percentage of heavy jets and Class A, and B is the perfentage of Class B. For Logan Airport, the first formula is usually the appropriate one to use for determining the mix number.

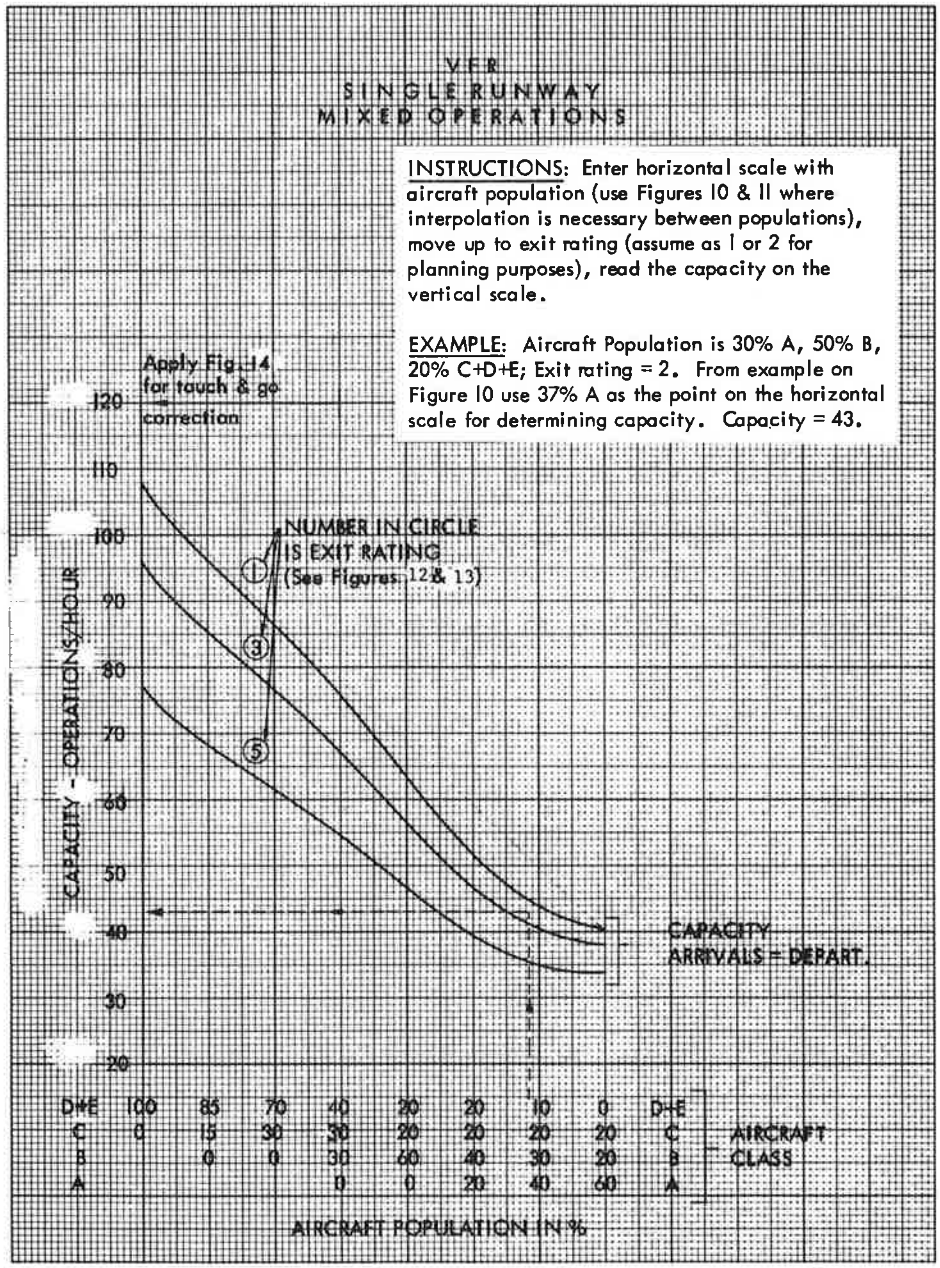

FIGURE 1. SINGLE RUNWAY CAPACITY - VFR

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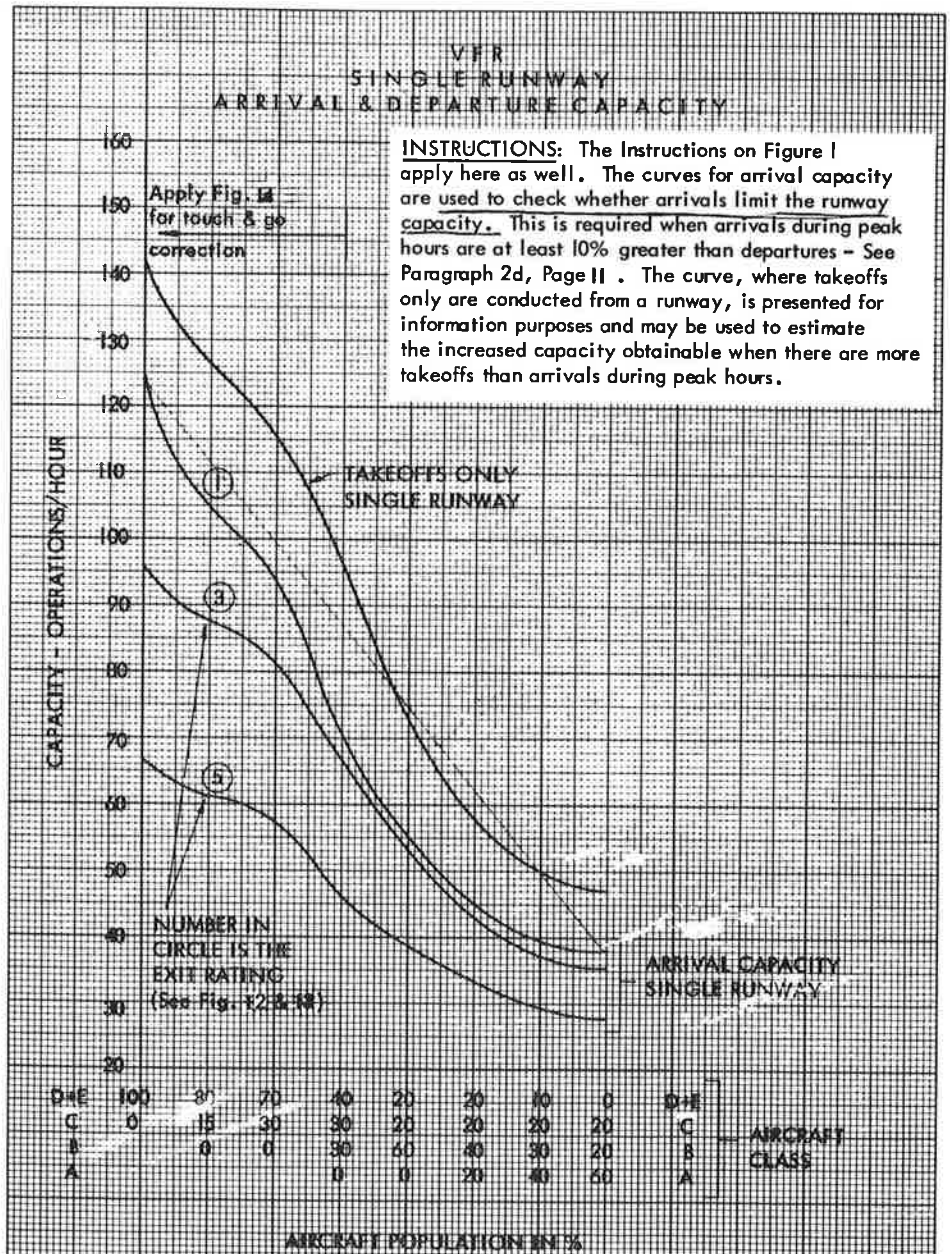

FIGURE 2. SINGLE RUNWAY - ARRIVAL & DEPARTURE CAPACITY - VFR

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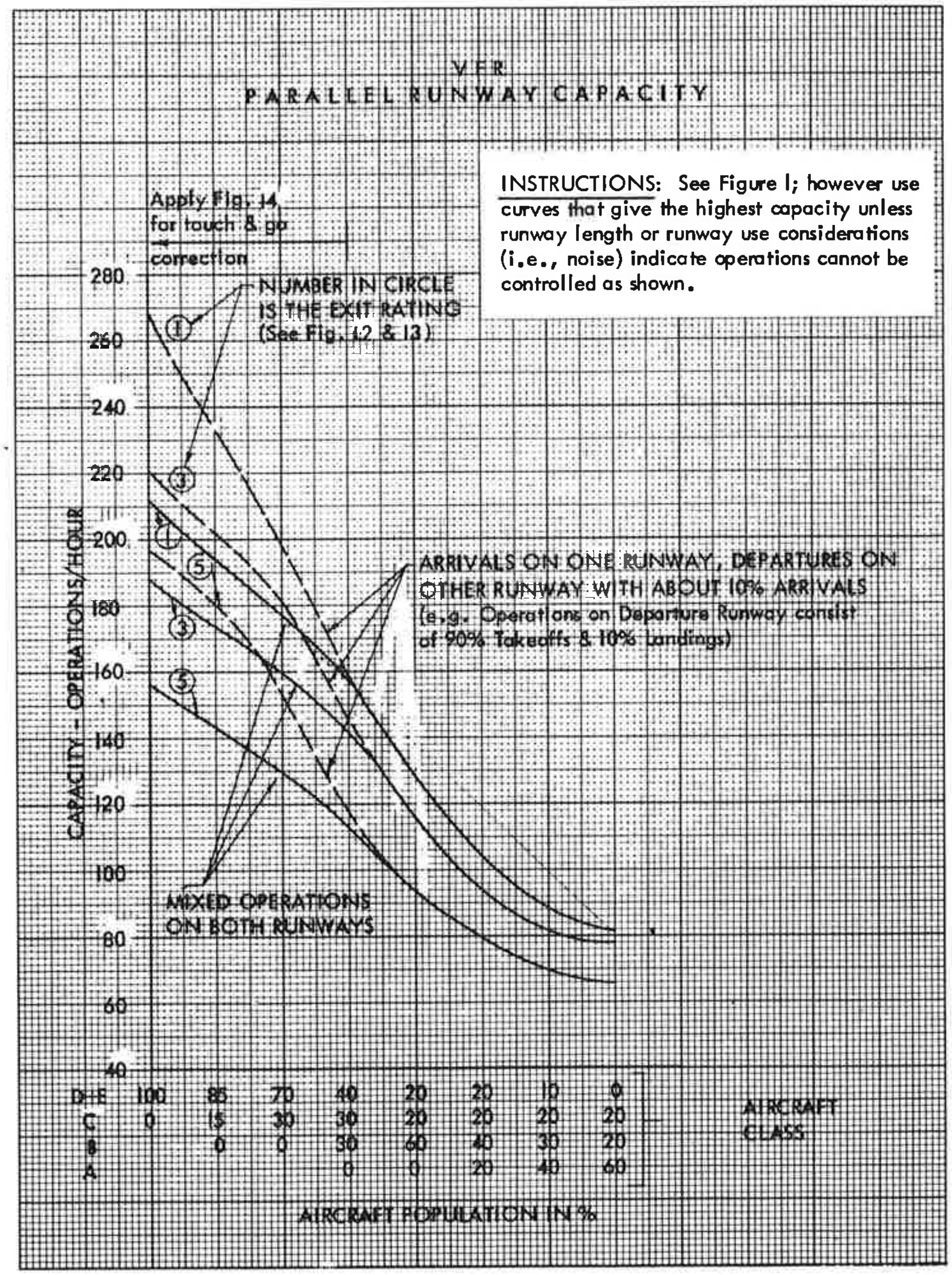

FIGURE 3. PARALLEL RUNWAY CAPACITY - VFR

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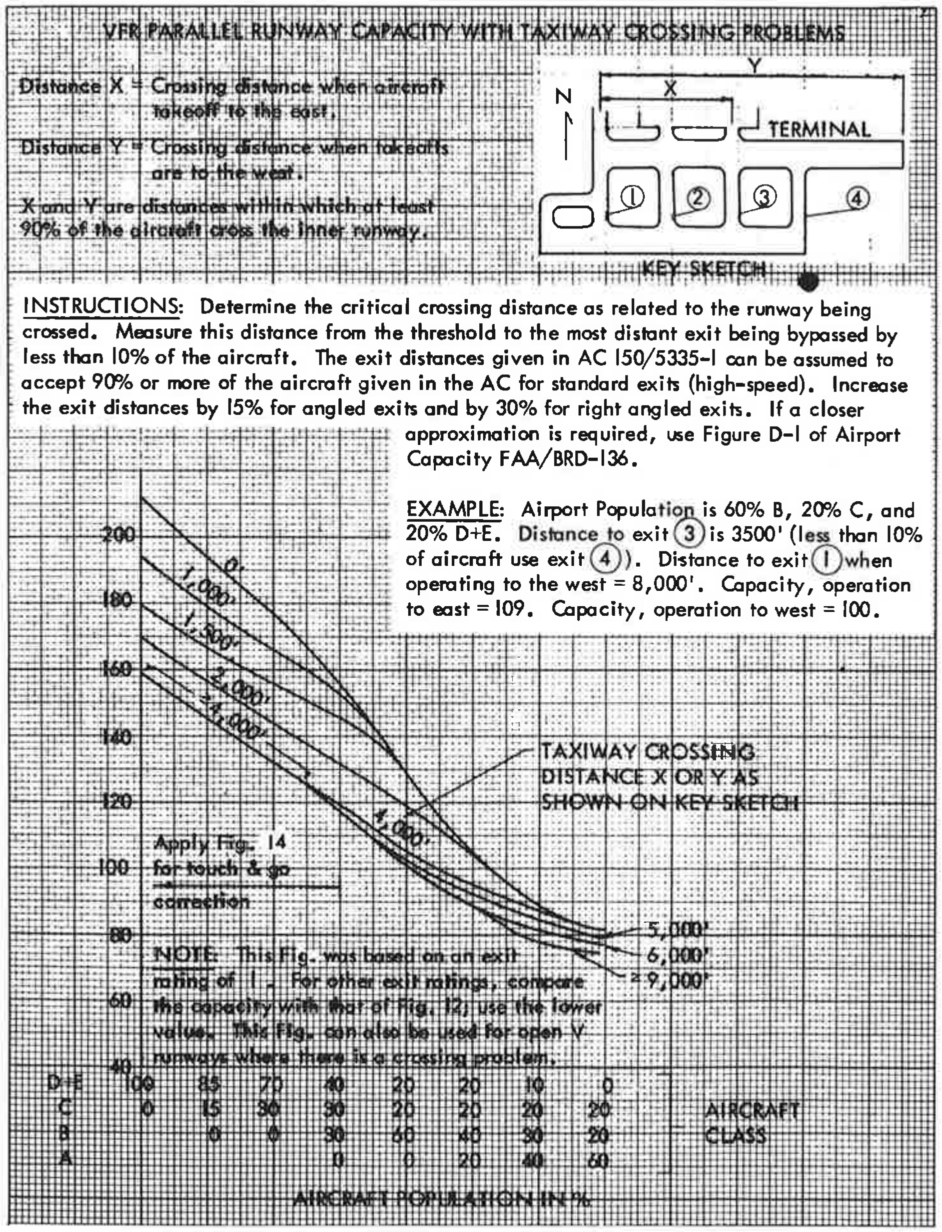

FIGURE 4. CAPACITY OF PARALLEL RUNWAYS WITH TAXIWAY CROSSING PROBLEMS - VFR

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VFR
2 & 3 INTERSECTING RUNWAYS

INSTRUCTIONS: See Instructions on Figure 1 for general method. Use of exit ratings are required only for interpolation involving 2 intersecting runways with intersections between the beginning and middle of runways.

EXAMPLE: Same conditions as Example on Figure 1 except there are 2 intersecting runways with intersection distance on one runway 1/3 down, on the other the intersection is at the end. Intersection distance with operation away from intersection = 1/2 (1/3 + 0) = 0.17. Capacity = 62. For operation towards intersection, average intersection = 1 - .17 = .83; Capacity = 46. For operation on one runway towards the intersection and on the other runway from the intersection, intersection distance = (2/3 + 0)1/2 = 1/3; Capacity = 56.

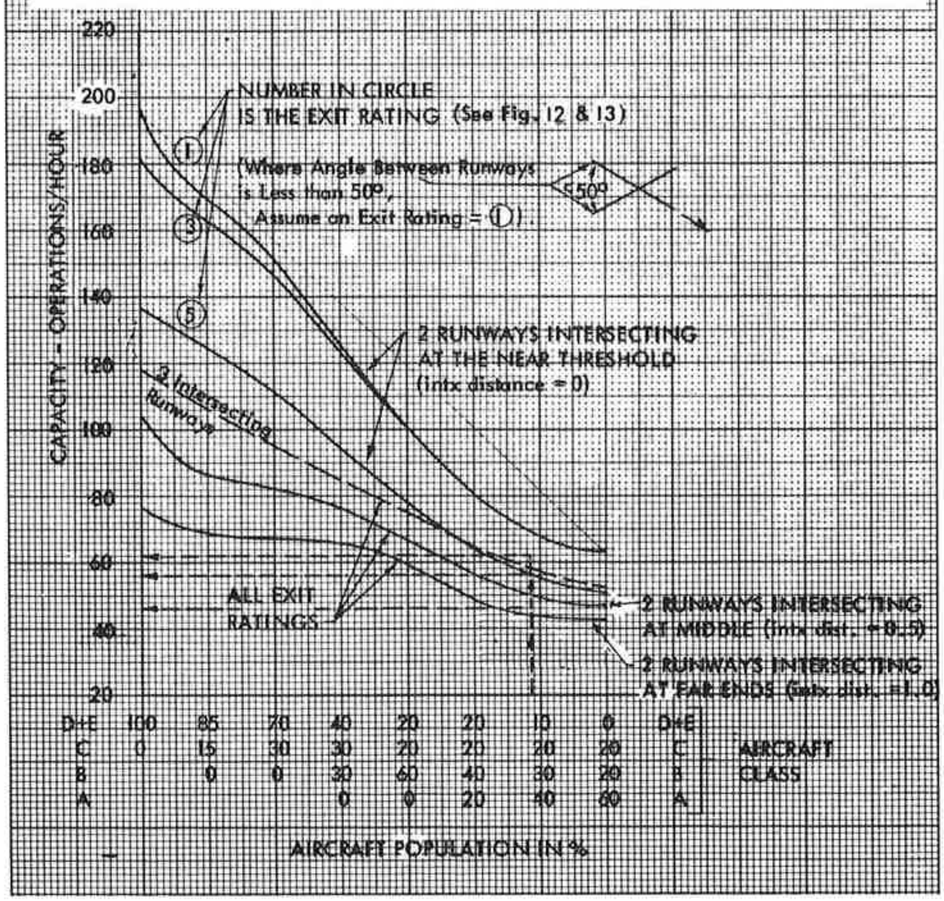

FIGURE 5. 2 & 3 INTERSECTING RUNWAYS - VFR

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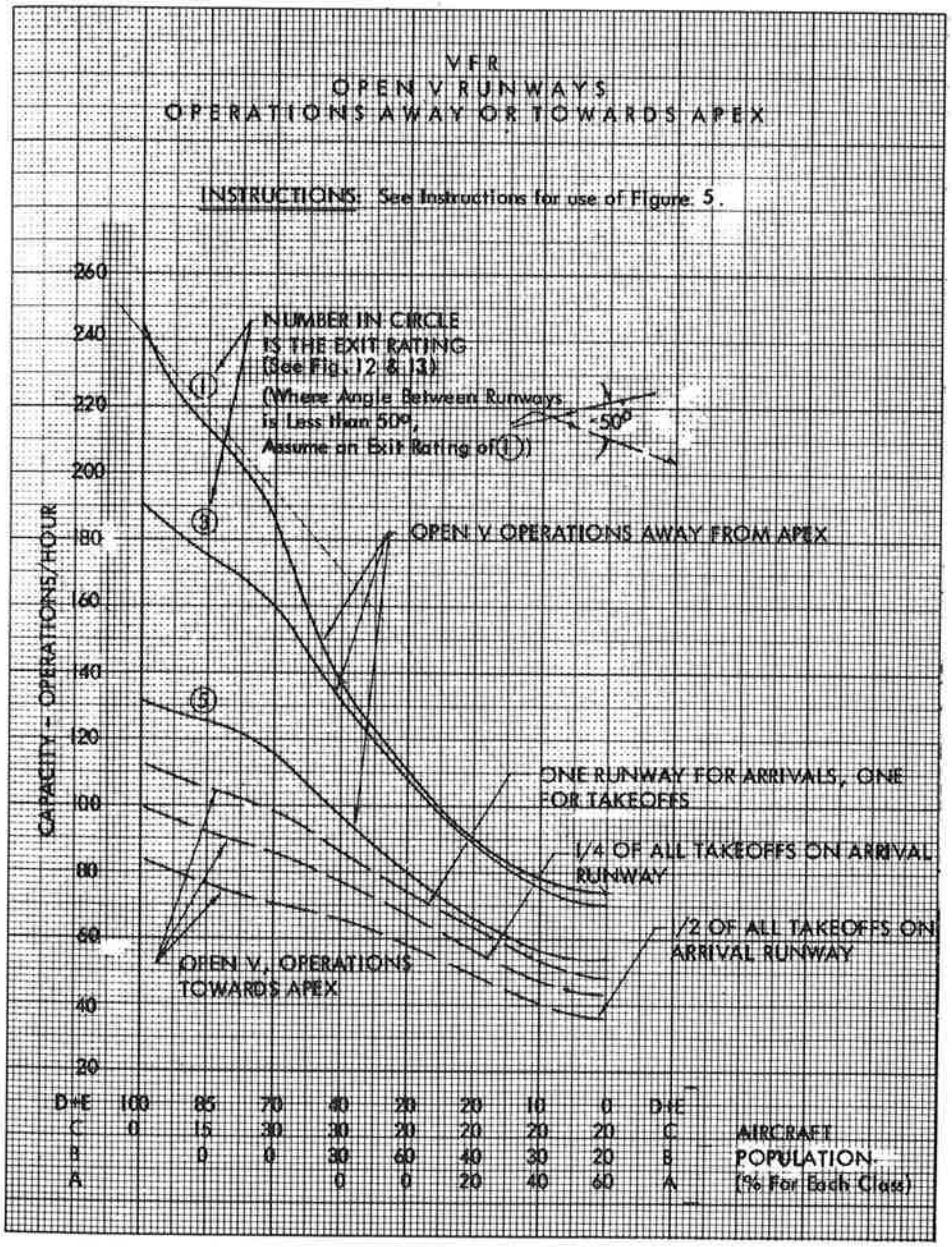

FIGURE 6. OPEN V RUNWAYS - VFR

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VFR
CLASS A AIRCRAFT
POPULATION INTERPOLATION GRAPHS

INSTRUCTIONS: This graph is used at airports consisting of Class A, B, C, and D+E that do not fall in the population groupings given on the capacity graphs. Obtain the converted % of Class A aircraft from this graph in the manner described in the example. Using this % the capacity curves may then be entered directly using linear interpolation between the percentages on the capacity curves for Class A aircraft only.

EXAMPLE: Aircraft Population is 30% A, 50% B, 20% C+D+E. Enter the horizontal scale at 50% B; move up to 30% A and read 37% A from the left scale. Linearly interpolate on the VFR capacity curves between A = 20% and A = 40% to determine the 37% point to use in capacity determination.

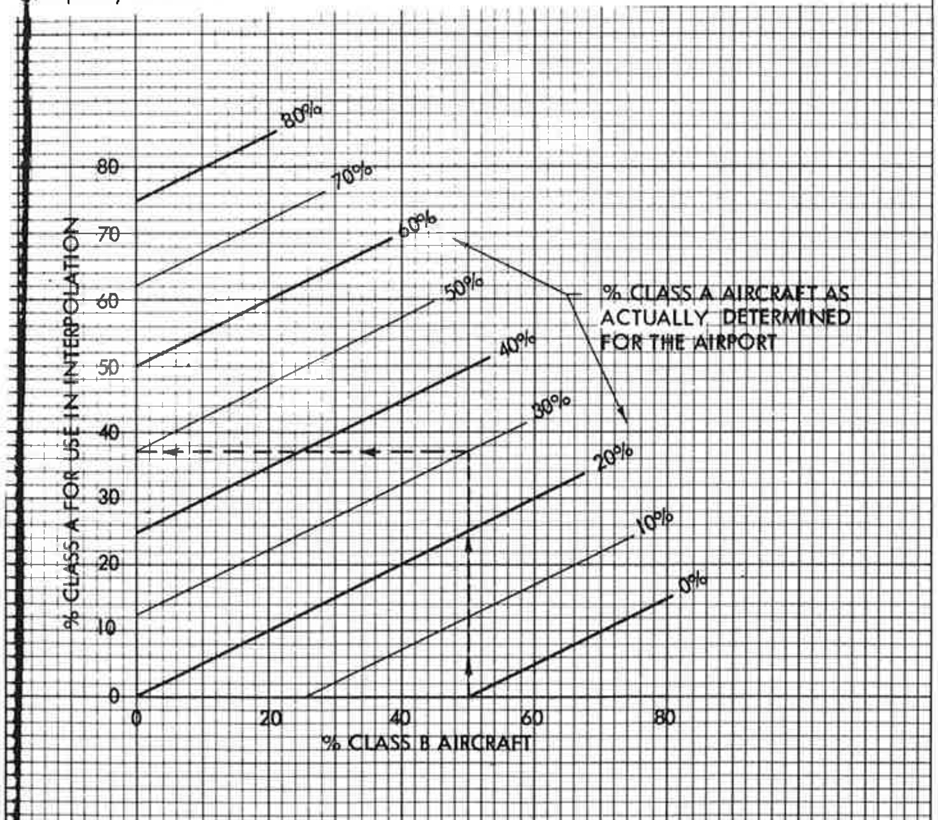

FIGURE 10. CLASS A AIRCRAFT - POPULATION INTERPOLATION - VFR

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VFR
CLASS B AIRCRAFT
POPULATION INTERPOLATION GRAPHS

INSTRUCTIONS: This graph is used at airports consisting of Class B, C, D+E that do not fall in the population groupings given on the capacity graphs. Obtain the converted % of Class B aircraft from this graph in the manner described in the example. Using this % the capacity curves may then be entered directly, using linear interpolation between the percentages on the capacity curves for Class B aircraft only.

EXAMPLE: Aircraft Population is 50% B, 35% C, and 15% D+E. Enter the horizontal scale at 35% C; move up to 50% B and read 56% B from the left scale. Linearly interpolate on the VFR capacity curves between B = 30% and B = 60% to determine the 56% point to use in capacity determination.

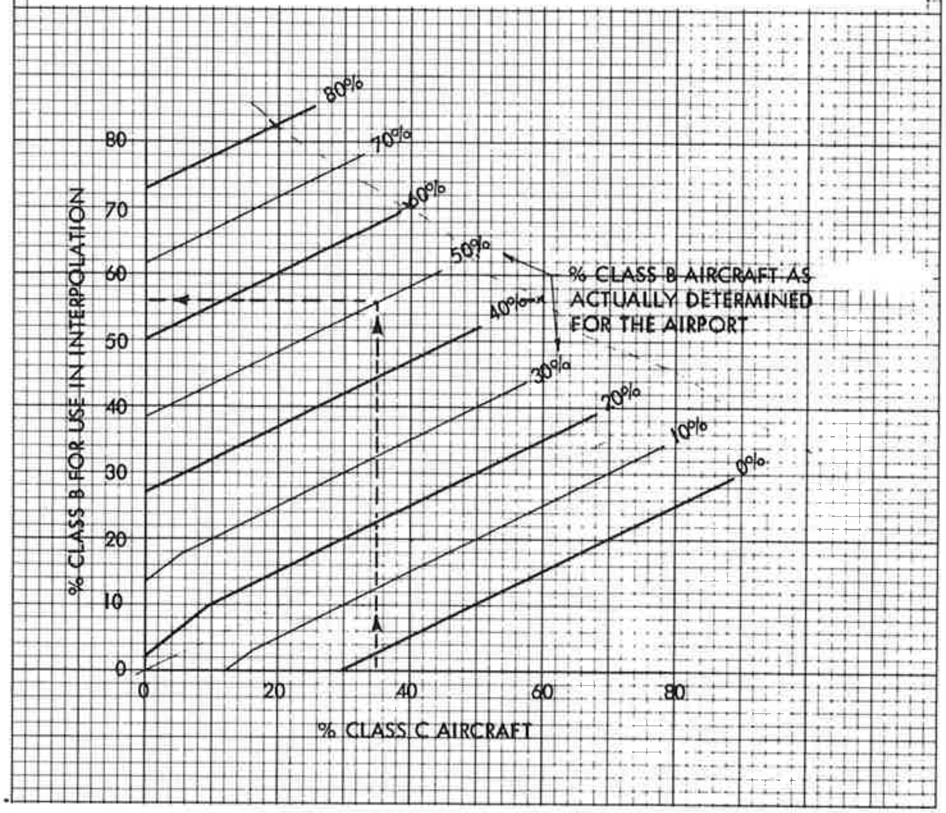

FIGURE 11. CLASS B AIRCRAFT POPULATION INTERPOLATION GRAPHS - VFR

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IFR: If one is dealing with IFR weather the aircraft mix is converted to mix numbers by using the lower of the two abscissa scales of Figures 7 and 8. An approximatiom is made to this lower scale that X increases uniformly from 0.0 to 6.0 as the percentage of Class A (including heavy jets) increases from 0 to 60, and remains at X=6.0 for percentages greater than 60.

From now on, the mix variable M will be interpreted to be the scalar mix number defined in this section instead of being interpreted as a 5-vector.

A.7 CALCULATING SLOPE AND INTERCEPT FOR CAPACITY CURVES

The practical capacity curves of Figures 1 through 8 have been approximated by straight lines in the Processing Rate Module. This is the major approximation in the Module. In order to completely define a straight line, it is sufficient to specify both a point through which the line passes and the slope of the line. The point through which the line passes will be taken to have the typical mix for the abscissa and the practical capacity calculated above for the ordinate.

The slope is more complicated. It is desirable to make the slope an increasing function of the practical capacity at the typical mix. This is because the greater the practical capacity, the greater the effect on practical capacity of a change in mix. For example, as the reader can see by examining Figures 1 and 3, a change in mix has a greater effect on practical capacity when there is a single runway than when there are two parallel ways. To include this effect in the model, the slope of the line is made proportional to its value at X=7.0 (for VFR) or X=6.0 (for IFR). The ratio of slope to the value of practical capacity at X=7.0 was found for VFR to average -0.225 with a standard deviation of 0.07 from Figures 1 to 6. For IFR the ratio averaged -0.047 with a standard deviation of 0.02 (Figures 7 and 8). (The slope for each curve in these figures was found by taking the slope of the straight line connecting the end points of the curve.)

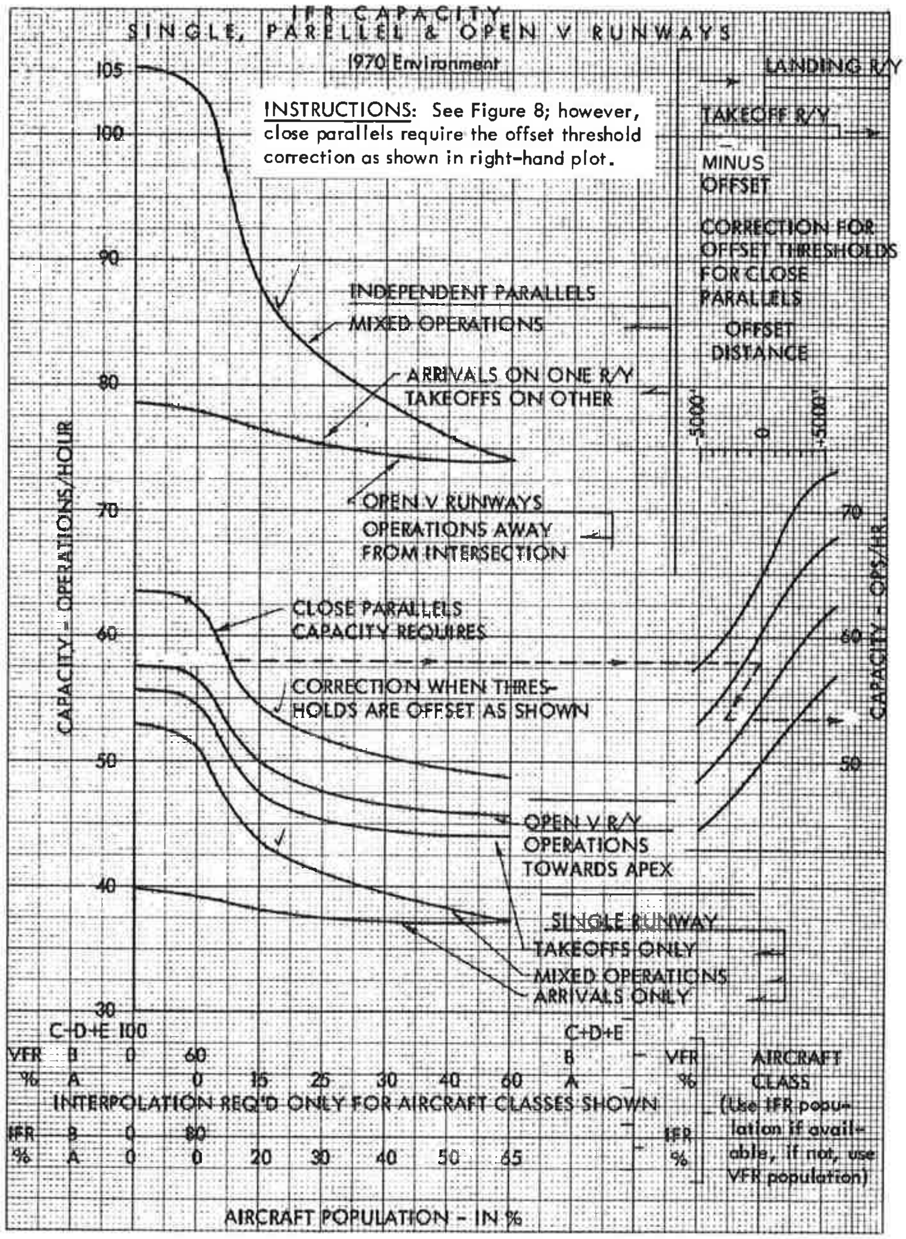


FIGURE 7. IFR CAPACITY

REPRINT

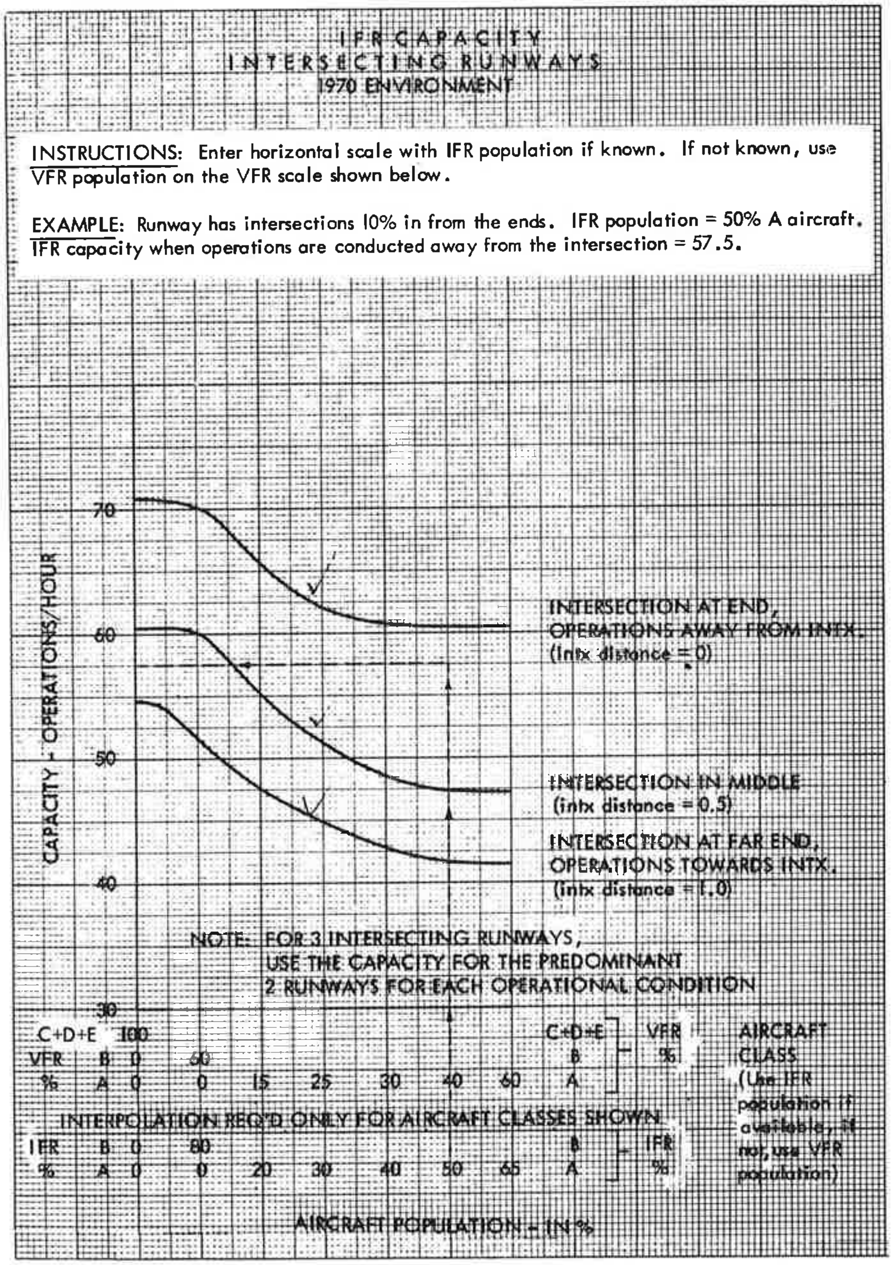


FIGURE 8. IFR CAPACITY - INTERSECTING RUNWAYS

REPRINT

We now develop the formulas for adjusting practical capacity to allow for changes in mix. Consider VFR. Let S be the unknown slope of the practical capacity curve in mix – practical capacity space. One point on the desired straight line [$\bar{M}$, C(VFR,$\bar{M}$,1)] where $\bar{M}$ is the typical mix. We will completely define the desired line by finding the point [7, C(VFR,7,1)] which is on this line. We have

$$S = 0.225C(VFR,7,1) \qquad (1)$$

since we have assumed that slope is proportional to the practical capacity at M=7 and since -0.225 is the factor of proportionality. We know the slope of this line also is given by

$$S = \frac{C(VFR,7,1) - C(VFR,0,1)}{7.0} \qquad (2)$$

Since the point [$\bar{M}$,C(VFR,$\bar{M}$,1)] is on this straight line, we have

$$C(VFR,\bar{M},1) = C(VFR,0,1) + S\bar{M}. \qquad (3)$$

Since (1), (2), and (3) are three linear equations in the three unknown S, C(VFR,0,1), and C(VFR,7,1), they can be solved. The first two are then substituted into

$$C(VFR,M,1) = C(VFR,0,1) + SM$$

which is the equation that approximates the effect of mix on practical capacity when the weather is VFR. The equation for IFR is found in the same way.

A.8 ADJUSTING THE PRACTICAL CAPACITY FOR CHANGES IN THE ARRIVAL-DEPARTURE RATIO

AC, Appendix 2, Section 2.d is now used to further adjust the practical capacity to reflect changes in the arrival-departure ratio, which has heretofore been assumed to be unity.

For VFR, a three step procedure is needed. First, the number of arrivals NA is given by

$$NA = \frac{C(.)}{1+(1/ADR)}$$

Second, the number of arrivals that can realistically be handled is determined from Figure 2. The curve for exit rating 1.0 on this figure has been approximated by a straight line going through the points (0,120) and (7,33). The maximum arrival capacity MAC is

$$MAC = 120 - M(120-33)/7. \qquad (4)$$

Third, if $NA \leq MAC$, then arrivals do not limit capacity and no adjustment is required. But if $NA > MAC$, then the practical capacity is multiplied by the ratio MAC/NA.

The calculation for IFR is similar, except that Figure 2 is replaced by the single runway, arrivals-only curve of Figure 7. The approximation for this curve is

$$MAC = 40 - M(40-37)/6$$

which is used in place of (4) above.

A.9 CONVERTING PRACTICAL CAPACITY BACK TO A PROCESSING RATE

The practical capacity has now been adjusted to reflect the effect of a mix that differs from the typical mix and of an arrival-departure ratio that differs from unity. It now remains to reverse the procedures described in Sections A.4 and A.5 in order to convert the practical capacity back to a processing rate.

The equations in Sections A.4 and A.5 can be used to do this without further explanation, except for one exception. The test for whether capacity is arrival-limited will not always fail since the arrival-departure ratio can now exceed unity. If capacity is arrival-limited, then the standard delay chosen is an average of 1 minute per aircraft. The 1-minute ordinate for any of the curves of Figure 16 corresponds to a practical capacity that is about .625 times that curve's asymptote. Hence, the conversion from C(W,M,ADR) to r(W,M,ADR) for arrival-limited VFR capacity is $r(W,M,ADR) = C(W,M,ADR)/.625$.

APPENDIX B — DEMAND PROFILES

B.1 INTRODUCTION

Section 2.3.3 described in general terms how total volume for a day is broken down into the volume for each minute during the day. The method consists of five steps:

1. Determine the volume for the day;
2. Break the total volume down into scheduled volume and unscheduled volume;
3. Construct a minute-by-minute profile for scheduled flights;
4. Construct a minute-by-minute profile for unscheduled flights; and
5. Add together the minute-by-minute profiles developed in Steps 3 and 4 to arrive at the total minute-by-minute demand profile.

The purpose of this appendix is to describe Step 3 in detail and to explain how the OAG is used to construct profiles.

B.2 CONSTRUCTING A PROFILE FROM THE OAG

The first step of the five-step procedure outline above is to determine the volume for the day. The preliminary version of the model only allows volumes of 649, 748, and 855 for weekend days and volumes of 641, 789, 880, 962, and 1036 for weekdays. The reason why these particular volumes are chosen was explained in Section 2.4.5. The second step is to determine the scheduled volume for the day. This requires multiplication of weekend volumes by 90 percent and weekday volumes by 80 percent (cf. Table 2-6). Thus, scheduled volumes on weekend days are currently limited to values of 584, 673, and 770, and scheduled volumes on weekdays are limited to values of 513, 631, 704, 770, and 829.

The third step requires each daily volume to be broken down into minute-by-minute volumes. Since the OAG gives the schedules by the minute, the most direct way to obtain an actual minute-by-minute demand profile is to use the OAG schedule for a day with the desired volume. For example, Sunday, September 15, 1974, had a scheduled volume of 585, so we can take this profile from the OAG and use it as our approximation to the profile for a weekend day with a volume of 584.

A problem we faced with taking a day from the OAG is that we have only the OAG tapes for September 1974, December 1974, and January 1975. Since none of these are heavy traffic months, they do not contain any days with heavier volumes. For example, the highest scheduled volume for these three months is 720, well short of the desired volumes of 770 and 829. To overcome this problem, profiles have been scaled up to give the appropriate volume; this will be explained shortly. Table B-1 gives the desired volume and the calendar date that provided the minute-by-minute profile for this volume. The notation "rescaled" means that no available day had the desired volume, so the profile had to be obtained by scaling up a profile that was available.

The following method was used to scale up a profile. For concreteness, consider the desired weekday volume of 829. We will scale up the profile for Friday, September 6, 1975, with 720 operations, since this is the largest available daily volume. Since $829 \div 720 = 1.15$, multiply the volume for each minute of the September 6 profile by 1.15. This yields another profile with a volume of 829. However, a problem is that this new profile contains fractions. For example, if particular minute of the September 6 profile contained one aircraft service request, then that minute in the new profile shows 1.15 aircraft service requests. The following rounding technique is used to eliminate fractions. Start at the first minute of the day. If the number of planes requesting service in that minute is not an integer, then truncate the fractional part so that that number is an integer. Save the truncated fraction. Go to the next minute. Truncate any fraction and add this to the previously truncated fraction. Continue through the minutes truncating and cumulating fractions until the cumulative sum of fractions is greater than or equal to one. Enough fractions have then been accumulated to represent a whole aricraft. This aircraft is placed in the minute in which the cumulative sum reaches one, and the processing of truncating and placing planes is continued through the rest of the day. Therefore, we now have the desired minute-by-minute profile for 829 operations.

TABLE B-1. SOURCES OF DEMAND PROFILES FOR SCHEDULED FLIGHTS

WEEKEND VOLUME	SOURCE OF PROFILE
584	Sept. 15, 1974
673	Sept. 8, 1974 (rescaled)
770	Sept. 8, 1974 (rescaled)
WEEKDAY VOLUME	**SOURCE OF PROFILE**
513	Jan. 13, 1975 (rescaled)
631	Jan. 6, 1975
704	Sept. 4, 1975
770	Sept. 6, 1975 (rescaled)
829	Sept. 6, 1975 (rescaled)

APPENDIX C — WEATHER PROFILES

C.1 INTRODUCTION

Since an airport's processing rate (saturation capacity) falls during bad weather, creating a potential for increased delays, it is important to have some idea of how often bad weather occurs and how long it lasts. The effects of weather are incorporated into the Airport Performance Model via hourly weather profiles that indicate the state of the weather for each hour during the day. This appendix explains how the two weather profiles incorporated in the preliminary model were obtained.

It is assumed that there are only two types of weather — good and bad. By definition, the weather is good if the ceiling is at least 1200 feet and visibility is at least 3 miles; otherwise, the weather is bad. Two weather profiles cannot completely model the weather that occurs during a year since a variety of diverse weather patterns are observed. However, only two weather profiles are used in order to reduce the computational cost of using the model. Since there are eight different types of days for which delay is calculated (i.e., three different volumes for weekends and five for weekdays), the number of days for which delay is calculated is eight times the number of weather profiles used. It was decided that for this year's model, the added accuracy that would be achieved by using more weather profiles would not justify the added cost.

C.2 DATA SOURCES

No published data source containing appropriate information could be located. We therefore went to the National Weather Bureau at Logan Airport and recorded all the intervals of bad weather in 1974. This was our sole source of weather data.

C.3 DATA ANALYSIS

We assumed that 1974 was a representative year for weather. We discarded all the bad weather from midnight to 8:00 a.m. because there was so little airport activity in that time interval. We then found that 73.4 percent of the days had no bad visibility. Hence, we took good weather for every hour throughout the day as the first weather profile, and we assumed that this profile occurred on 75 percent of the days.

This left the task of determining a profile to represent bad weather for the other 25 percent of the days. This task consisted of deciding how long the bad weather should last and when it should occur during the day.

C.4 DURATION OF BAD WEATHER

The first issue in modeling bad weather is: How long should an occurrence last? Table C-1 shows that there were 594 hours of bad weather in 1974, spread among 135 different occurrences. This means there was an average of 4.40 (=594 ÷ 135) hours of bad weather per occurrence. Since delay time increases more than proportionately when bad weather increases in duration (because queues built up during bad weather are not dissipated as quickly when bad weather continues), the typical bad weather profile should contain an occurrence of bad weather lasting for <u>more than 4.40 hours</u>.

Table C-1 also shows that there were 98 days in 1974 with bad weather. This means that a day with bad weather has, on average, 6.06 (=594 ÷ 98) hours of bad weather. On many of these days the bad weather is not continuous but is broken up into two or more occurences. Since, as explained above, delay is a nonlinear function of the duration of the bad weather, it seems appropriate to assume that each bad weather day has <u>less than 6.06 hours</u> of bad weather.

TABLE C-1. DURATION OF BAD WEATHER IN 1974

Total bad weather hours	594
Total bad weather occurrences	135
Total days with bad weather	98

The last two paragraphs have placed bounds of 4.40 and 6.06 hours on the duration of an occurrence of bad weather. We decided to set the duration for each occurrence of bad weather at 5 hours.

C.5 LOCATION OF BAD WEATHER

The final issue in modeling bad weather is: Where should the 5-hour occurrence be placed during the day? Let morning (M) be 0800-1200 local standard time, afternoon (A) be 1200-1800, and evening (E) be 1800-2400. We will say that bad weather occurs in the morning, afternoon, or evening if it is totally confined to the morning, afternoon, or evening, respectively. We will say that an occurrence is in the morning and afternoon if it starts in the morning and ends in the afternoon; it is in the afternoon and evening if it starts in the afternoon and extends into the evening; it is in the morning, afternoon, and evening if it starts in the morning and extends all the way through the afternoon and into the evening. Using this terminology, we can break up the occurrences of bad weather into six disjoint categories. These categories are disjoint in the sense that any one occurrence of bad weather falls into exactly one category. Table C-2 shows how many occurrences fell into each category in 1974.

TABLE C-2. LOCATION OF BAD WEATHER IN 1974

TIME	NUMBER OF OCCURRENCES
M: 0800 – 1200	36
M & A: 0800 – 1800	11
A: 1200 – 1800	16
A & E: 1200 – 2400	16
E: 1800 – 2400	43
M & A & E: 0800 – 2400	12

Inspection of this table shows that bad weather tends to be concentrated in the morning and evening. Therefore, we decided to place the five hours of bad weather between 6:00 p.m. and 11:00 p.m.

C.6 CONCLUSIONS

Analysis of the 1974 weather patterns for Logan Airport has led to the conclusion that, assuming only two weather profiles are to be used, the weather can be suitably modeled by assuming that 75 percent of the days have all good weather and that 25 percent of the days have bad weather from 6:00 p.m. to 11:00 p.m. and good weather otherwise. It should be emphasized that this is a coarse characterization of true weather patterns, but that it is in keeping with the level of detail incorporated elsewhere in this year's model. In future work it will be possible to include a much more detailed characterization of the weather.

APPENDIX D — CALCULATING DELAY

D.1 INTRODUCTION

This appendix describes the algorithm that is used to calculate delay for each individual aircraft. The complete details are displayed in the program listing in Appendix G; this appendix describes the logic behind the algorithm.

The algorithms used to calculate other statistics are not described here, either because some (e.g., total delay for an hour, maximum delay in an hour for an individual aircraft, etc.) are easily derived from the delay for individual aircraft or because others (e.g., queue length) are calculated by a simple counting process.

D.2 ASSUMPTIONS

Several assumptions made by the algorithm need to be spelled out. First, it is assumed that aircraft always request service at the beginning of a minute. Second, aircraft are served on a first-come, first-served bases. Third, it is assumed that only one aircraft at a time can enter the runway system and that the minimum amount of time between successive entries — the minimum acceptance interval — is equal to the inverse of the processing rate (and expressed in minutes per aircraft). When the runway system accepts an aircraft, it is "free" to accept a following aircraft (if one is present) only after the acceptance interval elapses. Since the runway system, which includes the glideslope and exits as well as the actual runway, is a "pipeline" facility such as a carwash rather than a "devoted" facility such as a toll booth, it becomes "free" whenever a new aircraft may enter it rather than when it actually becomes empty. An important variable is the Runway Free Time (RFT), which is the time that the runway system can accept the next aircraft. Fourth, delay is defined to be the difference between the time an aircraft is actually accepted into the runway system and the time it would have been accepted had there been no congestion.

D.3 THE ALGORITHM

Figure D-1 depicts a verbal flow chart for the delay calculating algorithm. (A more precise flowchart can be found in Appendix G). To see how the algorithm works, begin by setting the simulation clock to the beginning of an arbitrary minute during the day (box 1). The first question is whether any aircraft request service at the beginning of this minute (box 3).

If no aircraft request service, we take the left-hand branch and spend this minute working off the queue, if one exists. The next question is whether RFT occurs during the current minute (box 4). That is, are there aircraft in the runway system at the start of this minute and will the minimum acceptance interval elapse during the minute? The answer to this question is "no" if either no aircraft is using the runway or if an aircraft is using the runway but will not have released it by the end of the minute. In either case, no aircraft are removed from the queue during the minute, and so the clock is set to the next minute and the algorithm returns to START (box 5).

But RFT does occur in the current minute if the acceptance interval elapses during this minute. Set the clock to RFT (box 6). If no aircraft are in the queue, the clock is then set to the next minute and we go back to START (box 5). If aircraft is in the queue, it is removed and placed on the runway. The minimum acceptance interval is added to the old value of RFT to derive the new value for RFT. (Recall that the acceptance interval depends on the weather at the time the aircraft is accepted on the runway and on the mix and arrival-departure ratio for the time that it requested service.) The delay is calculated for this aircraft by subtracting the time it was accepted on the runway from the time it requested service (box 8). (Note that this is the point in the algorithm at which delay is calculated.) We then ask if the new RFT is still in the current minute (box 4), and thus repeat the steps already explained. Eventually either the queue is exhausted or the RFT spills over into the next minute, and we go back to START.

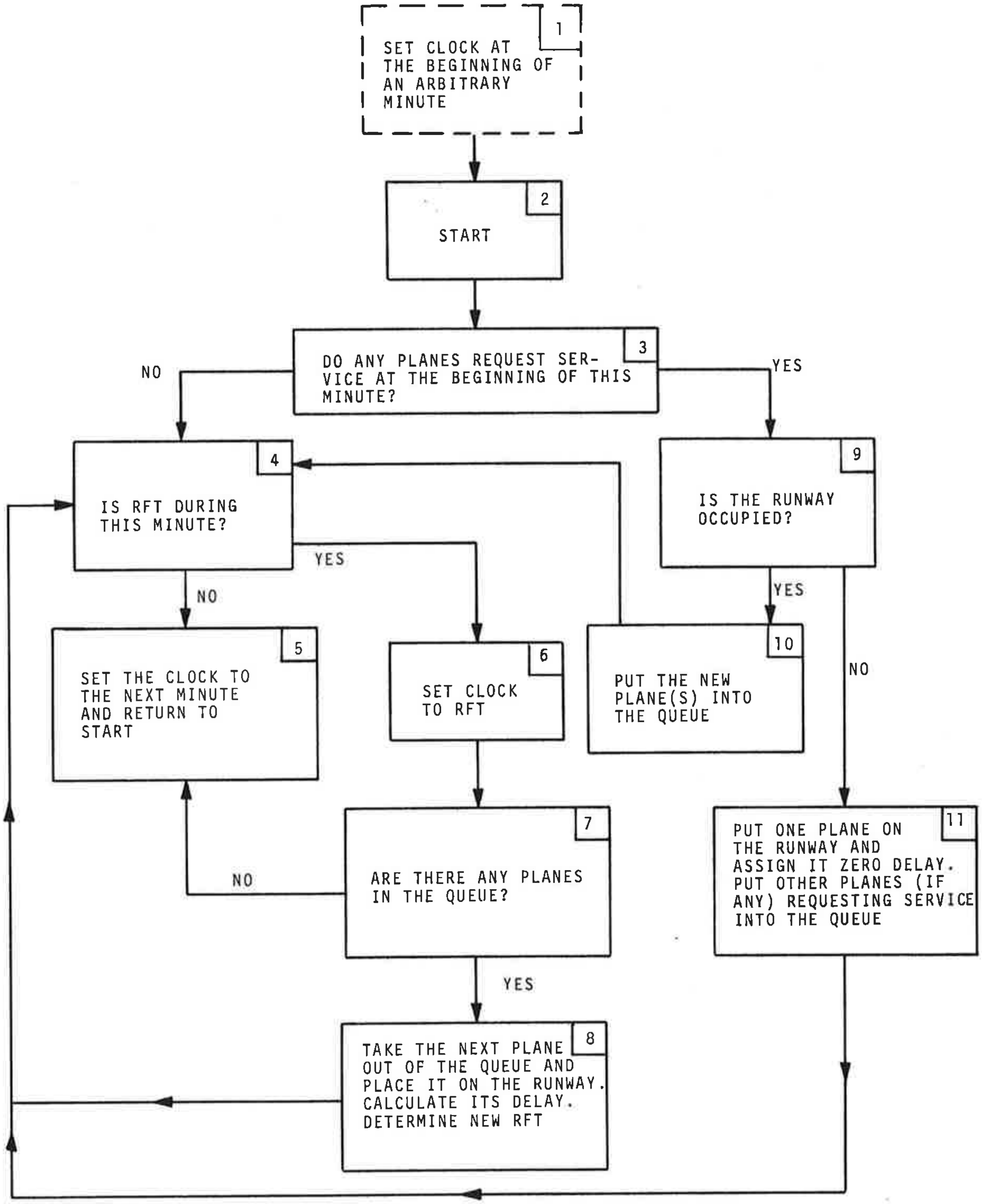


Figure D-1. Flow Chart – Algorithm for Calculating Delay

Now go back and suppose that at least one aircraft does request service in this minute. If so, then the right-hand branch will first insert these aircraft into the system and then spend the minute working off the queue. If the runway is not free, then all the new aircraft go into the queue (box 10). The rest of the minute is spent working off the queue, using the prcedure already explained starting at box 4. If the runway is free, then an aircraft is accepted on the runway and assigned zero delay. Its RFT is calculated. If any other aircraft requested service in that minute, they are placed in the queue (box 11). The queue is then worked off, again using the procedure starting at box 4.

In sum, this algorithm has shown how to calculate delay for individual aircraft. This procedure is the heart of the program listed in Appendix G, though that program has been reorganized for computational efficiency.

APPENDIX E — ALTERNATE METHOD FOR CALCULATING ANNUAL DELAY

Section 2.4.5 explained how to calculate annual delay by approximating the delay function with a step function. This appendix explains how a piecewise linear approximation can be used; this second method is a candidate for inclusion in future versions of the model.

A hypothetical delay function is sketched in dashed lines in Figure E-1. Five volumes, $v_1, \ldots, v_5$, are chosen. The procedure outlined in Section 2.4 is then used to evaluate the value of the delay function at these five volumes (assuming constant weather, mix, and arrival-departure profiles). The resulting five points (and the origin) are then connected by line segments to form a piecewise linear function that can be taken as an approximation to the true delay function. This function is shown as a solid line in Figure E-1. If we want to know the delay on a day with volume halfway between v_2 and v_3, we use this approximation to estimate the delay as half the delay for v_2, plus half the delay for v_3.

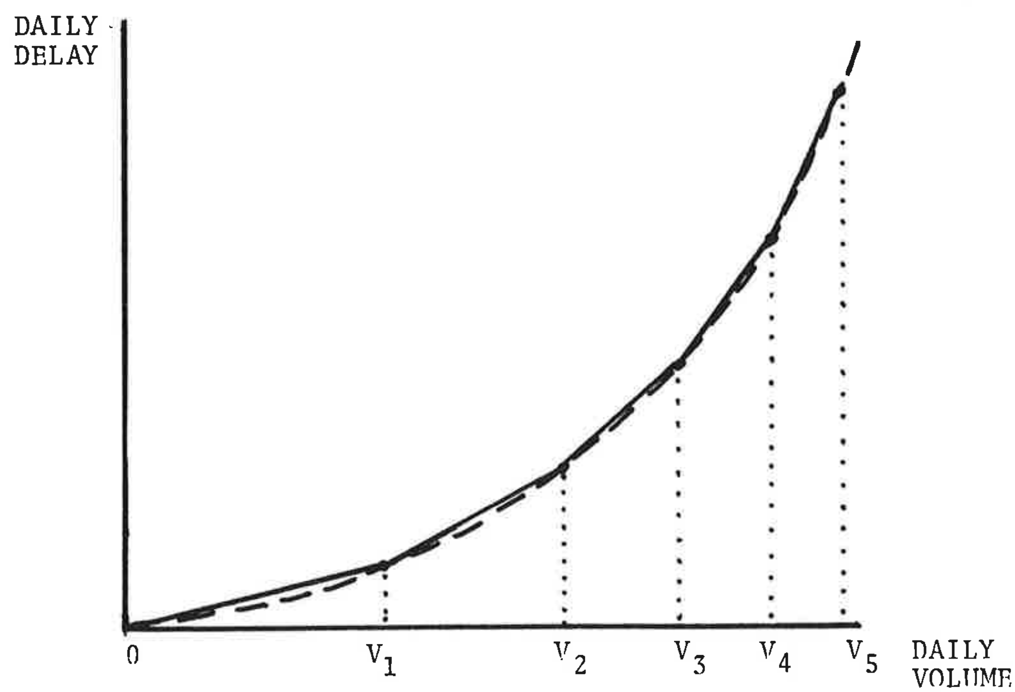


Figure E-1. Hypothetical Delay Function and Piecewise Linear Approximation

The question arises: Which of the two methods of approximating the delay function is better? We cannot at this time answer this question because the answer depends on what shape the delay function typically has and on what procedure is used to choose the volumes at which delay is evaluated. We can say that the second method has the advantage of using a continuous approximation and the disadvantage of always overestimating delay (if the delay function is convex), but these considerations do not alone determine which approximation is better. This question will be one area of future work.

APPENDIX F — MODEL USER'S GUIDE

F.1 INTRODUCTION

This appendix describes the interactive Airport Performance Model, the purpose of which is to translate improvements in airport facilities and airport operating procedures into increases in the quality of service or level of service provided.

The model consists of three modules:

1. The Runway Capacity Module
2. The Airside Demand Module
3. The Groundside Service Module.

The program consists of two major segments:

1. An airside segment that measures delays for the aircraft and passengers in terms of time and dollars, and
2. A groundside segment that determines which facilities are saturated and for how long a period of time.

F.2 AIRPORT PERFORMANCE MODEL

F.2.1 Runway Capacity Module

The runway capacity module computes a saturation arrival-departure rate based on the weather, the mix of aircraft types, the arrival-departure ratio, and the separation standards.

Since the VFR runway capacity is all that needs to be considered in most cases, the program considers the weather to be VFR unless otherwise instructed. The user may change any or all of the hours considered by the program to an IFR condition if he chooses.

The mix of aircraft types consists of aircraft type classifications numbered from 1-5; 1 for heavy jets; 2 for class A; 3 for class B; 4 for class C; and 5 for classes D and E. These classes range from the heavy jets (e.g., 747's and DC10's) to small light

1. RUN NAS

   The program will be loaded and made ready for the user.

2. HELLO, WHAT AIRPORT ARE YOU INTERESTED IN? PLEASE USE A THREE LETTER CODE FOR: ATL, BOS, DCA, JFK, LAX, LGA MIA, ORD OR SFO

   A. When BOS is keyed in the message: THANKS FOR SELECTING BOSTON is typed out.

   B. If any other airport on the list is keyed in, the message: CURRENT DATA EXISTS ONLY FOR BOSTON, PLEASE ENTER BOS THANK YOU is typed out.

   C. If any other combinations of letters is keyed in, the message: AIRPORT YOU HAVE SELECTED WAS NOT ON MY LIST, PLEASE TRY ANOTHER AIRPORT is typed out.

3. TYPE OF ANALYSIS DESIRED – HOURLY OR DAILY? If HOURLY is KEYED in

   The message: DO YOU WANT 1 PARTICULAR HOUR – YES OR NO? is typed out.

   A. If YES is keyed in, the message: TYPE IN THE PARTICULAR HOUR YOU WANT is typed out.

   B. If NO is keyed in, the message: TYPE IN HOURS – BEGINNING, END is typed out.

   If DAILY is keyed in no message for it is typed out.

4. STANDARD VFR RATE = 120 OPS/HR
   STANDARD IFR RATE = 65 OPS/HR
   DO YOU WISH TO CHANGE THESE RATES – YES OR NO?
   If YES, the message: TYPE IN VFR AND IFR RATES is typed out.
   If NO, the standard rates are assumed.

5. SPACING IS SET FOR 3 MILE/5 MILE – 35 DO YOU WANT TO CHANGE IT TO 37, YES OR NO?

6. DO YOU WANT TO CHANGE THE WEATHER ARRAY – YES OR NO? If YES is typed in, two requests are printed:

A. The message: TYPE IN THE NUMBER OF HOURS TO BE CHANGED.

B. TYPE IN THE NO. OF EACH HOUR 1-24 TO BE CHANGED.

A carriage return, after the number of each hour, must be used.

7. DO YOU WANT TO SEE INPUT FIGURES – YES OR NO? If YES is typed in

Input parameters listed are: The mix of aircraft, total number of AC, scheduled passengers by class, total number of passengers, number of AC arriving and departing, and scheduled concentration.

8. The delay output is then printed

The delay output parameters are always printed.

9. DO YOU WANT TO SEE GROUNDSIDE STATISTICS – YES OR NO? If YES is typed

A. *PASSENGER MOVEMENTS* is typed out as a heading with:

The HOUR, THROUGH, TRANSFERS, ORIGINATING, TERMINATING and ENPLANED passengers.

B. SATURATED GROUNDSIDE FACILITIES is typed as a heading along with:

The number of the facility, the FACILITY, and HOURS.

C. ENTER NUMERICAL CODE FOR FURTHER INFORMATION

The number associated with the facility.

D. IF A NUMBER IS NOT WITHIN THE RANGE 1-14 – EXIT RESULTS

1. When a number associated with a particular facility is activated, the number of each hour during which the facility was saturated is printed.

2. If any number less than one (1) or greater than 14 is activated, exit from the groundside portion of the program occurs.

10. DO YOU WANT TO RUN THE PROGRAM AGAIN FOR ANOTHER CASE? YES OR NO

If YES is typed in,

A. The parameters are all initialized

B. The message: HELLO, WHAT AIRPORT etc., is typed out and the program will be rerun. If NO is typed,

1. The CPU time and elapsed time are printed.
2. The number and type of errors, if any.
3. EXIT.

Two control C's (↑C↑C) will terminate the program if for any reason the user desires not to continue processing. The program is then returned to the monitor level.

F.4 SAMPLE OUTPUT

F.4.1 Hourly Run

```
.RUN NAS

HELLO, WHAT AIRPORT ARE YOU INTERESTED IN ?PLEASE USE A 3 LETTER CODE
FOR: ATL,BOS,DCA,JFK,LAX,LGA,MIA,ORD OR SFO
BOS

THANKS FOR SELECTING BOSTON

TYPE OF ANALYSIS DESIRED - HOURLY OR DAILY?
HOURLY

DO YOU WANT 1 PARTICULAR HOUR - YES OR NO?
YES

TYPE IN THE PARTICULAR HOUR YOU WANT
19

STANDARD VFR RATE = 120 OPS/HR
STANDARD IFR RATE =  65 OPS/HR
DO YOU WISH TO CHANGE THESE RATES ? YES OR NO
NO

 SPACING IS SET FOR 3MILE/3MILE - 35

 DO YOU WANT TO CHANGE IT TO 37, YES OR NO?
NO

DO YOU WANT TO CHANGE THE WEATHER ARRAY - YES OR NO ?
NO

DO YOU WANT TO SEE INPUT FIGURES - YES OR NO ?
NO
```

```
              MAX. Q LN.   CONT. OF    MAXIMUM DELAY AC
                           AIRSIDE Q   SERV.  REQ.SERV.
                           END OF HR      IN MINS.

17:00-18:00      8           1.0      5.4        5.4

               # OF AC DELAYED         TOTAL SECS OF DELAY
              SERVICED  REQ. SERV.    SERVICED   REQ.SERV

17:00-18:00      39          39.      3714.      3714.

             # OF AC DELAYED 30+ MIN  AV. DELAY FOR DELAYED AC
              SERVICED    REQ. SERV.  SERVICED   REQ. SERV.

17:00-18:00      0.           0        95.        95.

               AV. DELAY PER AC        TOTAL PAX DELAY FOR PAX
             SERVICED     REQ.SERV.   SERVICED   REQ.SERV.

17:00-18:00      73.         73.        232868.   232868.

             AIRCRAFT DELAY COST FOR AC SERV. IN HR. IH

17:00-18:00           $    1149.

DO YOU WANT TO SEE GROUNDSIDE STATISTICS - YES OR NO?
NO

DO YOU WANT TO RUN THE PROGRAM AGAIN FOR ANOTHER CASE ? YES OR NO
NO

CPU TIME: 2.16  ELAPSED TIME: 2:13.13
NO EXECUTION ERRORS DETECTED

EXIT
```

F.4.2 Daily Run

```
.RUN NAS

HELLO. WHAT AIRPORT ARE YOU INTERESTED IN ?PLEASE USE A 3 LETTER CODE
FOR: ATL,BOS,DCA,JFK,LAX,LGA,MIA,ORD OR SFO
BOS

THANKS FOR SELECTING BOSTON

 YPE OF ANALYSIS DESIRED - HOURLY OR DAILY?
 AILY

 TANDARD VFR RATE = 120 OPS/HR
 TANDARD IFR RATE =  65 OPS/HR
 O YOU WISH TO CHANGE THESE RATES ? YES OR NO
 O

  PACING IS SET FOR 3MILE/5MILE - 35

 DO YOU WANT TO CHANGE IT TO 37, YES OR NO?
 O

DO YOU WANT TO CHANGE THE WEATHER ARRAY - YES OR NO ?
NO

DO YOU WANT TO SEE INPUT FIGURES - YES OR NO ?
YES
```

HOUR	H	A	B	C	D	ADR	AC
1	0.29	0.14	0.57	0.00	0.00	2.50	7
2	0.33	0.00	0.17	0.17	0.33	0.50	6
3	0.29	0.14	0.14	0.43	0.00	2.50	7
4	0.50	0.00	0.50	0.00	0.00	3.00	4
5	0.00	0.00	0.00	0.33	0.67	2.00	3
6	0.00	0.00	0.00	0.33	0.67	0.50	3
7	0.00	0.00	0.75	0.00	0.25	0.33	4
8	0.10	0.07	0.66	0.00	0.17	0.26	29
9	0.14	0.06	0.53	0.06	0.22	0.71	36
10	0.19	0.06	0.48	0.08	0.19	0.85	48
11	0.15	0.05	0.59	0.10	0.12	0.71	41
12	0.00	0.09	0.67	0.03	0.21	1.54	33
13	0.09	0.04	0.67	0.09	0.11	0.84	46
14	0.03	0.03	0.65	0.06	0.24	0.79	34
15	0.14	0.03	0.61	0.06	0.17	1.40	36
16	0.00	0.05	0.68	0.12	0.15	1.28	41
17	0.09	0.09	0.59	0.07	0.17	0.70	46
18	0.10	0.08	0.60	0.10	0.13	1.17	52
19	0.10	0.06	0.48	0.06	0.30	0.92	50
20	0.10	0.07	0.63	0.10	0.10	1.28	41
21	0.22	0.03	0.63	0.03	0.09	1.13	32
22	0.08	0.12	0.76	0.04	0.00	2.13	25
23	0.05	0.11	0.79	0.00	0.05	1.38	19
24	0.10	0.10	0.70	0.00	0.10	8.00	10

TOTAL NO. OF AC = 653

% OF AC TYPE FOR WEATHER

VFR	H	A	B	C	D
	0.19	0.06	0.48	0.08	0.19
IFR	H	A	B	C	D
	0.19	0.06	0.48	0.08	0.27

SCHEDULED PASSENGERS BY CLASS:

HOUR	H	A			D
1	510	130	379	0	0
2	509	0	95	30	18
3	510	130	95	90	0
4	510	0	190	0	0
5	0	0	0	29	17
6	0	0	0	29	17
7	0	0	285	0	9
8	761	260	1904	0	44
9	1276	262	1805	60	71
10	2301	393	2184	119	80
11	1526	261	2278	120	45
12	0	390	2091	29	63
13	1020	257	2945	120	45
14	251	128	2089	60	71
15	1276	131	2089	60	53
16	0	261	2660	150	53
17	1020	520	2565	89	72
18	1272	520	2944	149	62
19	1275	390	2280	90	135
20	1024	389	2469	120	35
21	1787	128	1900	29	27
22	510	390	1805	30	0
23	256	259	1424	0	9
24	255	130	665	0	9

TOTAL NO. OF PASSENGERS = 62557

HOUR = 1	NO. OF PLANES ARRIVING =	5.
	NO. OF PLANES DEPARTING =	2.
HOUR = 2	NO. OF PLANES ARRIVING =	2.
	NO. OF PLANES DEPARTING =	4.
HOUR = 3	NO. OF PLANES ARRIVING =	5.
	NO. OF PLANES DEPARTING =	2.
HOUR = 4	NO. OF PLANES ARRIVING =	3.
	NO. OF PLANES DEPARTING =	1.
HOUR = 5	NO. OF PLANES ARRIVING =	2.
	NO. OF PLANES DEPARTING =	1.
HOUR = 6	NO. OF PLANES ARRIVING =	1.
	NO. OF PLANES DEPARTING =	2.
HOUR = 7	NO. OF PLANES ARRIVING =	1.
	NO. OF PLANES DEPARTING =	3.
HOUR = 8	NO. OF PLANES ARRIVING =	6.
	NO. OF PLANES DEPARTING =	23.
HOUR = 9	NO. OF PLANES ARRIVING =	15.
	NO. OF PLANES DEPARTING =	21.
HOUR = 10	NO. OF PLANES ARRIVING =	22.
	NO. OF PLANES DEPARTING =	26.
HOUR = 11	NO. OF PLANES ARRIVING =	17.
	NO. OF PLANES DEPARTING =	24.
HOUR = 12	NO. OF PLANES ARRIVING =	20.
	NO. OF PLANES DEPARTING =	13.
HOUR = 13	NO. OF PLANES ARRIVING =	21.
	NO. OF PLANES DEPARTING =	25.
HOUR = 14	NO. OF PLANES ARRIVING =	15.
	NO. OF PLANES DEPARTING =	19.
HOUR = 15	NO. OF PLANES ARRIVING =	21.
	NO. OF PLANES DEPARTING =	15.
HOUR = 16	NO. OF PLANES ARRIVING =	23.
	NO. OF PLANES DEPARTING =	18.
HOUR = 17	NO. OF PLANES ARRIVING =	19.
	NO. OF PLANES DEPARTING =	27.
HOUR = 18	NO. OF PLANES ARRIVING =	28.
	NO. OF PLANES DEPARTING =	24.
HOUR = 19	NO. OF PLANES ARRIVING =	24.
	NO. OF PLANES DEPARTING =	26.
HOUR = 20	NO. OF PLANES ARRIVING =	23.
	NO. OF PLANES DEPARTING =	18.
HOUR = 21	NO. OF PLANES ARRIVING =	17.
	NO. OF PLANES DEPARTING =	15.
HOUR = 22	NO. OF PLANES ARRIVING =	17.
	NO. OF PLANES DEPARTING =	8.
HOUR = 23	NO. OF PLANES ARRIVING =	11.
	NO. OF PLANES DEPARTING =	8.
HOUR = 24	NO. OF PLANES ARRIVING =	9.
	NO. OF PLANES DEPARTING =	1.

SCHEDULED CONCENTRATION

```
HOUR =     1 % CONCENTRATION =   85.71
HOUR =     2 % CONCENTRATION =   83.33
HOUR =     3 % CONCENTRATION =   71.43
HOUR =     4 % CONCENTRATION =  100.00
HOUR =     5 % CONCENTRATION =  100.00
HOUR =     6 % CONCENTRATION =  100.00
HOUR =     7 % CONCENTRATION =  100.00
HOUR =     8 % CONCENTRATION =   55.17
HOUR =     9 % CONCENTRATION =   58.33
HOUR =    10 % CONCENTRATION =   41.76
HOUR =    11 % CONCENTRATION =   43.90
HOUR =    12 % CONCENTRATION =   48.48
HOUR =    13 % CONCENTRATION =   45.65
HOUR =    14 % CONCENTRATION =   50.00
HOUR =    15 % CONCENTRATION =   36.11
HOUR =    16 % CONCENTRATION =    7.00
HOUR =    17 % CONCENTRATION =   50.00
HOUR =    18 % CONCENTRATION =   38.46
HOUR =    19 % CONCENTRATION =   48.00
HOUR =    20 % CONCENTRATION =   43.90
HOUR =    21 % CONCENTRATION =   34.38
HOUR =    22 % CONCENTRATION =   48.00
HOUR =    23 % CONCENTRATION =   63.16
HOUR =    24 % CONCENTRATION =   50.00
```

DAILY STATISTICS

MAX Q LENGTH	MAX AC DELAY	TOTAL # AC DELAYED
10	7.83	398.
TOTAL AC-MIN DELAY	TOTAL # AC DELAYED 30 MINS. OR MORE	AVERAGE MIN DELAY PE DELAYED AC
769.	0.00	1.93
AVERAGE MIN DELAY PER AC SERVICED	TOTAL PAX DELAY	PASSENGER DELAY COST
1.18	37602.	$ 9400.59

TOTAL AC DELAY COST

$ 492775.

DO YOU WANT TO SEE GROUNDSIDE STATISTICS - YES OR NO?
YES

PASSENGER MOVEMENTS

HOUR	THROUGH	TRANSFERS	ORIGINATING	TERMINATING	ENPLANED
1	40.	65.	914.	914.	1019.
2	25.	42.	585.	585.	652.
3	32.	53.	740.	740.	825.
4	27.	45.	628.	628.	700.
5	2.	3.	41.	41.	46.
6	2.	3.	41.	41.	46.
7	11.	19.	264.	264.	294.
8	112.	184.	2573.	2573.	2869.
9	135.	222.	3116.	3116.	3474.
10	198.	325.	4554.	4554.	5077.
11	165.	271.	3794.	3794.	4230.
12	100.	165.	2308.	2308.	2573.
13	171.	281.	3935.	3935.	4387.
14	101.	166.	2331.	2331.	2599.
15	141.	231.	3237.	3237.	3609.
16	122.	200.	2802.	2802.	3124.
17	166.	273.	3827.	3827.	4266.
18	193.	317.	4437.	4437.	4947.
19	163.	267.	3740.	3740.	4170.
20	157.	258.	3621.	3621.	4037.
21	151.	248.	3472.	3472.	3871.
22	107.	175.	2453.	2453.	2735.
23	76.	125.	1747.	1747.	1948.
24	41.	68.	950.	950.	1059.

SATURATED GROUNDSIDE FACILITIES

	FACILITY	HOURS
1	ACCESS HWY LANES	5
2	CIRCULATION RDWY LANES	6
3	ARRIVAL CURB SPACE	10
4	DEPARTURE CURB SPACE	6
5	SHORT TERM PRKG SPACE	24
6	LONG TERM PRKG SPACE	24
7	TICKET LOBBY AREA	4
8	PAX SERVICE COUNTER	11
9	AIRLINE OPERATIONS SPACE	9
10	BAGGAGE CLAIM AREA	11
11	WAITING AREA(SQUARE FEET)	7
12	WAITING AREA (SEATS)	4
13	MENS REST ROOM (FIXTURES)	4
14	WOMENS REST ROOM (FIXTURES)	4

```
ENTER NUMERICAL CODE FOR FURTHER INFORMATION
IF A NUMBER IS NOT WITHIN THE RANGE 1-14, - EXIT RESULTS
1

11:00 12:00 13:00 14:00 15:00

ENTER NUMERICAL CODE FOR FURTHER INFORMATION
IF A NUMBER IS NOT WITHIN THE RANGE 1-14, - EXIT RESULTS
2

11:00 12:00 13:00 14:00 15:00 16:00

ENTER NUMERICAL CODE FOR FURTHER INFORMATION
IF A NUMBER IS NOT WITHIN THE RANGE 1-14, - EXIT RESULTS
3

 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00

ENTER NUMERICAL CODE FOR FURTHER INFORMATION
IF A NUMBER IS NOT WITHIN THE RANGE 1-14, - EXIT RESULTS
4

10:00 11:00 12:00 13:00 14:00 15:00

ENTER NUMERICAL CODE FOR FURTHER INFORMATION
IF A NUMBER IS NOT WITHIN THE RANGE 1-14, - EXIT RESULTS
5

 1:00  2:00  3:00  4:00  5:00  6:00  7:00  8:00  9:00 10:00 11:00 12:00 13:00 14

:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00

ENTER NUMERICAL CODE FOR FURTHER INFORMATION
IF A NUMBER IS NOT WITHIN THE RANGE 1-14, - EXIT RESULTS
6

 1:00  2:00  3:00  4:00  5:00  6:00  7:00  8:00  9:00 10:00 11:00 12:00 13:00 14

:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00 24:00

ENTER NUMERICAL CODE FOR FURTHER INFORMATION
IF A NUMBER IS NOT WITHIN THE RANGE 1-14, - EXIT RESULTS
7

12:00 13:00 14:00 15:00
```

```
ENTER NUMERICAL CODE FOR FURTHER INFORMATION
IF A NUMBER IS NOT WITHIN THE RANGE 1-14, - EXIT RESULTS
8

 8:00  9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00

ENTER NUMERICAL CODE FOR FURTHER INFORMATION
IF A NUMBER IS NOT WITHIN THE RANGE 1-14, - EXIT RESULTS
9

 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00

ENTER NUMERICAL CODE FOR FURTHER INFORMATION
IF A NUMBER IS NOT WITHIN THE RANGE 1-14, - EXIT RESULTS
10

  8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00

ENTER NUMERICAL CODE FOR FURTHER INFORMATION
IF A NUMBER IS NOT WITHIN THE RANGE 1-14, - EXIT RESULTS
11

10:00 11:00 12:00 13:00 14:00 15:00 16:00

ENTER NUMERICAL CODE FOR FURTHER INFORMATION
IF A NUMBER IS NOT WITHIN THE RANGE 1-14, - EXIT RESULTS
12

12:00 13:00 14:00 15:00

ENTER NUMERICAL CODE FOR FURTHER INFORMATION
IF A NUMBER IS NOT WITHIN THE RANGE 1-14, - EXIT RESULTS
13

12:00 13:00 14:00 15:00

ENTER NUMERICAL CODE FOR FURTHER INFORMATION
IF A NUMBER IS NOT WITHIN THE RANGE 1-14, - EXIT RESULTS
14

12:00 13:00 14:00 15:00

ENTER NUMERICAL CODE FOR FURTHER INFORMATION
IF A NUMBER IS NOT WITHIN THE RANGE 1-14, - EXIT RESULTS
[illegible]
```

```
DO YOU WANT TO RUN THE PROGRAM AGAIN FOR ANOTHER CASE ? YES OR NO
NO


CPU TIME: 8.72  ELAPSED TIME: 10:24.60
NO EXECUTION ERRORS DETECTED

EXIT

.K.\.\/F
JOB 28, USER [4072,546]  LOGGED OFF TTY17     1500  27-AUG-75
SAVED ALL FILES (1392 BLOCKS)
RUNTIME 10.31 SEC
```

F.5 DATA FILES

F.5.1 FOR11.DAT

This file contains the OAG airline schedule for December 20, 1974, at Boston's Logan Airport. For each hour of the day, the hour, the mix as a percent for each class of aircraft, the arrival/departure ratio for that hour, the total number of operations during that hour, the percentage of operations occuring during the four highest minutes of that hour (the concentration), and the number of operations occuring at each minute of that hour are listed.

The parameters are in an integer format on a disk file because (a) mixed formatted and unformatted files are not randomly accessible, and (b) random access is used for disk files only. Although the file is not read in the random access manner, there is a possibility that several days worth of data may have been used to develop the prototype of this program. Therefore, the integer format is best suited should random access programming be employed.

The read format for FOR11.DAT is

```
    READ(11,105) IHR, [MIX(1,I,J), J=1,6], IADR(I), ITOT(I),
         ICON(I), [IV(I,L), L=1, 60]
105 FORMAT(I5,7I4,2I5,/(12I5)]
```

when the hour, the mix, the arrival/departure ratio, the total number of aircraft, the concentration, and the number of operations occuring during each minute of that hour are read.

F.5.2 FOR10.DAT

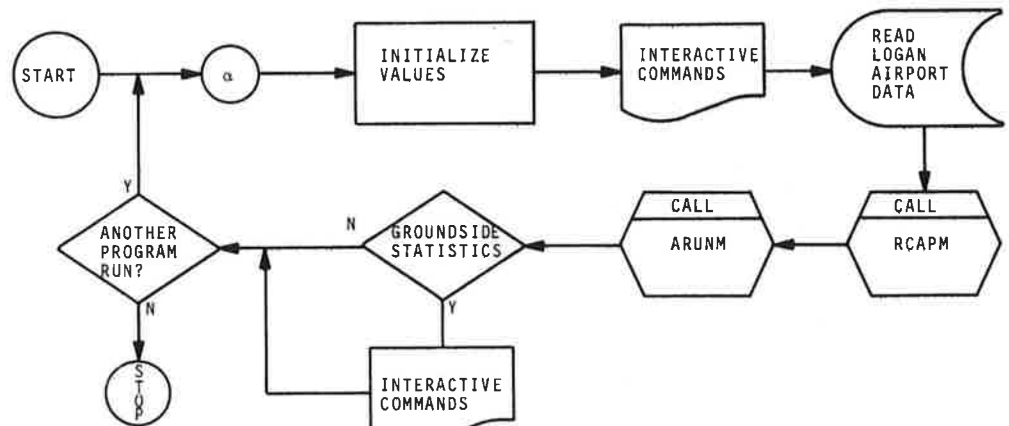
This file contains the load factors that were used in conjunction with FOR11.DAT for each hour of the day. Since the load factors were to be used in a floating point format, and there were not too many of them (24), it was decided to keep them in floating point format.

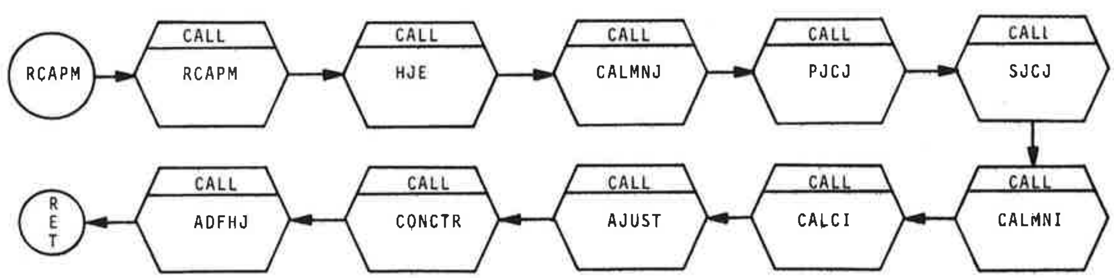
The read format for FOR10.DAT is

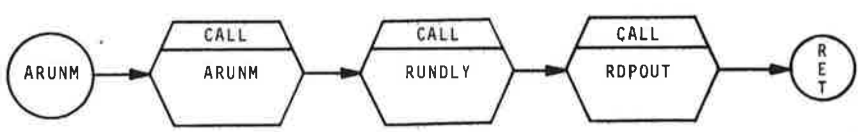
```
        READ(10, 4)[ALF(1,I), I=1, 24]
4       FORMAT [12(F4,2,1X)]
```

F.6 PROGRAM FLOW

N A S







APPENDIX G — PROGRAM LISTING — AIRPORT PERFORMANCE MODEL

```
****************************************************************************
*                         NATIONAL AIRPORT SYSTEM                          *
****************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:NAS.F4    [4072,546] 26-AUG-75 *
****************************************************************************
      REAL NMIX,MAC,MAD
      COMMON CI(24,2),CJ(2),CJØ(2),MAC(24),MAD(24),
     X P(2),PA(2),RI(24,2),
     X S(2),XI(24),XJ(2),SPN
      COMMON /BLK14/ITOT(24)
      COMMON /BLK1/IWF(24)
      COMMON /BLK2/ADR(24),ADRAV
      COMMON /BLK3/ARR(24),DEP(24)
      COMMON /BLK4/EMIX(1,24,6),NMIX(2,5)
      COMMON /BLK6/IBEG,IEND,TYPAN
      COMMON /BLK8/RA(24,2)
      COMMON /BLK9/ISPRC(24,5),ITSPC,ITPHR(24)
      COMMON /BLK10/IV(24,6Ø)
      COMMON /BLK12/CON(24)
      COMMON /BLK13/ALF(1,24)
      DIMENSION AIRDB(9),ICAP(5),ICON(24)
      DIMENSION MIX(1,24,6),IADR(24)
      DATA (IWF(K),K=1,24)/24*1/
      DATA ICAP/255,130,95,30,9/
      DATA AIRDB/'ATL','BOS','DCA','JFK','LAX','LGA',
     X 'MIA','ORD','SFO'/
      DATA YES/'YES'/,ANO/'NO '/
      DATA DAILY/'DAILY'/,HOURL/'HOURL'/
      CALL ASSDEV (1Ø,'DSK')
      CALL ASSDEV(11,'DSK')
      READ (1Ø,4) (ALF(1,I),I=1,24)
4     FORMAT (12(F4.2,1X))
5     CONTINUE
      ADRAV=Ø.Ø
      DO 6 N=1,24
      ADR(N)=Ø.Ø
      ARR(N)=Ø.Ø
      CON(N)=Ø.Ø
      DEP(N)=Ø.Ø
      ITPHR(N)=Ø
      MAC(N)=Ø.Ø
      MAD(N)=Ø.Ø
      XI(N)=Ø.Ø
6     CONTINUE
      DO 7 N=1,2
      CJ(N)=Ø.Ø
      CJØ(N)=Ø.Ø
      P(N)=Ø.Ø
      PA(N)=Ø.Ø
      S(N)=Ø.Ø
```

```
*************************************************************************
*                      NATIONAL AIRPORT SYSTEM                          *
*************************************************************************
        XJ(N)=0.0
7       CONTINUE
        DO 11 I=1,24
        DO 11 J=1,6
        EMIX(1,I,J)=0.0
11      CONTINUE
        DO 12 I=1,24
        DO 12 J=1,5
        ISPRC(I,J)=0
12      CONTINUE
        DO 13 I=1,2
        DO 13 J=1,5
        NMIX(I,J)=0.0
13      CONTINUE
        DO 8 I=1,24
        DO 8 J=1,2
        CI(I,J)=0.0
        RI(I,J)=0.0
        RA(I,J)=0.0
8       CONTINUE
        DO 9 I=1,24
        DO 9 J=1,5
        ISPRC(I,J)=0
9       CONTINUE
        WRITE (5,10)
10      FORMAT ( ' HELLO, WHAT AIRPORT ARE YOU INTERESTED IN ?',
     X  'PLEASE USE A 3 LETTER CODE ',/,1X,'FOR: ATL,BOS,DCA,JFK,'
     X  'LAX,LGA,MIA,ORD OR SFO ',/)
15      CONTINUE
        READ (5,20) AIRIN
20      FORMAT (A3)
        DO 25 I=1,9
        IF (AIRIN.EQ.AIROB(I)) GO TO 35
25      CONTINUE
        WRITE (5,30)
30      FORMAT ( ' AIRPORT YOU HAVE SELECTED WAS NOT ON MY LIST,PLEASE',
     X  ' TRY ANOTHER AIRPORT',/)
        GO TO 15
35      CONTINUE
        IF (AIRIN.EQ.AIROB(2)) GO TO 45
        WRITE (5,40)
40      FORMAT (' CURRENT DATA EXISTS ONLY FOR BOSTON, PLEASE',
     X  ' ENTER BOS THANK YOU.',/)
        GO TO 15
45      CONTINUE
        WRITE (5,50)
50      FORMAT (' THANKS FOR SELECTING BOSTON',/)
```

```
********************************************************************************
*                          NATIONAL AIRPORT SYSTEM                             *
********************************************************************************
          WRITE (5,55)
55        FORMAT (' TYPE OF ANALYSIS DESIRED - HOURLY OR DAILY?',/)
          READ (5,60) TYPAN
60        FORMAT (A5)
          IF (TYPAN.EQ.DAILY) GO TO 95
          WRITE (5,65)
65        FORMAT (' DO YOU WANT 1 PARTICULAR HOUR - YES OR NO?',/)
          READ (5,70) PARHR
70        FORMAT (A3)
          IF (PARHR.EQ.YES) GO TO 85
          WRITE (5,75)
75        FORMAT ( ' TYPE IN HOURS - BEGINNING,END ',/)
          READ (5,80) IBEG,IEND
80        FORMAT (2I)
          GO TO 100
85        CONTINUE
          WRITE (5,90)
90        FORMAT (' TYPE IN THE PARTICULAR HOUR YOU WANT ',/)
          READ (5,81) IEND
81        FORMAT(I)
          IBEG=IEND
          GO TO 100
95        CONTINUE
          IBEG=1
          IEND=24
100       CONTINUE
          DO 110 I=1,IEND
          READ (11,105) IHR,(MIX(1,I,J),J=1,6),IADR(I),ITOT(I),ICON(I),
     X    (IV(I,L),L=1,60)
C         WRITE (5,105) IHR,(MIX(1,I,J),J=1,6),IADR(I),ITOT(I),ICON(I),
     X    (IV(I,L),L=1,60)
105       FORMAT (I5,7I4,2I5,/(12I5))
110       CONTINUE
          DO 106 I=IBEG,IEND
          DO 106 J=1,6
          EMIX(1,I,J)=FLOAT(MIX(1,I,J))/1000.0
          ADR(I)=FLOAT(IADR(I))/100.0
          CON(I)=FLOAT(ICON(I))/100.0
106       CONTINUE
          DO 107 I=IBEG,IEND
          EMIX(1,I,5)=EMIX(1,I,5)+EMIX(1,I,6)
107       CONTINUE
          DO 119 I=1,2
          DO 119 J=1,5
          IF (J.EQ.5) MIX(1,10,5)=MIX(1,10,5)+MIX(1,10,6)
          NMIX(I,J)=FLOAT(MIX(1,10,J))/1000.0
C         WRITE (5,156) I,J,NMIX(I,J),MIX(1,10,J)
```

```
**************************************************************
*                   NATIONAL AIRPORT SYSTEM                  *
**************************************************************
156     FORMAT (2I,F10.3,I)
119     CONTINUE
        DO 120 I=IBEG,IEND
        DO 120 J=1,5
        ISPRC(I,J)=FLOAT(ITOT(I)*ICAP(J))*EMIX(1,I,J)
120     CONTINUE
        DO 122 I=IBEG,IEND
        DO 122 J=1,5
        ITPHR(I)=ITPHR(I)+ISPRC(I,J)
C       WRITE (5,121) ITPHR(I)
121     FORMAT (' ITPHR(I) = ',I)
122     CONTINUE
        ITSPC=0
        DO 125 I=IBEG,IEND
        DO 125 J=1,5
        ITSPC=ITSPC+ISPRC(I,J)
125     CONTINUE
C       IF (PARHR.EQ.YES) IBEG=IEND
        IF (TYPAN.EQ.DAILY ) GO TO 109
        IF (TYPAN.EQ.HOURL.AND.IEND.GT.10) GO TO 109
        DO 108 I=1,10
        READ (11,105) IHR,(MIX(1,I,J),J=1,6),IADR(I),ITOT(I),ICON(I),
     X  (IV(I,L),L=1,60)
108     CONTINUE
        DO 104 I=1,10
        DO 104 J=1,6
        EMIX(1,I,J)=FLOAT(MIX(1,I,J))/1000.0
104     CONTINUE
        DO 112 I=1,2
        DO 112 J=1,5
        NMIX(I,J)=EMIX(1,10,J)
112     CONTINUE
109     CONTINUE
        DO 115 I=IBEG,IEND
        DEP(I)=FLOAT(ITOT(I))/(ADR(I)+1.0)
        ARR(I)=FLOAT(ITOT(I))-DEP(I)
115     CONTINUE
        CALL RCAPH
        CALL ARUNM
200     CONTINUE
        WRITE (5,205)
205   FORMAT(/' DO YOU WANT TO SEE GROUNDSIDE STATISTICS - YES OR NO?'
     X  ,/)
        READ (5,70) GNDST
        IF (GNDST.EQ.ANO) GO TO 210
        CALL GNDMAN
210     CONTINUE
```

```
****************************************************************************
*                          NATIONAL AIRPORT SYSTEM                         *
****************************************************************************
        WRITE (5,220)
220     FORMAT ( ' DO YOU WANT TO RUN THE PROGRAM AGAIN FOR ANOTHER',
     X  ' CASE ? YES OR NO',/)
        READ (5,70) AGAIN
        IF (AGAIN.EQ.ANO) GO TO 300
        REWIND 11
        GO TO 5
300     CONTINUE
        STOP
        END
```

```
****************************************************************************
*                          NATIONAL AIRPORT SYSTEM                         *
****************************************************************************
```

```
*************************************************************************
*                       NATIONAL AIRPORT SYSTEM                         *
*************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:RCAPM.F4  [4072,546] 26-AUG-75 *
*************************************************************************
      SUBROUTINE RCAPM
C     RUNWAY CAPACITY MODULE OR
C     AIRSIDE PROCESSING RATE MODULE
      INTEGER SPN
      REAL NMIX
      COMMON CI(24,2),CJ(2),CJ0(2),MAC(24),MAD(24),
     X P(2),PA(2),RI(24,2),
     X S(2),XI(24),XJ(2),SPN
      COMMON /BLK14/ITOT(24)
      COMMON /BLK1/IWF(24)
      COMMON /BLK2/ADR(24),ADRAV
      COMMON /BLK3/ARR(24),DEP(24)
      COMMON /BLK4/EMIX(1,24,6),NMIX(2,5)
      COMMON /BLK6/IBEG,IEND,TYPAN
      COMMON /BLK8/RA(24,2)
      COMMON /BLK9/ISPRC(24,5),ITSPC,ITPHR(24)
      COMMON /BLK10/IV(24,60)
      COMMON /BLK12/CON(24)
      DIMENSION IPA(2),IFLG(24)
      DATA IYES/'YES  '/,NO/'NO   '/
      DO 3 I=1,24
      IFLG(I)=1
3     CONTINUE
      WRITE (5,1)
1     FORMAT (' STANDARD VFR RATE = 120 OPS/HR',/,
     X ' STANDARD IFR RATE =  65 OPS/HR',/,
     X ' DO YOU WISH TO CHANGE THESE RATES ? YES OR NO'/)
      READ (5,25) NUOPS
      IF (NUOPS.EQ.IYES ) GO TO 4
      IPA(1)=120
      IPA(2)=65
      PA(1)=IPA(1)
      PA(2)=IPA(2)
      GO TO 14
4     CONTINUE
      WRITE (5,5)
5     FORMAT ( 1X,' TYPE IN VFR AND IFR RATES',/)
      READ (5,10) IPA(1),IPA(2)
10    FORMAT (2I)
      PA(1)=IPA(1)
      PA(2)=IPA(2)
14    CONTINUE
      WRITE (5,15)
15    FORMAT (1X,' SPACING IS SET FOR 3MILE/5MILE - 35',/)
      WRITE (5,20)
```

```
************************************************************************
*                         NATIONAL AIRPORT SYSTEM                      *
************************************************************************
20      FORMAT (1X,' DO YOU WANT TO CHANGE IT TO 37, YES OR NO?',/)
        READ (5,25) ICHNG
25      FORMAT (A5)
        SPN=35
        IF (ICHNG.EQ.IYES) SPN=37
        SUM=0.0
        DO 30 I=IBEG,IEND
        SUM=SUM+ADR(I)
30      CONTINUE
        DIV=IEND-IBEG+1
        ADRAV=SUM/DIV
        WRITE (5,35)
35      FORMAT (' DO YOU WANT TO CHANGE THE WEATHER ARRAY - YES'
     X   ' OR NO ?',/)
        READ (5,25) IWTHR
        IF (IWTHR.EQ.NO) GO TO 59
        WRITE (5,36)
36      FORMAT (' TYPE IN THE NUMBER OF HOURS TO BE CHANGED',/)
        READ (5,10) NHRS
        WRITE (5,37)
37      FORMAT (' TYPE IN THE NO. OF EACH HOUR 1-24 TO BE CHANGED',/)
        DO 39 L=1,NHRS
        READ (5,10) IFLG(L)
39      CONTINUE
        DO 40 K=1,NHRS
        N=IFLG(K)
        IWF(N)=2
40      CONTINUE
C       WRITE (5,42) (IWF(J),J=1,24)
42      FORMAT (4I)
59      CONTINUE
        WRITE (5,60)
60      FORMAT (' DO YOU WANT TO SEE INPUT FIGURES - YES OR NO ?',/)
        READ (5,25) INFIG
        IF (INFIG.EQ.NO) GO TO 125
        WRITE (5,65)
65      FORMAT (3X,'HOUR',3X,'H',6X,'A',6X,'B',6X,'C',6X,'D',5X,
     X  'ADR',5X,'AC',/)
        DO 75 I=IBEG,IEND
        WRITE (5,70) I,(EMIX(1,I,J),J=1,5),ADR(I),ITOT(I)
70      FORMAT (1X,I5,5(F7.2),2X,F5.2,3X,I3)
75      CONTINUE
        WRITE (5,80)
80      FORMAT (//)
        ITAC=0
        DO 85 I=IBEG,IEND
        ITAC=ITAC+ITOT(I)
```

```
*************************************************************************
*                        NATIONAL AIRPORT SYSTEM                         *
*************************************************************************
85      CONTINUE
        WRITE (5,90) ITAC
90      FORMAT ( ' TOTAL NO. OF AC = ',I5/)
        WRITE (5,95)
95      FORMAT (' % OF AC TYPE FOR WEATHER',/,1X,'VFR',6X,
     X  'H',6X,'A',6X,'B',6X,'C',6X,'D')
        WRITE (5,100) (NMIX(1,K),K=1,5)
100     FORMAT (6X,5F7.2)
        WRITE (5,105)
105     FORMAT (1X,'IFR',6X,'H',6X,'A',6X,'B',6X,'C',6X,'D')
        WRITE (5,100) (NMIX(2,K),K=1,5)
        WRITE (5,106)
106     FORMAT (' SCHEDULED PASSENGERS BY CLASS:')
        WRITE (5,66)
66      FORMAT (3X,'HOUR',7X,'H',9X,'A',9X,'B',9X,'C',9X,'D')
        DO 108 I=IBEG,IEND
        WRITE (5,107) I,(ISPRC(I,J),J=1,5)
107     FORMAT (1X,I5,3X,5(I7,3X))
108     CONTINUE
        WRITE (5,109) ITSPC
109     FORMAT (' TOTAL NO. OF PASSENGERS = ',I10,/)
        DO 111 I=IBEG,IEND
        WRITE (5,110) I,ARR(I),DEP(I)
110     FORMAT (' HOUR = ',I3,'  NO. OF PLANES ARRIVING = ',F5.0,/,
     X  11X,' NO. OF PLANES DEPARTING = ',F5.0)
111     CONTINUE
        WRITE (5,112)
112     FORMAT (' SCHEDULED CONCENTRATION ',/)
        DO 114 I=IBEG,IEND
        WRITE (5,113) I,CON(I)
113     FORMAT (' HOUR = ',I5,' % CONCENTRATION = ',F7.2,/)
114     CONTINUE
125     CONTINUE
C       DO 130 I=IBEG,IEND
C       DO 130 J=1,5
C       EMIX(1,I,J)=EMIX(1,I,J)/100.0
C130    CONTINUE
C       DO 135 K=1,2
C       DO 135 L=1,5
C       NMIX(K,L)=NMIX(K,L)/100.0
C135    CONTINUE
C
C       SUBROUTINE CALLS
C
        CALL HJE
        CALL CALMNJ
        CALL PJCJ
```

```
*****************************************************************************
*                          NATIONAL AIRPORT SYSTEM                          *
*****************************************************************************
        CALL SJCJ
        CALL CALMNI
        CALL CALCI
        CALL AJUST
        CALL CONCTR
        CALL ADFHJ
C
        GO TO 150
        WRITE (5,200)
200     FORMAT('  OUTPUT FROM RUNWAY CAPACITY YES OR NO?',/)
        READ (5,25) IROUT
        IF (IROUT.EQ.NO) GO TO 150
C       CALL RCOUT
150     CONTINUE
        RETURN
        END
```

```
*****************************************************************************
*                          NATIONAL AIRPORT SYSTEM                          *
*****************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:HJE.F4     [4072,546] 26-AUG-75 *
*****************************************************************************
        SUBROUTINE HJE
C       TAKE OUT HEAVY JET EFFECT
        INTEGER SPN
        REAL NMIX
        COMMON CI(24,2),CJ(2),CJ0(2),MAC(24),MAD(24),
     X  P(2),PA(2),RI(24,2),
     X  S(2),XI(24),XJ(2),SPN
        COMMON /BLK4/EMIX(1,24,6),NMIX(2,5)
C       SPACING NUMBER IS EITHER 35 OR 37
        IF (SPN.EQ.37) GO TO 40
C       SPACING NUMBER IS 35 - 3MILE/5MILE SPACING
        DO 20 J=1,2
        H=NMIX(J,1)
        P(J)=PA(J)*(0.997-(0.426*H)+0.109*(H*H))
20      CONTINUE
        GO TO 100
40      CONTINUE
C       SPACING NUMBER IS 37 - 3MILE/7MILE SPACING
        DO 50 J=1,2
        H=NMIX(J,1)
        P(J)=PA(J)*(0.987-(0.640*H)+0.184*(H*H))
50      CONTINUE
C
100     CONTINUE
        RETURN
        END
```

```
**************************************************************************
*                      NATIONAL AIRPORT SYSTEM                           *
**************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:CALMNJ.F4 [4072,546] 26-AUG-75 *
**************************************************************************
            SUBROUTINE CALMNJ
C           CALCULATES MIX NUMBERS X(J),X(I)
            INTEGER SPN
            REAL NMIX
            COMMON CI(24,2),CJ(2),CJØ(2),MAC(24),MAD(24),
        X   P(2),PA(2),RI(24,2),
        X   S(2),XI(24),XJ(2),SPN
            COMMON /BLK4/EMIX(1,24,6),NMIX(2,5)
            DO 125 I=1,2
C           I IS EQUAL TO 1 - VFR
            H=NMIX(I,1)
            A=NMIX(I,2)
            B=NMIX(I,3)
            C=NMIX(I,4)
            IF (I.EQ.2) GO TO 100
            IF (H+A.GT.Ø.Ø) GO TO 20
            IF (H+A.EQ.Ø.Ø.AND.B.GT.Ø.Ø) GO TO 3Ø
            IF (H+A.EQ.Ø.Ø.AND.B.EQ.Ø.Ø.AND.C.GT.Ø.Ø) GO TO 4Ø
            IF (H+A.EQ.Ø.Ø.AND.B.EQ.Ø.Ø.AND.C.EQ.Ø.Ø) GO TO 7Ø
            WRITE (5,1Ø)
 1Ø         FORMAT (2X,' NONE OF THE CONDITIONS HOLD FOR MIX NOS.')
            GO TO 125
 2Ø         CONTINUE
            XJ(I)=4.Ø+(B/2.Ø+(5.Ø/4.Ø*(H+A-2Ø.Ø)))*1.Ø/2Ø.Ø
            GO TO 9Ø
 3Ø         CONTINUE
            XJ(I)=2.Ø+(C/2.Ø+(1Ø.Ø/9.Ø*(B-15.Ø)))*1.Ø/3Ø.Ø
            GO TO 9Ø
 4Ø         CONTINUE
            IF (C.LE.3Ø.Ø) GO TO 6Ø
 5Ø         CONTINUE
C           C IS GT 3Ø
            XJ(I)=2.Ø
            GO TO 9Ø
 6Ø         CONTINUE
C           C IS LE 3Ø
            XJ(I)=2.Ø*(C/3Ø.Ø)
            GO TO 9Ø
 7Ø         CONTINUE
            WRITE (5,8Ø)
 8Ø         FORMAT (2X,' H+A=Ø.Ø B=Ø.Ø C=Ø.Ø')
            GO TO 125
 9Ø         CONTINUE
C           MIX NO. FOR VFR MUST BE BETWEEN Ø.Ø AND 7.Ø
            IF (XJ(I).LT.Ø.Ø) XJ(I)=Ø.Ø
```

```
*********************************************************************************
*                          NATIONAL AIRPORT SYSTEM                              *
*********************************************************************************
      IF (XJ(I).GT.7.0) XJ(I)=7.0
      GO TO 125
100   CONTINUE
      IF (H+A.GE.0.0) XJ(I)=(A+H)/10.0
      IF (XJ(I).LE.0.0) XJ(I)=0.0
      IF (XJ(I).GE.6.0) XJ(I)=6.0
125   CONTINUE
      RETURN
      END
```

```
*********************************************************************************
*                          NATIONAL AIRPORT SYSTEM                              *
*********************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:PJCJ.F4    [4072,546] 26-AUG-75 *
*********************************************************************************
        SUBROUTINE PJCJ
C       CONVERTS P(J) TO C(J)
        INTEGER SPN
        REAL NMIX
        COMMON CI(24,2),CJ(2),CJ0(2),MAC(24),MAD(24),
     X  P(2),PA(2),RI(24,2),
     X  S(2),XI(24),XJ(2),SPN
        COMMON /BLK2/ADR(24),ADRAV
        COMMON /BLK4/EMIX(1,24,6),NMIX(2,5)
        AMAC=0.0
        AMAD=0.0
        TEST=0.0
        DO 100 J=1,2
        IF (J.EQ.2) GO TO 70
        IF (ADRAV.LE.1.1) GO TO 20
C       AVERAGE ARRIVAL-DEPARTURE RATE GT 1.1
        AMAD=P(J)/(1.0+(1.0/ADRAV))
        AMAC=120.0-(XJ(J)/7.0*(120.0-33.0))
        IF (AMAC.GE.AMAD) GO TO 20
C       MAC IS LESS THAN MAD
        CJ(J)=P(J)/1.60
        GO TO 100
20      CONTINUE
C       AV. ARRIVAL-DEPARTURE RATIO LE 1.1 OR MAC GE MAD
        DO 30 I=1,3
        TEST =TEST+NMIX(1,I)
30      CONTINUE
        IF (TEST.GE.10.0) GO TO 40
        IF (TEST.GE.1.0.AND.TEST.LE.10.0) GO TO 50
        IF (TEST.LT.1.0) GO TO 60
        GO TO 100
40      CONTINUE
C       TEST GREATER THAN 10
        CJ(J)=P(J)/1.10
        GO TO 100
50      CONTINUE
C       TEST GE 1 AND TEST LE 10
        CJ(J)=P(J)/1.15
        GO TO 100
60      CONTINUE
C       TEST LT 1.0
        CJ(J)=P(J)/1.25
        GO TO 100
70      CONTINUE
C       IFR
```

```
************************************************************************
*                        NATIONAL AIRPORT SYSTEM                       *
************************************************************************
        CJ(J)=P(J)/1.10
100     CONTINUE
        RETURN
        END
```

```
************************************************************************
*                        NATIONAL AIRPORT SYSTEM                       *
************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:SJCJ.F4    [4072,546] 26-AUG-75 *
************************************************************************
        SUBROUTINE SJCJ
C       CALCULTAES CAPACITY CURVE PARAMETERS
C       CALCULATES S(J) AND CJ(0)
        REAL K1,K2
        INTEGER SPN
        COMMON CI(24,2),CJ(2),CJ0(2),MAC(24),MAD(24),
     X  P(2),PA(2),RI(24,2),
     X  S(2),XI(24),XJ(2),SPN
        DATA K1/0.225/,K2/0.047/
        CJ6=0.0
        CJ7=0.0
        DO 50 J=1,2
        IF (J.EQ.2) GO TO 40
        CJ7=CJ(J)/(1.0+7.0*K1)-(XJ(J)*K1)
        S(J)=K1*CJ7
        CJ0(J)=CJ7+(7.0*S(J))
        GO TO 50
40      CONTINUE
        CJ6=CJ(J)/(1.0+(6.0*K2)-(XJ(J)*K2))
        S(J)=K2*CJ6
        CJ0(J)=CJ6+(6.0*S(J))
50      CONTINUE
        RETURN
        END
```

```
****************************************************************************
*                        NATIONAL AIRPORT SYSTEM                           *
****************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:CALMNI.F4 [4072,546] 26-AUG-75 *
****************************************************************************
        SUBROUTINE CALMNI
C       CALCULATES MIX NUMBERS X(J),X(I)
        INTEGER SPN
        REAL NMIX
        COMMON CI(24,2),CJ(2),CJ0(2),MAC(24),MAD(24),
     X  P(2),PA(2),RI(24,2),
     X  S(2),XI(24),XJ(2),SPN
        COMMON /BLK1/IWF(24)
        COMMON /BLK4/EMIX(1,24,6),NMIX(2,5)
        COMMON /BLK6/IBEG,IEND,TYPAN
        DO 125 I=IBEG,IEND
C       I IS EQUAL TO 1 - VFR
        H=EMIX(1,I,1)
        A=EMIX(1,I,2)
        B=EMIX(1,I,3)
        C=EMIX(1,I,4)
        IF (IWF(I).EQ.2) GO TO 100
        IF (H+A.GT.0.0) GO TO 20
        IF (H+A.EQ.0.0.AND.B.GT.0.0) GO TO 30
        IF (H+A.EQ.0.0.AND.B.EQ.0.0.AND.C.GT.0.0) GO TO 40
        IF (H+A.EQ.0.0.AND.B.EQ.0.0.AND.C.EQ.0.0) GO TO 70
        WRITE (5,10)
10      FORMAT (2X,' NONE OF THE CONDITIONS HOLD FOR MIX NOS.')
        GO TO 125
20      CONTINUE
        XI(I)=4.0+(B/2.0+(5.0/4.0*(H+A-20.0)))*1.0/20.0
        GO TO 90
30      CONTINUE
        XI(I)=2.0+(C/2.0+(10.0/9.0*(B-15.0)))*1.0/30.0
        GO TO 90
40      CONTINUE
        IF (C.LE.30.0) GO TO 60
50      CONTINUE
C       C IS GT 30
        XI(I)=2.0
        GO TO 90
60      CONTINUE
C       C IS LE 30
        XI(I)=2.0*(C/30.0)
        GO TO 90
70      CONTINUE
        WRITE (5,80)
80      FORMAT (2X,' H+A=0.0 B=0.0 C=0.0')
        GO TO 125
90      CONTINUE
```

```
******************************************************************************
*                      NATIONAL AIRPORT SYSTEM                               *
******************************************************************************
C       MIX NO: FOR VFR MUST BE BETWEEN 0.0 AND 7.0
        IF (XI(I).LT.0.0) XI(I)=0.0
        IF (XI(I).GT.7.0) XI(I)=7.0
        GO TO 125
100     CONTINUE
        IF (H+A.GE.0.0) XI(I)=(A+H)/10.0
        IF (XI(I).LE.0.0) XI(I)=0.0
        IF (XI(I).GE.6.0) XI(I)=6.0
125     CONTINUE
        RETURN
        END
```

```
******************************************************************************
*                      NATIONAL AIRPORT SYSTEM                               *
******************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:CALCI.F4  [4072,546] 26-AUG-75 *
******************************************************************************
        SUBROUTINE CALCI
C       CALCULATE C(I)
C       LET J=WF(I)
C       C(I)=CJ(0)-S(J)*X(I)
        INTEGER SPN
        COMMON CI(24,2),CJ(2),CJ0(2),MAC(24),MAN(24),
     X  P(2),PA(2),RI(24,2),
     X  S(2),XI(24),XJ(2),SPN
        COMMON /BLK6/IBEG,IEND,TYPAN
        DO 50 I=IBEG,IEND
        DO 50 J=1,2
        CI(I,J)=CJ0(J)-S(J)*XI(I)
50      CONTINUE
        RETURN
        END
```

```
****************************************************************************
*                           NATIONAL AIRPORT SYSTEM                        *
****************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:AJUST.F4  [4072,546] 26-AUG-75    *
****************************************************************************
            SUBROUTINE AJUST
C           ADJUST C(I) FOR ADR(I)
            INTEGER SPN
            REAL MAC,MAD
            COMMON CI(24,2),CJ(2),CJ0(2),MAC(24),MAD(24),
      X     P(2),PA(2),RI(24,2),
      X     S(2),XI(24),XJ(2),SPN
            COMMON /BLK1/IWF(24)
            COMMON /BLK2/ADR(24),ADRAV
            COMMON /BLK6/IBEG,IEND,TYPAN
            SUB1=120.0-33.0
            SUB2=40.0-37.0
            DO 50 I=IBEG,IEND
            IF (ADR(I).LE.1.1) GO TO 50
            J=IWF(I)
            IF (IWF(I).EQ.2) GO TO 35
            MAD(I)=CI(I,J)/(1.0+(1.0/ADR(I)))
            MAC(I)=120.0-XI(I)*SUB1/7.0
            GO TO 40
35          CONTINUE
            MAC(I)=40.0-XI(I)*SUB2/6.0
40          CONTINUE
            IF (MAC(I).GE.MAD(I)) GO TO 50
            CI(I,J)=CI(I,J)*(MAC(I)/MAD(I))
50          CONTINUE
            RETURN
            END
```

```
****************************************************************************
*                          NATIONAL AIRPORT SYSTEM                         *
****************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:CONCTR.F4 [4072,546] 26-AUG-75 *
****************************************************************************
      SUBROUTINE CONCTR
C     CONVERT C(I) TO R(I)
C     ARRAYS ADR,C,MAC,MAD,MIX,R,X
      INTEGER SPN
      REAL MAC,MAD
      COMMON CI(24,2),CJ(2),CJ0(2),MAC(24),MAD(24),
     X P(2),PA(2),RI(24,2),
     X S(2),XI(24),XJ(2),SPN
      COMMON /BLK1/IWF(24)
      COMMON /BLK2/ADR(24),ADRAV
      COMMON /BLK4/EMIX(1,24,6),NMIX(2,5)
      COMMON /BLK6/IBEG,IEND,TYPAN
      TEST=0.0
      DO 200 I=IBEG,IEND
      J=IWF(I)
      IF (IWF(I).EQ.2) GO TO 40
      IF (ADR(I).LE.1.1) GO TO 20
C     A/D RATE GT 1.1
      MAD(I)=CI(I,J)/(1.0+(1.0/ADR(I)))
      MAC(I)=120.0-XI(I)*((120.0-33.0)/7.0)
      IF (MAC(I).GE.MAD(I)) GO TO 20
      RI(I,J)=1.6*CI(I,J)
      GO TO 200
20    CONTINUE
C     A/D RATE LE 1.1 OR MAC GE MAD
      DO 30 K=1,3
      TEST=TEST+EMIX(1,I,K)
30    CONTINUE
      IF (TEST.GT.10.0) GO TO 40
      IF (TEST.LT.1.0) GO TO 50
      IF (TEST.GE.1.0.AND.TEST.LE.10.0) RI(I,J)=1.15*CI(I,J)
      GO TO 200
40    CONTINUE
      RI(I,J)=1.10*CI(I,J)
      GO TO 200
50    CONTINUE
      RI(I,J)=1.25*CI(I,J)
200   CONTINUE
      RETURN
      END
```

```
************************************************************************
*                         NATIONAL AIRPORT SYSTEM                      *
************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:ADFHJ.F4  [4072,546] 26-AUG-75 *
************************************************************************
        SUBROUTINE ADFHJ
C       ADJUST R(I) FOR HEAVY JETS
        INTEGER SPN
        REAL NMIX
        COMMON CI(24,2),CJ(2),CJ0(2),MAC(24),MAD(24),
     X  P(2),PA(2),RI(24,2),
     X  S(2),XI(24),XJ(2),SPN
        COMMON /BLK1/IWF(24)
        COMMON /BLK4/EMIX(1,24,6),NMIX(2,5)
        COMMON /BLK6/IBEG,IEND,TYPAN
        COMMON /BLK8/RA(24,2)
        DO 50 I=IBEG,IEND
        J=IWF(I)
        H=EMIX(1,I,1)
        IF (SPN.EQ.35) GO TO 20
        IF (SPN.EQ.37) GO TO 30
        WRITE (5,10)
10      FORMAT (2X,'SPACING NUMBER OTHER THAN 35 OR 37')
        GO TO 50
20      CONTINUE
        RA(I,J)=RI(I,J)*(1.0-((0.32*H)/100.0))
        GO TO 50
30      CONTINUE
        RA(I,J)=RI(I,J)*(1.0-((0.47*H)/100.0))
50      CONTINUE
C       RA(I,J) IS DESIRED OUTPUT
        RETURN
        END
```

```
*************************************************************************
*                          NATIONAL AIRPORT SYSTEM                      *
*************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE!ARUNM.F4  [4072,546] 26-AUG-75 *
*************************************************************************
          SUBROUTINE ARUNM
          COMMON /BLK2/ADR(24),ADRAV
          COMMON /BLK5/ACS(24),ACSZ(24),AST(24),APAX(24),
     X    D(24),DAC(24),DACZ(24),D30(24),D30Z(24),DZ(24),
     X    ITPAX(24),MXD(24),MXDZ(24),MXQ(24),Q(200),QEND(24),
     X    R(24,2),ENDQ,KNTQ,QLGTH,RFT,TOPQ
          COMMON /BLK9/ISPRC(24,5),ITSPC,ITHPR(24)
          COMMON /BLK10/IV(24,60)
          COMMON /BLK6/IBEG,IEND,TYPAN
          COMMON /BLK8/RA(24,2)
          COMMON /BLK13/ALF(1,24)
C         TOPQ=1
5         CONTINUE
          DO 15 I=1,24
          DO 15 J=1,2
          R(I,J)=0.0
15        CONTINUE
          DO 20 I=IBEG,IEND
          DO 20 J=1,2
          IF (RA(I,J).EQ.0.00) GO TO 20
          R(I,J)=(1.0/RA(I,J))*3600.0
C         WRITE (5,25) I,J,RA(I,J),R(I,J)
25        FORMAT (2I,2F)
20        CONTINUE
          CALL RUNDLY
          CALL RDPOUT
          RETURN
          END
```

```
********************************************************************************
*                          NATIONAL AIRPORT SYSTEM                             *
********************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:RUNDLY.F4 [4072,546] 26-AUG-75        *
********************************************************************************
      SUBROUTINE RUNDLY
      REAL ITPAX
      INTEGER ENDQ,Q,QLGTH,RFT,TOPQ,DELAY
      COMMON /BLK5/ACS(24),ACSZ(24),AST(24),APAX(24),
     X D(24),DAC(24),DACZ(24),D30(24),D30Z(24),DZ(24),
     X ITPAX(24),MXD(24),MXDZ(24),MXQ(24),Q(200),QEND(24),
     X R(24,2),ENDQ,KNTQ,QLGTH,RFT,TOPQ
      COMMON /BLK1/IWF(24)
      COMMON /BLK2/ADR(24),ADRAV
      COMMON /BLK6/IBEG,IEND,TYPAN
      COMMON /BLK9/ISPRC(24,5),ITSPC,ITPHR(24)
      COMMON /BLK10/IV(24,60)
      COMMON /BLK13/ALF(1,24)
      COMMON /BLK14/ITOT(24)
C     START HERE AT BEGINNING OF HOUR
      DO 17 I=1,24
      AST(I)=0.0
      ACS(I)=0.
      ACSZ(I)=0.
      APAX(I)=0.
      D(I)=0.
      DAC(I)=0.
      DACZ(I)=0.
      D30(I)=0.
      D30Z(I)=0.0
      DZ(I)=0.
      ITPAX(I)=0.
      MXD(I)=0
      MXDZ(I)=0
      QEND(I)=0.
      MXQ(I)=0
17    CONTINUE
      DO 18 I=IBEG,IEND
      AST(I)=ITPHR(I)/ITOT(I)
18    CONTINUE
      DO 16 I=1,200
      Q(I)=0
16    CONTINUE
      DELAY=0
      ENDQ=0
      ISEC=0
      ITO=0
      KNTQ=0
      NXS=0
      QLGTH=0
```

```
*************************************************************************
*                          NATIONAL AIRPORT SYSTEM                     *
*************************************************************************
          RFT=0
          TOPQ=1
C         THIS IS PRINCIPAL DECISION POINT
1         CONTINUE
          DO 2000 IH=IBEG,IEND
          IM=0
          IW=IWF(IH)
C         WRITE (5,19) IH,IWF(IH)
19        FORMAT ( ' IH = ',I5,' IWF(IH) = ',I5/)
C         IM=1
 37       IF (QLGTH) 701,10,11
701       CONTINUE
          WRITE (5,702) QLGTH,IH,IM
702       FORMAT (2X,' QLGTH =',I5,'IH=',I3,'IM=',I3)
          QLGTH=0
10        CONTINUE
C         Q IS EMPTY OR NEW MINUTE IS NEXT
 38       IM=IM+1
          IF (IM.GT.60) GO TO 1000
          ISEC=IM*60
C         WRITE (5,24) ISEC,IV(IH,IM)
24        FORMAT (' ISEC = ',I5, ' IV(IH,IM) = ', I5)
          IF (IV(IH,IM)) 703,37,12
703       CONTINUE
          WRITE (5,704) IV(IH,IM),IH
704       FORMAT (2X,' IV(IH,IM) =',I5,' IH=',I3)
          IV(IH,IM)=0
12        CONTINUE
C         NEW AC TO PUT IN Q
          K=IV(IH,IM)
C         WRITE (5,21) IV(IH,IM),K
21        FORMAT (' IV(IH,IM) = ',I5,' K = ',I3)
          DO 15 I=1,K
          ENDQ=ENDQ+1
          IF (ENDQ.GT.200) ENDQ=1
          Q(ENDQ)=3600*IH+ISEC
          QLGTH=QLGTH+1
15        CONTINUE
          IF (ISEC-RFT) 11,13,13
C         AC DELAYED IN Q
11        CONTINUE
          IF (QLGTH.GT.MXQ(IH)) MXQ(IH)=QLGTH
C         WHAT IS NEXT? RUNWAY FREE TIME OR NEXT MINUTE
          NXS=60*IM+60
          IF (NXS-RFT) 38,38,14
14        CONTINUE
C         RUNWAY FREE, RFT NON-ZERO
```

```
************************************************************************
*                         NATIONAL AIRPORT SYSTEM                      *
************************************************************************
      ISEC=RFT
C     RUNWAY FREE ISEC ALREADY CURRENT
C     WHAT IS IN Q - CURRENT OR PREVIOUS HR AC?
13    CONTINUE
C     WRITE (5,22) KNTQ
22    FORMAT ( ' KNTQ = ',I3)
      IF (KNTQ) 705,100,200
705   CONTINUE
      WRITE (5,706) KNTQ,IH,IM
706   FORMAT (2X,' KNTQ = ',I5,' IH = ',I3,' IM = ',I3)
C     RETURN
100   CONTINUE
C     PLANES FROM CURRENT HR ONLY IN Q
      ITO=3600*IH+ISEC
      IF (ITO-Q(TOPQ)) 707,101,110
707   CONTINUE
      WRITE (5,708) ITO,Q(TOPQ),TOPQ,IM,IH
708   FORMAT (2X,'ITO= ',I3,'Q(TOPQ)= ',I3,'TOPQ= ',I3,
     X ' IM= ',I3,' IH= ',I3)
      Q(TOPQ)=ITO
101   CONTINUE
      QLGTH=QLGTH-1
      ACS(IH)=ACS(IH)+1.0
      TOPQ=TOPQ+1
      IF (TOPQ.GT.200) TOPQ=1
      RFT=ISEC+R(IH,IW)
C     WRITE (5,271) IH,IW,RFT,ISEC,R(IH,IW)
271   FORMAT (4I,F)
C     WRITE (5,27) AST(IH),ALF(1,IH),ADR(IH)
      APAX(IH)=APAX(IH)+AST(IH)*ALF(1,IH)*(1.0-(1.0/1.0+
     X ADR(IH)))
      ITPAX(IH)=ITPAX(IH)+AST(IH)*ALF(1,IH)
C     BACK TO SEE WHAT IS IN Q
      GO TO 37
110   CONTINUE
C     DELAY FOR THIS AC ( CURRENT HR, AC )
      QLGTH=QLGTH-1
      ACS(IW)=ACS(IH)+1.0
      RFT=ISEC+R(IH,IW)
      DELAY=ITO-Q(TOPQ)
C     WRITE (5,23) DELAY
23    FORMAT ( ' DELAY = ',I5)
      TOPQ=TOPQ+1
      IF (TOPQ.GT.200) TOPQ=1
C     COLLECT DELAY STATISTICS FOR THIS AC
      D(IH)=D(IH)+DELAY
      DAC(IH)=DAC(IH)+1.0
```

```
      IF (DELAY.GT.MXD(IH)) MXD(IH)=DELAY
      IF (DELAY.GE.1800) D30(IH)=D30(IH)+1.0
C     WRITE (5,31) D(IH),DAC(IH),D30(IH),MXD(IH)
31    FORMAT ('D=',F6.0,' DAC=',F7.0,' D30= ',F8.0,' MXD=',I10)
C     GENERATE ARRIVING PAX
C     WRITE (5,27) AST(IH),ALF(1,IH),ADR(IH)
27    FORMAT (' AST = ',F6.0,' ALF ',F6.3,' ADR = ',F5.3)
      APAX(IH)=APAX(IH)+AST(IH)*ALF(1,IH)*(1.0-(1.0/(1.0+
     X ADR(IH))))
      ITPAX(IH)=ITPAX(IH)+AST(IH)*ALF(1,IH)
C     BACK TO SEE WHAT IS IN Q
      GO TO 37
200   CONTINUE
C     PROCESSED PLANE IS FROM PREVIOUS HOUR
      DELAY=3600*IH+ISEC-Q(TOPQ)
      KNTQ=KNTQ-1
      QLGTH=QLGTH-1
      ACSZ(IH)=ACSZ(IH)+1.0
      TOPQ=TOPQ+1
      IF (TOPQ.GT.200) TOPQ=1
      RFT=ISEC+R(IH-1,IH)
C     COLLECT DELAY STATISTICS FOR THIS AC
      DZ(IH)=DZ(IH)+DELAY
      DACZ(IH)=DACZ(IH)+1.0
      IF (DELAY.GT.MXDZ(IH)) MXDZ(IH)=DELAY
      IF (DELAY.GE.1800) D30Z(IH)=D30Z(IH)+1.0
C     GENERATE ARRIVIING PAX
C     WRITE (5,28) ALF(1,IH-1),ADR(IH-1)
28    FORMAT (' ALF(1,IH-1) = ',F,' ADR(IH-1) = ',F)
      APAX(IH)=APAX(IH)+AST(IH-1)*ALF(1,IH-1)*
     X (1.0-(1.0/(1.0+ADR(IH-1))))
      ITPAX(IH)=ITPAX(IH)+AST(IH-1)*ALF(1,IH-1)
C     MAY WANT TO TEST RFT TO SEE IF QING PLANES FOR 2 HRS.
C     GO BACK TO SEE WHAT IS IN Q
      GO TO 37
1000  CONTINUE
C     END OF HOUR
      KNTQ=QLGTH
      QEND(IH)=QLGTH
      RFT=RFT-3600
      IF (RFT.LT.0) RFT=0
C     PASS APAX(IH) TO GROUNDSIDE MODULE
2000  CONTINUE
C     DO 2500 I=IBEG,IEND
C     WRITE (5,2600) D(I),DAC(I),MXD(I),MXQ(I)
2600  FORMAT (' D= ',F9.0,' DAC = ',F9.0,' MXD = ',I10,' MXQ = ',I5)
2500  CONTINUE
```

```
************************************************************************
*                          NATIONAL AIRPORT SYSTEM                     *
************************************************************************
C        DO 2800 I=IBEG,IEND
C        WRITE (5,2700) DACZ(I),DZ(I),D30(I),D30Z(I)
2700     FORMAT (4(F12.3,3X))
C2800    CONTINUE
         RETURN
         END
```

```
*****************************************************************************
*                          NATIONAL AIRPORT SYSTEM                          *
*****************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:RDPOUT.F4 [4072,546] 26-AUG-75 *
*****************************************************************************
      SUBROUTINE RDPOUT
      INTEGER DELAY,ENDQ,Q,QLGTH,RFT,TOPQ
      COMMON /BLK3/ARR(24),DEP(24)
      COMMON /BLK4/EMIX(1,24,6),NMIX(2,5)
      COMMON /BLK5/ACS(24),ACSZ(24),AST(24),APAX(24),
     X D(24),DAC(24),DACZ(24),D30(24),D30Z(24),DZ(24),
     X ITPAX(24),MXD(24),MXDZ(24),MXQ(24),Q(200),QEND(24),
     X R(24,2),ENDQ,KNTQ,QLGTH,RFT,TOPQ
      COMMON /BLK6/IBEG,IEND,TYPAN
      COMMON /BLK13/ALF(1,24)
      COMMON /BLK14/ITOT(24)
      DIMENSION ACRSD(24),ADDRS(24),AVDPS(24)
      DIMENSION AD30S(24),NDACS(24)
      DIMENSION AVDPR(24),AVDS(24)
      DIMENSION MXDRS(24),MXDS(24),ND30R(24)
      DIMENSION TPAXR(24),TPAXS(24),TSDRS(24),TSDS(24)
      DIMENSION H1(24),H2(24),XDS(24),XDRS(24)
      DIMENSION AIRC(5),GNDC(5)
      DIMENSION PCTA(24),PCTG(24),COSTH(24)
      DATA AIRC/1560.,980.,740.,250.,150./
      DATA GNDC/1325.,850.,605.,200.,125./
      DATA DAILY/'DAILY'/,HOURL/'HOURL'/
      DATA H1/'00:00','01:00','02:00','03:00','04:00',
     X '05:00','06:00','07:00','08:00','09:00','10:00',
     X '11:00','12:00','13:00','14:00','15:00','16:00',
     X '17:00','18:00','19:00','20:00','21:00','22:00',
     X '23:00'/
      DATA H2/'01:00','02:00','03:00','04:00','05:00',
     X '06:00','07:00','08:00','09:00','10:00','11:00',
     X '12:00','13:00','14:00','15:00','16:00','17:00',
     X '18:00','19:00','20:00','21:00','22:00','23:00',
     X '24:00'/
      AXDLY=0.0
      DPACS=0.0
      DPDAC=0.0
      MXDL2=0
      MAXQL=0
      DO 3 I=1,24
      ACRSD(I)=0.0
      ADDRS(I)=0.0
      AD30S(I)=0.0
      AVDPR(I)=0.0
      AVDPS(I)=0.0
      AVDS(I)=0.0
      COSTH(I)=0.0
```

```
          MXDRS(I)=0
          MXDS(I)=0
          NDACS(I)=0
          ND30R(I)=0
          PCTA(I)=0.0
          PCTG(I)=0.0
          TPAXR(I)=0.0
          TPAXS(I)=0.0
          TSDRS(I)=0.0
          TSDS(I)=0.0
          XDS(I)=0.0
          XDRS(I)=0.0
3         CONTINUE
          DO 4 K=IBEG,IEND
          PCTA(K)=ARR(K)/FLOAT(ITOT(K))
          PCTG(K)=DEP(K)/FLOAT(ITOT(K))
4         CONTINUE
          IF (TYPAN.EQ.DAILY) GO TO 200
C         HOURLY STATISTICS
C         MAX. DELAY FOR SERVICED AC IN HR. IH - 2
          DO 10 IH=IBEG,IEND
          MXDS(IH)=MAX0(MXD(IH),MXDZ(IH))
          XDS(IH)=FLOAT(MXDS(IH))/60.0
10        CONTINUE
C         MAX. DELAY FOR AC REQUESTING SERVICE IN HR. IH - 3
          DO 20 IH=IBEG,IEND
          MXDRS(IH)=MAX0(MXD(IH),MXDZ(IH+1))
          XDRS(IH)=FLOAT(MXDRS(IH))/60.0
20        CONTINUE
C         NO. OF AC DELAYED SERVICED IN HR. IH - 4
          DO 30 IH=IBEG,IEND
          NDACS(IH)=DAC(IH)+DACZ(IH)
30        CONTINUE
C         NO. OF AC REQUESTING SERVICE IN HR. BUT DELAYED - 5
          DO 40 IH=IBEG,IEND
          ACRSD(IH)=DAC(IH)+DACZ(IH+1)
40        CONTINUE
C         TOTAL SECS. OF DELAY 4 AC SERVICED IN HR. IH - 6
          DO 50 IH=IBEG,IEND
          TSDS(IH)=D(IH)+DZ(IH)
50        CONTINUE
C         TOTAL SECS. OF DELAY 4 AC REQ. SERV. IN HR. IH - 7
          DO 60 IH=IBEG,IEND
          TSDRS(IH)=D(IH)+DZ(IH+1)
60        CONTINUE
C         NO. AC DELAYED 30 MIN. OR MORE SERV. IN HR. IH - 8
          DO 70 IH=IBEG,IEND
```

```
      AD30S(IH)=D30(IH)+D30Z(IH)
 70   CONTINUE
 C    NO. OF AC REQ. SERV. THAT WERE DELAYED 30 OR MORE MIN. -9
      DO 80 IH=IBEG,IEND
      ND30R(IH)=D30(IH)+D30Z(IH+1)
 80   CONTINUE
 C    AV. DELAY 4 DELAYED AC SERVICED IN HR. IH - 10 (6/4)
      DO 90 IH=IBEG,IEND
      AVDS(IH)=TSDS(IH)/FLOAT(NDACS(IH))
 90   CONTINUE
 C    AV. DELAY FOR DELAYED AC REQ. SERV. 11(7/5)
      DO 100 IH=IBEG,IEND
      ADDRS(IH)=TSDRS(IH)/ACRSD(IH)
 100  CONTINUE
 C    AV. DELAY/AC  SERVICED IN HR. IH - 12(6/ACS+ACSZ)
      DO 110 IH=IBEG,IEND
      AVDPS(IH)=TSDS(IH)/(ACS(IH)+ACSZ(IH))
 110  CONTINUE
 C    AV. DELAY/AC REQ. SERV. IN HR. IH - 13(7/ACS+ACSZ(IH+1))
      DO 120 IH=IBEG,IEND
      AVDPR(IH)=TSDRS(IH)/(ACS(IH)+ACSZ(IH+1))
 120  CONTINUE
 C    TOTAL PAX. DELAY 4 PAX SERVICED IN HR. IH - 14
      DO 130 IH=IBEG,IEND
      TPAXS(IH)=D(IH)*AST(IH)*ALF(1,IH)+DZ(IH)*AST(IH-1)*ALF(1,IH-1)
 130  CONTINUE
 C    TOTAL PAX DELAY 4 AC REQUESTING SERVICE IN HR. IH - 15
      DO 140 IH=IBEG,IEND
      TPAXR(IH)=D(IH)*AST(IH)*ALF(1,IH)+DZ(IH+1)*AST(IH)*ALF(1,IH)
 140  CONTINUE
 C    AC DELAY COST FOR AC SERVICED IN HR. IH
      DO 150 IH=IBEG,IEND
      DO 150 J=1,5
      COSTH(IH)=(DZ(IH)*PCTA(IH-1)*(EMIX(1,IH-1,J)*AIRC(J))
     X +DZ(IH)*PCTG(IH-1)*(EMIX(1,IH-1,J)*GNDC(J))
     X +D(IH)*PCTA(IH)*(EMIX(1,IH,J)*AIRC(J))
     X +D(IH)*PCTG(IH)*(EMIX(1,IH,J)*GNDC(J)))/60.0
 150  CONTINUE
      GO TO 300
 C
 C    DAILY STATISTICS
 C
 200  CONTINUE
 C    MAX Q LENGTH DURING DAY
      MAXQL=MXQ(1)
      DO 210 IH=2,24
      IF (MAXQL.GE.MXQ(IH)) GO TO 210
```

```
****************************************************************
*                  NATIONAL AIRPORT SYSTEM                      *
****************************************************************
      MAXQL=MXQ(IH)
210   CONTINUE
C     MAX AC DELAY
      MXDLY=0
      DO 220 IH=1,24
      MXDL2=MAX0(MXD(IH),MXDZ(IH))
      IF (MXDLY.GE.MXDL2) GO TO 220
      MXDLY=MXDL2
220   CONTINUE
      AXDLY=FLOAT(MXDLY)/60.0
C     TOTAL NUMBER OF DELAYED AC
      TOTND=0.0
      DO 230 IH=1,24
      TOTND=TOTND+(DAC(IH)+DACZ(IH))
230   CONTINUE
C     TOTAL AC DELAY
      TOTAD=0.
      DO 240 IH=1,24
      TOTAD=TOTAD+(D(IH)+DZ(IH))
240   CONTINUE
      TOTAD=TOTAD/60.
C     TOTAL NO. OF AC DELAYED 30 MIN. OR MORE
      TND30=0.
      DO 250 IH=1,24
      TND30=TND30+(D30(IH)+D30Z(IH))
250   CONTINUE
C     AVERAGE DELAY PER DELAYED AC
      DPDAC=TOTAD/TOTND
C     AV. DELAY PER AC SERVICED
      SUM=0.
      DO 260 IH=1,24
      SUM=SUM+(ACS(IH)+ACSZ(IH))
260   CONTINUE
      DPACS=TOTAD/SUM
C     TOTAL PAX DELAY
      TPAXD=0.
      DO 270 IH=1,24
      TPAXD=TPAXD+(D(IH)*AST(IH)*ALF(1,IH)+DZ(IH+1)*
     X AST(IH)*ALF(1,IH))
270   CONTINUE
      TPAXD=TPAXD/60.
C     PASSENGER DELAY COST
      COSTP=0.0
      COSTP=(TPAXD/60.0)*15.0
C     TOTAL DELAY COST FOR AC SERVICED IN HR. IH
      COSTD=0.0
      DO 280 IH=1,24
```

```
              DO 280 J=1,5
              COSTD=COSTD+((D2(IH)*PCTA(IH-1)*(EMIX(1,IH-1,J)*AIRC(J))
          X   +D2(IH)*PCTG(IH-1)*(EMIX(1,IH-1,J)*GNDC(J))
          X   +D(IH)*PCTA(IH)*(EMIX(1,IH,J)*AIRC(J))
          X   +D(IH)*PCTG(IH)*(EMIX(1,IH,J)*GNDC(J))))/60.0
  280         CONTINUE
              GO TO 500
  C
  300         CONTINUE
  C           HOURLY STATISTICS
              WRITE (5,310)
  310         FORMAT (16X,'MAX. Q LN.',3X,'CONT. OF',3X,'MAXIMUM',1X,
          X   'DELAY AC',/,29X,'AIRSIDE Q    SERV.   REQ.SERV.',/,
          X   29X,'END OF HR',6X,'IN MINS.'/)
              DO 330 IH=IBEG,IEND
              WRITE (5,320) H1(IH),H2(IH),MXQ(IH),QEND(IH),XDS(IH),XDRS(IH)
  320         FORMAT(3X,A5,'-',A5,4X,I5,6X,F6.1,4X,F5.1,6X,F5.1)
  330         CONTINUE
              WRITE (5,340)
  340         FORMAT (/,18X,'# OF AC DELAYED ',6X'TOTAL SECS OF DELAY',/,
          X   15X,' SERVICED  REQ. SERV.',4X,'SERVICED   REQ.SERV',/)
              DO 360 IH=IBEG,IEND
              WRITE(5,350)H1(IH),H2(IH),NDACS(IH),ACRSD(IH),TSDS(IH),TSDRS(IH)
  350         FORMAT(3X,A5,'-',A5,4X,I5,6X,F6.0,4X,F6.0,6X,F6.0)
  360         CONTINUE
              WRITE (5,370)
  370         FORMAT (/,15X,'# OF AC DELAYED 30+ MIN  AV. DELAY FOR',
          X   1X,'DELAYED AC',/,16X,'SERVICED',4X,'REQ. SERV.  SERVICED',
          X   3X,'REQ. SERV.',/)
              DO 390 IH=IBEG,IEND
              WRITE(5,380)H1(IH),H2(IH),AD30S(IH),ND30R(IH),AVDS(IH),ADDRS(IH)
  380         FORMAT (3X,A5,'-',A5,4X,F6.0,6X,I5,6X,G7.2,5X,G7.2)
  390         CONTINUE
              WRITE (5,400)
  400         FORMAT (/,18X,'AV. DELAY PER AC',6X,'TOTAL PAX DELAY',
          X   ' FOR PAX',/,15X,'SERVICED',5X,'REQ.SERV.   SERVICED',
          X   '    REQ.SERV.',/)
              DO 420 IH=IBEG,IEND
            WRITE(5,410)H1(IH),H2(IH),AVDPS(IH),AVDPR(IH),TPAXS(IH),TPAXR(IH)
  410         FORMAT (3X,A5,'-',A5,1X,2(F8.0,3X),4X,2(F8.0,3X))
  420         CONTINUE
              WRITE (5,430)
  430         FORMAT (/,15X,'AIRCRAFT DELAY COST FOR AC SERV. IN HR. IH',/)
              DO 450 IH=IBEG,IEND
              WRITE (5,440) H1(IH),H2(IH),COSTH(IH)
  440         FORMAT (3X,A5,'-',A5,10X,'$',1X,F8.0)
  450         CONTINUE
```

```
*************************************************************************
*                          NATIONAL AIRPORT SYSTEM                      *
*************************************************************************
          GO TO 600
C
C         DAILY STATISTICS
C
500       CONTINUE
          WRITE (5,510)
510       FORMAT (5X,'DAILY STATISTICS',/)
          WRITE (5,515)
515       FORMAT (///4X,'MAX Q LENGTH',8X,'MAX AC DELAY',10X,
     X    'TOTAL # AC DELAYED',/)
          WRITE (5,520) MAXQL,AXDLY,TOTND
520       FORMAT (7X,I5,15X,F7.2,15X,F6.0)
          WRITE (5,525)
525       FORMAT (///2X,'TOTAL AC-MIN DELAY',5X,'TOTAL # AC DELAYED',3X,
     X    'AVERAGE MIN DELAY PER',/,27X,'30 MINS. OR MORE',7X,
     X    'DELAYED AC',/)
          WRITE (5,530) TOTAD,TND30,DPDAC
530       FORMAT (7X,F6.0,2(15X,F6.2))
          WRITE (5,540)
540       FORMAT (///2X,'AVERAGE MIN DELAY PER',4X,'TOTAL PAX DELAY',
     X    4X,'PASSENGER DELAY COST',/,5X,'AC SERVICED',/)
          WRITE (5,550) DPACS,TPAXD,COSTP
550       FORMAT (7X,F8.2,10X,F14.0,8X,'$',F10.2)
C         TOTAL AC DELAY COST FOR AC SERVICED
          WRITE (5,560)
560       FORMAT (///,2X,'TOTAL AC DELAY COST ',/)
          WRITE (5,570) COSTn
570       FORMAT (6X,'$',F10.0)
600       CONTINUE
          RETURN
          END
```

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*******************************************************************************
*                          NATIONAL AIRPORT SYSTEM                            *
*******************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:GNDMAN.F4 [4072,546] 26-AUG-75        *
*******************************************************************************
        SUBROUTINE GNDMAN
        COMMON /HLCS/HLC,HCS,PSCPP
      COMMON /PARK/TDTD,TDTA,FEPO
      COMMON /IAHTD/  AHTM(3,3)
      COMMON /NVPHR/  AHTP(3,24)
      COMMON / INDATA/ FEPIR,FEPTH,AEPEP,FCSL,VPEP,FAPLT,FAPST,
     1 FPWB,AOC,BOC,TOC,LOC,DLTP,DSTP ,DPLT,APLT,BCAPP,
     2  BDTA,BDTD
      COMMON / FRMVN / FPMBM(2,4)
      COMMON /GNDIMP/  FA(20)
      COMMON/ AISEXP/ AHTD, DP(25),DPL(25),AP(25),APL(25)
      COMMON /2ATCON/ SAT(25,15)
        COMMON /BLK6/IBEG,IEND,TYPAN
        COMMON /BLK9/ISPRC(24,5),ITSPC,ITPHR(24)
        COMMON /BLK15/WAAPP,WASPP,LDTD,ADTA,MRRPP,WRRPP
        COMMON /BLK16/BEC,LEC,TLAPP,AOSPP
        REAL LOC,LEC,LDTA,LDTD,MRRPP
      INTEGER SAT
      INTEGER AHTD,AHTM
C   VARIABLE INITIALIZATION
      DATA (AP(IN),IN=1,24) /500.,600.,700.,800.,900.,1000.,1100.,
     1  1200.,1300.,1400.,1500.,1600.,1700.,1800.,1600.,1400.,1300.,
     2  1200.,1100., 900.,800., 700., 600.,500./
      DATA (DP(IN),IN=1,24) /500.,600.,700.,800.,900.,1000.,1100.,
     1  1200.,1300.,1400.,1500.,1600.,1700.,1800.,1600.,1400.,1300.,
     2  1200.,1100., 900.,800., 700., 600.,500./
      DATA (FPMBM(1,IO),IO=1,4) /.67,.19,.10,.04 /
        DATA (FPMBM(2,I0),I0=1,4) /.67,.19,.10,.04/
        DATA (FA(I),I=1,14) /2.,2.,17000.,800.,155.,8200.,26000.,650.,
     1  1200.,5000.,25000.,1000.,60.,60./
      DATA (AHTM(1,J1),J1=1,3)  /5,2,1 /
      DATA (AHTM(2,J2),J2=1,3) /2,3,2 /
      DATA (AHTM(3,J3),J3=1,3) /5,5,3 /
      DATA (AHTP(1,K1) ,K1=1,24)/ .010,.010,.005,.005,.010,.035,.075,
     1 .095,.070,.045,.045,.045,.045,.045,.055,.075,.095,.070,.045,.045,
     2 .010,.010,.010,.010  /
      DATA (AHTP(2,K1) ,K1=1,24)/ .010,.010,.005,.005,.010,.035,.075,
     1 .095,.070,.045,.045,.045,.045,.045,.055,.075,.095,.070,.045,.045,
     2 .010,.010,.010,.010  /
      DATA (AHTP(3,K1) ,K1=1,24)/ .010,.010,.005,.005,.010,.035,.075,
     1 .095,.070,.045,.045,.045,.045,.045,.055,.075,.095,.070,.045,.045,
     2 .010,.010,.010,.010  /

        CALL ASSDEV (12,'DSK')
        REWIND 12
```

```
****************************************************************************
*                          NATIONAL AIRPORT SYSTEM                         *
****************************************************************************
        READ (12,102) FEPO,FEPIA,FEPIR,BEC,LEC,TLAPP,PSCPP,AOSPP,
     X  BCAPP,WAAPP,WASPP,MRRPP,WRRPP,ADTA,ADTD,TDTA,TDTD,BDTA,BDTD,
     X  LDTA,LDTD,AHTD,AOC,BOC,TOC,LOC,DLTP,DSTP,DPLT,APLT,AEPEP,FCSL,
     X  VPEP,FAPLT,FAPST,FPWB,HLC,HCS
102     FORMAT (5(8F10.3/))
C      WRITE(5,104)  FEPO,FEPIA,FEPIR,BEC,LEC
C      WRITE(5,106) TLAPP,PSCPP,AOSPP,BCAPP,WAAPP
C      WRITE(5,107) WASPP,MRRPP,WRRPP,ADTA,TDTA
C      WRITE(5,108) BDTA,LDTA,AHTD,ADTD,TDTD
C      WRITE(5,109) BDTD,LDTD
  104 FORMAT(1X,' FEPO=',F,'FEPIA=',F,'FEPIR=',F,'  BEC=',F,'  LEC=',F)
  106 FORMAT(1X,'TLAPP=',F,'PSCPP=',F,'AOSPP=',F,'BCAPP=',F,'WAAPP=',F)
  107 FORMAT(1X,'WASPP=',F,'MRRPP=',F,'WRRPP=',F,' ADTA=',F,' TDTA=',F)
  108 FORMAT(1X,' BDTA=',F,' LDTA=',F,' AHTD=',F,' ADTD=',F,' TDTD=',F)
  109 FORMAT(1X,' BDTD=',F,' LDTA=',F)
C      WRITE(5,111)  AOC,BOC,TOC,LOC,DLTP
C      WRITE(5,112)  DSTP,DPLT,APLT,AEPEP,FCSL
C      WRITE (5,113)  VPEP,FAPLT,FAPST,FPWB,HLC
C      WRITE(5,114)  HCS
  111 FORMAT(1X,'  AOC=',F,'  BOC=',F,'  TOC=',F,'  LOC=',F,' DLTP=',F)
  112 FORMAT(1X,' DSTP=',F,' DPLT=',F,' APLT=',F,'AEPEP=',F,'FCSL =',F)
  113 FORMAT(1X,' VPEP=',F,'FAPLT=',F,'FAPST=',F,' FPWB=',F,'F HLC=',F)
  114 FORMAT(1X,'  HCS=',F)
        DPCT1=DPLT/60.0
        DPCT2=(60.0-DPLT)/60.0
        DO 120 I=IBEG,IEND
        J=I+1
        IF (I.LT.IEND) GO TO 119
        DP(J)=DP(I)
119     CONTINUE
        DPL(I)=DPCT2*DP(I)+(DPCT1*DP(J))
120     CONTINUE
        APCT1=APLT/60.0
        APCT2=(60.0-APCT1)/60.0
        DO 130 I=IBEG,IEND
        J=I-1
        IF (I.EQ.IBEG) AP(J)=AP(I)
        APL(I)=APCT1*AP(J)+(APCT2*AP(I))
130     CONTINUE
      CALL GNDMOD
        RETURN
      END
```

```
*****************************************************************************
*                         NATIONAL AIRPORT SYSTEM                           *
*****************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:GNDMOD.F4 [4072,546] 26-AUG-75      *
*****************************************************************************
      SUBROUTINE  GNDMOD
        COMMON /HLCS/HLC,HCS,PSCPP
      COMMON /PARK/   TDTD,TDTA,FEPO
      COMMON /IAHTD/    AHTM(3,3)
      COMMON /NVPHR/   AHTP(3,24)
      COMMON / INDATA/ FEPIR,FEPTH,AEPEP,FCSL,VPEP,FAPLT,FAPST,
     1 FPWB,AOC,BOC,TOC,LOC,DLTP,DSTP ,DPLT,APLT,BCAPP,
     2  BDTA,BDTD
      COMMON / FRMVN / FPMBM(2,4)
      COMMON /GNDIMP/  FA(20)
      COMMON/ AISEXP/ AHTD, DP(25),DPL(25),AP(25),APL(25)
      COMMON /SATCON/ SAT(25,15)
        COMMON /BLK6/IBEG,IEND,TYPAN
        COMMON /BLK15/WAAPP,WASPP,LDTD,ADTA,MRRPP,WRRPP
        COMMON /BLK16/BEC,LEC,TLAPP,AOSPP
        DIMENSION FR(14)
CC      LOGICAL SAT
        REAL LEA,LOC,LEC,LTDA,LDTD,MRRPP
      INTEGER AHTD,AHTM
      INTEGER SAT
C      IHR=0
C  VARIABLE INITIALIZATION
        BEA=0.7
        BED=2.0
        LEA=0.54
      FALTP= FA(6)
      FASTP= FA(5)
      DPTOT=0.
        DO 90 I=1,25
        DO 90 IS=1,15
        SAT(I,IS)=0
90      CONTINUE
      DO 112 IJ=IBEG,IEND
      DPTOT=DPTOT+DP(IJ)
112   CONTINUE
      FR(5) = (DSTP/FLOAT(IEND-IBEG+1))*DPTOT
        FRSTP=FR(5)
      FR(6) = (DLTP/FLOAT(IEND-IBEG+1))*DPTOT
        FRLTP=FR(6)
        IF (FRSTP.LT.0.0) FRSTP=0.0
        IF (FRLTP.LT.0.0) FRLTP=0.0
C       WRITE (5,124) FRSTP,FRLTP,DPLT
124     FORMAT (3F)
      DO 400 I=IBEG,IEND
C      I=IHR
```

```
*********************************************************************************
*                             NATIONAL AIRPORT SYSTEM                          *
*********************************************************************************
C  100 CONTINUE
C       IHR=IHR+1
C       I=IHR
C       DO 120 IHR=IBEG,IEND
       DO 120 IS=1,14
       SAT(I,IS)=0
  120  CONTINUE
C       IF(IHR.GE.25) GO TO 1000
       TEMPAP=(APL(I))*(FEPO+VPEP/2.)
       TEMPDP=(DPL(I))*(FEPO+VPEP/2.)
       ARA= TEMPAP*(FPMBM(1,1)/AOC)
       ART= TEMPAP*(FPMBM(1,2)/TOC)
       ARB= TEMPAP*(FPMBM(1,3)/BOC)
       ARL= TEMPAP*(FPMBM(1,4)/LOC)
       DPA= TEMPDP*(FPMBM(2,1)/AOC)
       DPT= TEMPDP*(FPMBM(2,2)/TOC)
       DPB= TEMPDP*(FPMBM(2,3)/BOC )
       DEPL=TEMPDP*(FPMBM(2,4)/LOC)
       FCRL1= .5*(ART+DPT+(ARB+DPB)*BEA+(ARL+DEPL)*LEA)
     1  +ARA+DPA*(1.-FAPLT-FAPST)
       FCRL2= .5*(ART+DPT+(ARB+DPB)*BEA+(ARL+DEPL)*LEA)
     1  +DPA+ARA*(1.-FAPLT-FAPST)
       FR(2) =AMAX1(FCRL1,FCRL2)/HLC
C        WRITE (5,234) FR(2)
234      FORMAT ( ' FR(2)= ' F,/)
       FR(1) = ( 1./HLC)*( AHTM(AHTD,2)*AHTP(AHTM(AHTD,3),I)
     X  +0.5*FCRL1+0.5*FCRL2)
C        WRITE (5,345) FR(1)
345      FORMAT ( ' FR(1) = ',F,/)
       FR(3) = (1./HCS) *(ARA*FCSL*ADTA+ART*TDTA+ARB*BDTA
     1  * BEC+ARL*LDTA*LEC)
       FR(4) = (1./HCS) *(DPA*FCSL*ADTD+DPT*TDTD+DPB*BDTD*
     1  BED *DEPL*LDTD*LEC)
C        WRITE (5,123) FRSTP,FASTP,ARA,FAPST,DPA,TEMPAP,TEMPDP
123      FORMAT (7(F9.2,1X))
       FR(5) =AMIN1(FRSTP,FASTP)+ ARA*FAPST-DPA*FAPST
       FRSTP = FR(5)
         IF (FRSTP.LT.0.0) FRSTP=0.0
         IF (FRLTP.LT.0.0) FRLTP=0.0
C        WRITE (5,123) FRLTP,FALTP,FAPLT
       FR(6) =AMIN1(FRLTP,FALTP)+ARA*FAPLT-DPA*FAPLT+
     1 AMAX1((FAPST-FRPST),0.0)
        FRLTP=FR(6)
       FR(7) = (APL(I)*FEPO)* (1.+ VPEP/2.)*TLAPP
       FR(8) = (APL(I)*FEPO)*PSCPP
       FR(9) = (AP(I)+DP(I))*(AOSPP)
       FR(10)= (AP(I)*FEPO)*(1.+VPEP/2.)* BCAPP*FPWB
```

```
************************************************************************************
*                            NATIONAL AIRPORT SYSTEM                               *
************************************************************************************
      FR(11)= (AP(I)+DP(I))*  .5*(FEPIA+FEPIR)
     1  +FEPO*(AP(I))*(VPEP/2.)+(DP(I) *FEPO*WAAPP)
        FRWAA=FR(11)
C       WRITE(5,226) FRWAA,WASPP,WAAPP
226     FORMAT(1X,'FRWAA= ',E,'WASPP= ',E,'WAAPP= ',E)
      FR(12) = FRWAA*WASPP/WAAPP
C      WRITE(5,678) FR(12)
678     FORMAT(1X,'FR(12)= ',F,/)
      FR(13) = (AP(I)+DP(I))*MRRPP
      FR(14) = (AP(I)+DP(I))*WRRPP
      DO 300 IST=1,14
C         WRITE (5,305) FR(IST),FA(IST),I
305     FORMAT ( ' FR= ',F,' FA= ',F,' I= ',I5)
      IF( FR(IST).GT.FA(IST))  SAT(I,IST)=I
  300 CONTINUE
  400 CONTINUE
C      GO TO 100
1000    CONTINUE
        CALL GNDPNT
        RETURN
      END
```

```
************************************************************************
*                        NATIONAL AIRPORT SYSTEM                       *
************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:GNDPNT.F4 [4072,546] 26-AUG-75 *
************************************************************************
      SUBROUTINE GNDPNT
        INTEGER SAT
        COMMON /SATCON/SAT(25,15)
        COMMON /BLK6/IBEG,IEND,TYPAN
        COMMON /BLK9/ISPRC(24,5),ITSPC,ITPHR(24)
      DIMENSION FACIL(14,6)
      DIMENSION IW(25),EMP(24)
      DIMENSION HOURS(25)
      DIMENSION  ISAT(15)
        DIMENSION EPO(24),TERM(24),THRU(24),TRAN(24)
      DATA((FACIL(IJ,I),I=1,6),IJ=1,14)/'ACCESS HWY LANES              ',
     1 'CIRCULATION RDWY LANES        ','ARRIVAL CURB SPACE            ',
     2 'DEPARTURE CURB SPACE          ','SHORT TERM PRKG SPACE         ',
     3 'LONG TERM PRKG SPACE          ','TICKET LOBBY AREA             ',
     4 'PAX SERVICE COUNTER           ','AIRLINE OPERATIONS SPACE      ',
     5 'BAGGAGE CLAIM AREA            ','WAITING AREA(SQUARE FEET)     ',
     6 'WAITING AREA (SEATS)          ','MENS REST ROOM (FIXTURES)     ',
     7 'WOMENS REST ROOM (FIXTURES)   '/
      DATA(HOURS(IH),IH=1,24)/' 1:00',' 2:00',' 3:00',' 4:00',' 5:00',
     1 ' 6:00',' 7:00',' 8:00',' 9:00','10:00','11:00','12:00','13:00',
     2 '14:00','15:00','16:00','17:00','18:00','19:00','20:00','21:00',
     3 '22:00','23:00','24:00'/
        WRITE (5,10)
10      FORMAT (/,25X,'*PASSENGER MOVEMENTS*',/)
        WRITE (5,15)
15      FORMAT (1X,'HOUR',3X,'THROUGH',3X,'TRANSFERS',3X,'ORIGINATING',
     X  2X,'TERMINATING',3X,'ENPLANED',/)
        DO 16 I=1,25
        IW(I)=0
16      CONTINUE
        DO 17 J=1,15
        ISAT(J)=0
17      CONTINUE
        FEPO=0.897
        FEPIA=0.024
        FEPIR=0.040
        DO 25 I=IBEG,IEND
        EPO(I)=ITPHR(I)*FEPO
        TERM(I)=EPO(I)
        THRU(I)=ITPHR(I)*0.039
        TRAN(I)=ITPHR(I)*(FEPIA+FEPIR)
        EMP(I)=THRU(I)+TRAN(I)+EPO(I)
        WRITE (5,20) I,THRU(I),TRAN(I),EPO(I),TERM(I),EMP(I)
20      FORMAT (I5,F9.0,F11.0,3F13.0)
25      CONTINUE
```

```
*************************************************************************
*                           NATIONAL AIRPORT SYSTEM                     *
*************************************************************************
  100 CONTINUE
      WRITE(5,122)
  122 FORMAT(/,23X,'SATURATED GROUNDSIDE FACILITIES  ')
      WRITE(5,127)
  127 FORMAT(15X,'FACILITY',40X,'HOURS ')
      DO 200 IK=1,14
      DO 175 IS=IBEG,IEND
      IF(SAT(IS,IK).GE.1)  ISAT(IK)=ISAT(IK)+1
  175 CONTINUE
      WRITE(5,132) IK,(FACIL(IK,KO),KO=1,6),ISAT(IK)
132     FORMAT (2X,I5,1X,6A5,24X,I5)
  200 CONTINUE
  210 CONTINUE
      WRITE(5, 215)
  215 FORMAT(/,1X,'ENTER NUMERICAL CODE FOR FURTHER INFORMATION')
        WRITE (5,220)
220     FORMAT (' IF A NUMBER IS NOT WITHIN THE RANGE 1-14,'
     X    ' - EXIT RESULTS',/)
      ACCEPT ,235, IL
  235 FORMAT( I5)
      IF(IL.LE.0.OR.IL.GE.15) GO TO 1000
      ISN=0
      DO 300 ISO=IBEG,IEND
C       WRITE (5,500) SAT(ISO,IL),ISO,IL
500     FORMAT (3I)
      IF(SAT(ISO,IL).EQ.0)  GO TO 300
      ISN=ISN+1
      IW(ISN)= SAT(ISO,IL)
C       WRITE (5,501) SAT(ISO,IL),ISN,IW(ISN)
501     FORMAT ( ' SAT(ISO,IL) = ',I5,' ISN = ',I5,' IW(ISN) = ',I5,/)
  300 CONTINUE
      IF(ISN.EQ.0)  GO TO 210
      WRITE(5,315) (HOURS(IW(ISO)),ISO=1,ISN)
  315 FORMAT(1X,24(A5,1X))
      GO TO 210
 1000 CONTINUE
        RETURN
      END
```

APPENDIX H — DATA FILE

H.1 DATA FILE FOR11.DAT

```
**************************************************************************
*                 DECEMBER 20, 1974  LOGAN AIRPORT (BOS)                 *
**************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:FOR11.DAT [4072,546] 26-AUG-75 *
**************************************************************************
1 286 143 571 000 000 000 250    7 8571
0   0   0   0   0   0   0   0   1   0   1   0
0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   2   0   0   0   0   0   0
0   0   1   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   2   0   0   0   0   0
2 333 000 167 167 167 167 050    6 8333
1   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   2   0   0   0
0   0   1   0   0   0   1   0   0   0   0   0
0   0   0   0   0   0   0   0   0   1   0   0
0   0   0   0   0   0   0   0   0   0   0   0
3 286 143 143 429 000 000 250    7 7143
1   0   0   0   0   0   1   0   0   0   0   1
0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   1   1   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   1   0   0
0   0   0   0   0   0   0   0   0   0   0   0
4 500 000 500 000 000 000 300    410000
1   0   0   0   0   0   0   0   0   0   0   0
0   0   1   0   0   0   0   0   1   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   1
5 000 000 000 333 333 333 200    310000
1   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   2   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0
6 000 000 000 333 333 333 050    310000
1   0   0   0   0   1   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0
0   1   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0
7 000 000 750 000 000 250 033    410000
1   0   0   0   0   0   0   0   0   0   0   0
0   0   0   1   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   2   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0
8 103 069 655 000 069 103 026   29 5517
6   1   0   0   0   1   0   0   0   0   1   0
0   0   0   2   0   0   0   0   3   0   0   0
```

DECEMBER 20, 1974 LOGAN AIRPORT (BOS)

0	2	0	0	0	0	2	1	0	0	0	3
0	0	0	0	0	0	0	1	0	1	0	0
0	0	4	0	0	0	0	0	1	0	0	0
9	139	056	528	056	083	139	071	36	5833		
11	0	0	0	0	0	0	0	0	0	0	0
0	0	0	2	0	0	0	0	1	0	0	0
1	3	0	0	0	0	5	0	0	0	0	2
0	0	0	2	1	0	0	0	2	0	0	0
1	0	2	1	1	0	0	1	0	0	0	0
10	188	063	479	083	104	083	085	48	4176		
9	1	0	0	0	3	0	0	0	0	3	0
0	0	0	1	1	0	0	0	1	2	2	0
1	2	0	1	0	1	4	0	1	0	0	3
1	0	0	0	4	0	0	0	0	2	0	0
0	0	2	1	0	0	0	1	1	0	0	0
11	146	049	585	098	049	073	071	41	4390		
7	0	0	0	0	1	1	0	0	0	4	1
0	0	0	2	1	0	1	0	1	0	0	0
1	1	0	0	1	0	3	0	0	0	0	1
1	0	0	0	1	0	0	0	0	3	0	1
2	0	4	0	0	0	0	1	0	1	0	1
12	000	091	667	030	061	152	154	33	4848		
4	0	0	0	0	1	0	1	0	0	0	0
0	0	1	0	1	0	1	0	1	0	0	0
0	4	0	0	0	1	4	0	0	0	2	1
0	1	0	1	4	0	0	1	1	1	0	0
1	0	0	0	0	0	0	1	0	0	0	0
13	087	043	674	087	087	022	084	46	4565		
8	2	0	0	1	2	1	0	0	0	0	1
0	0	0	5	1	2	1	0	3	0	0	0
0	3	0	0	0	1	5	1	0	0	0	0
0	1	0	0	1	0	0	0	0	3	1	1
1	0	0	1	0	0	0	0	0	0	0	0
14	029	029	647	059	059	176	079	34	5000		
7	0	0	0	0	0	0	0	0	0	2	0
0	0	1	2	1	0	0	0	0	0	0	0
0	3	0	0	1	0	4	0	1	0	0	1
0	0	0	0	2	1	1	0	0	3	0	0
0	2	0	0	0	0	1	1	0	0	0	0
15	139	028	611	056	083	083	140	36	3611		
5	0	0	1	0	0	0	0	1	0	1	0
0	0	0	2	2	2	1	1	2	1	0	0
0	1	0	1	0	0	3	1	0	0	0	0
0	0	0	0	3	0	1	0	0	2	0	0
1	0	2	1	0	0	0	1	0	0	0	0
16	000	049	683	122	024	122	128	41	070		
5	0	0	0	0	1	0	0	1	0	0	2

DECEMBER 20, 1974 LOGAN AIRPORT (BOS)

0	0	1	3	1	1	1	2	0	0	0	1
0	1	0	0	0	0	6	0	2	0	0	2
0	1	0	1	0	0	1	0	0	4	0	0
0	0	0	0	1	0	1	2	0	0	0	0
17	087	087	587	065	109	065	070	46	5000		
6	0	0	0	0	1	0	0	0	0	3	2
0	0	0	4	1	0	0	0	3	0	1	0
0	2	0	0	0	0	7	0	0	1	0	0
0	0	0	0	1	0	0	0	0	6	0	1
0	0	2	1	0	0	0	2	2	0	0	0
18	096	077	596	096	038	096	117	52	3846		
5	0	0	1	0	2	0	0	0	0	3	1
0	0	0	2	2	1	2	0	1	0	0	0
0	1	0	1	0	3	7	0	0	0	0	1
0	0	0	0	3	0	0	0	0	3	0	0
0	0	3	1	0	1	0	5	0	2	1	0
19	100	060	480	060	180	120	092	50	4800		
5	0	0	0	0	2	0	1	0	0	2	0
0	0	0	1	1	1	0	0	5	0	0	0
0	3	0	0	0	1	10	0	1	0	0	1
1	0	0	0	1	0	0	0	0	4	1	1
0	1	2	0	1	0	0	1	0	0	0	3
20	098	073	634	098	073	024	128	41	4390		
6	0	0	1	0	0	0	0	0	0	3	0
0	0	0	3	1	0	0	0	1	0	1	0
0	1	0	0	1	0	6	0	0	0	0	0
0	1	0	1	2	1	0	1	0	2	0	1
1	0	2	0	3	0	0	2	0	0	0	0
21	219	031	625	031	000	094	113	32	3438		
4	0	0	0	0	2	0	0	0	1	1	1
0	0	1	0	2	1	0	1	0	0	1	0
0	0	0	1	0	0	3	0	0	0	1	1
0	0	1	1	1	0	0	0	0	2	0	0
0	1	2	0	0	2	0	1	0	0	0	0
22	080	120	760	040	000	000	213	25	4800		
4	0	0	0	0	2	0	0	0	1	4	1
0	0	0	2	1	1	0	0	2	0	0	0
0	0	0	0	1	0	1	0	0	0	0	0
0	1	0	0	0	0	0	1	0	1	0	1
0	0	0	0	0	0	0	1	0	0	0	0
23	053	105	789	000	053	000	138	19	6316		
8	0	0	0	0	0	0	1	0	0	1	0
0	0	0	0	1	0	0	0	0	0	0	0
0	0	0	0	0	1	1	1	0	1	0	0
0	0	0	0	0	0	0	0	1	0	0	0
0	0	1	0	0	0	0	0	0	0	0	2
24	100	100	700	000	000	100	800	10	5000		

DECEMBER 20, 1974 LOGAN AIRPORT (BOS)

0	0	1	1	0	0	0	0	0	0	0	0
0	0	0	1	1	0	0	0	0	0	0	0
0	0	1	1	0	0	0	0	0	0	0	0
0	1	0	0	1	0	0	0	2	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0

H.2 DATA FILE FOR10.DAT

```
************************************************************************
*                             LOAD FACTORS                             *
************************************************************************
* FOLLOWING TEXT PRINTED FROM FILE DSKE:FOR1Ø.DAT [4Ø72,546] 26-AUG-75 *
************************************************************************
Ø.42 Ø.Ø5 Ø.Ø4 Ø.Ø5 Ø.Ø5 Ø.Ø8 Ø.12 Ø.32 Ø.37 Ø.37 Ø.44 Ø.46
Ø.48 Ø.52 Ø.56 Ø.68 Ø.63 Ø.66 Ø.65 Ø.64 Ø.52 Ø.42 Ø.3Ø Ø.18
```

APPENDIX I — PROGRAM DESCRIPTIONS — AIRPORT PERFORMANCE DATA BASE ROUTINES

I.1 INTRODUCTION

This appendix documents the programs and output setup for the National Airport System Study's Airport Performance Data Base using the Reuben Donnelley OAG Flight Stage Data tapes. A complete listing of the programs and the record layout of the tapes are included in Section I.4

I.2 SUMMARY OF TAPES

The OAG Flight Stage Data Tapes are produced monthly by the Reuben Donnelley Corporation. These tapes contain a complete listing of all scheduled flights, both domestic and foreign, scheduled to occur during a particular month. Included are the origin and destination airport and country codes, the times of departure and arrival (both local and GMT), the elapsed time, the airline code, the aircraft type, the flight number, the class of service, the days of service, the effective and discontinued date, and the latitude and longitude for each of the departure and destination airports. Each record constitutes one distinct flight stage. A complete record layout is displayed in Section I.4.

Presently available at TSC are monthly OAG tapes from September 1974 through January 1975. The tapes are 9-track in ASCII format for use on the PDP-10. The Information Division is in the process of acquiring a more complete library of OAG tapes extending from 1969 through the present, to be stored in the TSC Technical Information Center Statistical Reference Library. In addition to those already available in the Information Division, more recent tapes are received monthly. These tapes are 9-track, EBCDIC format, 800 BPI, but can easily be converted into ASCII format for use on the PDP-10.

I.3 DESCRIPTION

Basically two types of programs were developed for manipulation of the OAG data for the National Airport System Study. The first type involved the reporting of desired data, such as the total number of operations by day and by airport for a particular month. The second type of program was developed to provide interactive user capabilities.

I.3.1 Type A

As stated previously, these programs were designed to report the necessary data in a format suitable for the model. It should be mentioned that although the programs were each written for a particular airport, day, etc., they can be easily expanded to generate similar reports for another set of constraints (e.g., a different airport, day, etc.).

I.3.1.1 DAYOPS.F4 – This program generates the total number of operations by day and by airport for a particular month. A sample output for the January 1975 OAG data at Boston is displayed in Figure I-1.

I.3.1.2 TIMEOPS.F4 – This program generates the number of scheduled operations by hour for a series of selected days at a particular airport. (See Figure I-2.)

I.3.2 Type B

These programs were designed to generate daily profiles of operations at a particular airport. Since we were limited in the number of monthly OAG data available, days with an extremely high or low number of operations could not be included. For this reason, a series of standard days were selected. By using the number of operations occurring at that day and airport, the user could then scale this number up or down as desired. A more detailed explanation follows in the program descriptions.

OAG AIRLINE SCHEDULE FOR DEC, 1974 AT BOSTON
TOTAL NUMBER OF SCHEDULED OPERATIONS PER DAY

DAY	# OF OPS
DEC 1	553
DEC 2	621
DEC 3	646
DEC 4	644
DEC 5	655
DEC 6	644
DEC 7	550
DEC 8	560
DEC 9	623
DEC 10	645
DEC 11	644
DEC 12	655
DEC 13	644
DEC 14	552
DEC 15	565
DEC 16	625
DEC 17	655
DEC 18	653
DEC 19	666
DEC 20	653
DEC 21	559
DEC 22	569
DEC 23	632
DEC 24	656
DEC 25	652
DEC 26	664
DEC 27	651
DEC 28	557
DEC 29	567
DEC 30	629
DEC 31	656

Figure I-1. Sample Output — January 1975 OAG Data, Boston

OAG AIRLINE SCHEDULE FOR JAN, 1975 AT BOS
TOTAL NUMBER OF SCHEDULED OPERATIONS FOR SELECTED DAYS BY TIME (GMT)

TIME(GMT)	JAN 4	5	6	7	15	19	24	25	26
0- 59	20	30	36	34	34	36	34	29	35
100- 159	27	34	35	40	38	40	39	31	37
200- 259	14	25	25	23	22	25	22	17	23
300- 359	16	19	19	19	20	19	18	15	19
400- 459	4	7	9	9	8	9	8	8	8
500- 559	6	7	6	6	6	7	6	6	6
600- 659	6	3	3	7	7	6	7	6	8
700- 759	7	3	3	6	7	7	7	7	4
800- 859	5	3	3	5	5	5	5	5	3
900- 959	2	0	0	2	2	2	2	2	2
1000-1059	4	3	2	5	4	5	4	4	4
1100-1159	3	3	1	3	3	3	3	3	3
1200-1259	21	28	29	28	28	28	28	26	18
1300-1359	37	23	33	39	40	40	40	37	28
1400-1459	37	31	44	44	44	44	44	37	33
1500-1559	38	33	38	39	38	39	38	35	29
1600-1659	36	32	33	31	31	31	31	29	29
1700-1759	40	38	45	43	42	44	42	38	38
1800-1859	39	33	36	35	36	36	36	33	31
1900-1959	33	31	33	35	35	35	34	32	31
2000-2059	37	39	44	39	42	40	38	33	36
2100-2159	36	48	46	46	47	47	47	38	50
2200-2259	41	51	49	49	49	49	50	39	48
2300-2359	36	50	51	51	52	51	52	34	51

Figure I-2. Sample Output — TIMEOPS.F4 Program

I.3.2.1 TOTMAT.F4 – This program allows the user to input the day, month, and year he wishes the data displayed for. The output is then generated for this day at Boston. It should be mentioned that while the program was set up exclusively for Boston, it can be easily changed to allow the user to choose his airport. The data generated includes:

1. The percentage of hourly operations by class aircraft:

   Class H – 747, D10, L10, D8S, D8F, B3F
   Class A – Y62, DC8, 707, 720, 880, V10, CVL
   Class B – MR4, VIS, A24, Y18, Y11, 748, HLD, JET, B11, DC9, D9S, 72S, 727, 73S, 737, F28, CV3, CV4, CV5, CV6, DC6, D6A, D6B, FH7, LEC
   Class C – LJT, B18, B99, DC3, DTO, F27, N26, SKV, TB8, DHC, SWM, PHP, PR4, PRP
   Class D – ACD, A50, BBR, BTP, B80, DDV, PAP, PA2, PNV, TC4, TS4, BNI, BCH, CES, PCH, PCB

2. The arrival/departure ratio by hour.
3. The fraction of the day's volume that occurs in each minute.
4. The fraction of the number of operations by hour.
5. The percentage of operations occurring during the 4 highest minute-by-minute number of operations for each hour (defined as the "Concentration Ratio").

I.3.2.2 NTOTMAT.F4 – Here also the user inputs the day, month, and year for which he wishes the data displayed. Output will be the same as that generated by TOTMAT.F4. The difference between the two programs lies in the fact that TOTMAT.F4 generates the information directly from the OAG schedule for that particular day at Boston. NTOTMAT.F4 allows the user to use a standard day as reference to generate the mix by aircraft class and arrival/departure ratios. The volume of operations are scaled up or down depending on the user's desired daily volume. In this way, flights not appearing on the OAG tapes (e.g., nonscheduled, general aviation) can be included in the output volumes generated.

To generate these new volumes, each of the minute-by-minute number of operations obtained for a particular day are scaled according to the desired factor. For example, if the actual volume for 1/18/75 was 540 and the user wished the volume to be 600, each minute's operation would be scaled up by a factor of 600/540. An accumulative rounding technique is included in the program to remove the fractional parts, yet include all the new operations. Each of these minute-by-minute operations are then divided by the new daily volume to generate the fraction of the daily volume by minute.

I.4 OAG FLIGHT STAGE FILE — RECORD LAYOUT DESCRIPTION

FIELD NO.	FIELD NAME	LOCATION FROM	LOCATION TO	FIELD SIZE	DATA TYPE	DATA CODE	COMMENTS
1	Departure Country	1	3	3	N		World Area Code
2	Filler	4					
3	Departure Airport Code	5	7	3	A		FAA Code
4	Filler	8	9				
5	Departure Time-Local	10	13	4	A		Local Leave Time
6	Departure Time-GMT	14	17	4	A/N		GMT Leave Time
7	Arrival Country	18	20	3	N		World Area Code
8	Filler	21					
9	Arrival airport Code	22	24	3	A		FAA Code
10	Filler	25	26				
11	Arrival Time-Local	27	30	4	A/N		Local Arrive Time
12	Flag Code	31		1	N		Flag code in relation to its pattern of Service
13	Arrival Time-GMT	32	35	4	A/N		GMT Arrival time
14	Equipment Type	36		1	A		J=Jet, P=Propeller, T=Turboprop
15	Equipment Code	37	39	3	A/N		ATA Code describing the type of equipment
16	Filler	40					
17	Carrier	41	42	2	A		ATA Code
18	Flight Number	43	47	5	A/N		
19	Class of Service	48	52	5	A		
20	Days of Service	53	59	7	N		Each position will contain a '1' if service is scheduled and a '0' if not.
21	Suppress Code	60	60	1	N		Contains a 1 if stage is suppressed for any reason
22	Type of Operator	61		1	A		T=Commuter Air Carrier,Air Taxi I=Intra-state Blank=Sched.Air Carrier or other
23	Elapsed Time	62	65	4	N		
24	Effective Date	66	69	4	N		66-67= Month 68-69= Day
25	Discontinued Date	70	73	4	N		70-71= Month 72-73= Day
26	Departure Latitude	74	79	6	N		
27	Departure Longitude	80	85	6	N		
28	Arrival Latitude	86	91	6	N		
29	Arrival Longitude	92	97	6	N		
30	Filler	98	105	8			
31	Record Mark	106		1	A		

I.5 PROGRAM LISTINGS

I.5.1 DAYSOPS.F4

```
      DIMENSION MATRX(31,2),IDAY(7),ITOT(31),N(31)
      DATA ((MATRX(I,J),I=1,31),J=1,2)/1,2,3,4,5,6,7,8,9,
     & 10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,
     & 30,31,1,2,3,4,5,6,7,1,2,3,4,5,6,7,1,2,3,4,5,6,7,1,2,3,4,5,6,7,
     & 1,2,3/
      DO 300 K=1,31
      ITOT(K)=0
300   CONTINUE
      I=0
      DO 800 NL=1,2
      READ(20,52)DAIR
52    FORMAT(4X,A3)
800   CONTINUE
40    I=I+1
      READ(20,50,ERR=99,END=100)DAIR,AAIR,IDAY,ISUP,IEFDY,IDSDY
50    FORMAT(4X,A3,14X,A3,28X,7I1,I1,7X,I2,2X,I2)
      IF(ISUP.EQ.1) GO TO 40
C     TYPE 74,DAIR,AAIR,IEFDY,IDSDY
74    FORMAT(1X,'DAIR=',A3,'AAIR=',A3,'IEFDY=',I2,'IDSDY=',I2)
C     TYPE 75,I
75    FORMAT(1X,'AFT READ',I5)
      IF(DAIR.EQ.'BOS') GO TO 51
      IF(AAIR.EQ.'BOS') GO TO 51
      GO TO 40
51    ICHK=1
      KCHK=31
      IF(IEFDY.NE.0) ICHK=IEFDY
C     TYPE 76,ICHK,KCHK,IEFDY
76    FORMAT(1X,'ICHK=',I2,'KCHK=',I2,'EFDY=',I2)
      IF(IDSDY.NE.0) KCHK=IDSDY
      IF(KCHK.EQ.0) GO TO 40
      DO 200 L=ICHK,KCHK
      N(L)=MATRX(L,2)
      IF(IDAY(N(L)).EQ.0) GO TO 200
C     TYPE 77,N(L),IDAY(N(L))
77    FORMAT(1X,'N(L))=',I1,'IDAY(N(L))=',I1)
      ITOT(L)=ITOT(L)+1
200   CONTINUE
      GO TO 40
99    TYPE 15,I
15    FORMAT(1X,'ERR ON REC=',1X,I5)
      GO TO 40
100   WRITE(24,60)
60    FORMAT(15X,'OAG AIRLINE SCHEDULE FOR DEC,1974 AT BOSTON')
      WRITE(24,61)
61    FORMAT(15X,'TOTAL NUMBER OF SCHEDULED OPERATIONS PER DAY')
      WRITE(24,69)
69    FORMAT(1H0,27X,'DAY',4X,'# OF OPS')
      DO 900 IL=1,31
      WRITE(24,62)MATRX(IL,1),ITOT(IL)
62    FORMAT(26X,'DEC',1X,I2,3X,I5)
900   CONTINUE
      STOP
      END
```

I.5.2 JDAYOPS.F4

```
      DIMENSION MATRX(31,2),IDAY(7),ITOT(31),N(31)
      DATA ((MATRX(I,J),I=1,31),J=1,2)/1,2,3,4,5,6,7,8,9,
     & 10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,
     & 30,31,4,5,6,7,1,2,3,4,5,6,7,1,2,3,4,5,6,7,1,2,3,4,5,6,7,
     & 1,2,3,4,5,6/
      DO 300 K=1,31
      ITOT(K)=0
300   CONTINUE
      I=0
      DO 800 NL=1,2
      READ(11,52)DAIR
52    FORMAT(4X,A3)
800   CONTINUE
40    I=I+1
      READ(11,50,ERR=99,END=100)DAIR,AAIR,IDAY,ISUP,IEFDY,IDSDY
50    FORMAT(4X,A3,14X,A3,28X,7I1,I1,7X,I2,2X,I2)
      IF(ISUP.EQ.1) GO TO 40
C     TYPE 74,DAIR,AAIR,IEFDY,IDSDY
74    FORMAT(1X,'DAIR=',A3,'AAIR=',A3,'IEFDY=',I2,'IDSDY=',I2)
C     TYPE 75,I
75    FORMAT(1X,'AFT READ',I5)
      IF(DAIR.EQ.'BOS') GO TO 51
      IF(AAIR.EQ.'BOS') GO TO 51
      GO TO 40
51    ICHK=1
      KCHK=31
      IF(IEFDY.NE.0) ICHK=IEFDY
C     TYPE 76,ICHK,KCHK,IEFDY
76    FORMAT(1X,'ICHK=',I2,'KCHK=',I2,'EFDY=',I2)
      IF(IDSDY.NE.0) KCHK=IDSDY-1
      IF(KCHK.EQ.0) GO TO 40
      DO 200 L=ICHK,KCHK
      N(L)=MATRX(L,2)
      IF(IDAY(N(L)).EQ.0) GO TO 200
C     TYPE 77,N(L),IDAY(N(L))
77    FORMAT(1X,'N(L))=',I1,'IDAY(N(L))=',I1)
      ITOT(L)=ITOT(L)+1
200   CONTINUE
      GO TO 40
99    TYPE 15,I
15    FORMAT(1X,'ERR ON REC=',1X,I5)
      GO TO 40
100   WRITE(3,60)
60    FORMAT(15X,'OAG AIRLINE SCHEDULE FOR JAN,1975 AT BOSTON')
      WRITE(3,61)
61    FORMAT(15X,'TOTAL NUMBER OF SCHEDULED OPERATIONS PER DAY')
      WRITE(3,69)
69    FORMAT(1H0,27X,'DAY',4X,'# OF OPS')
      DO 900 IL=1,31
      WRITE(3,62)MATRX(IL,1),ITOT(IL)
62    FORMAT(26X,'JAN',1X,I2,3X,I5)
900   CONTINUE
      STOP
      END
```

I.5.3 TIMEOPS.F4

```
          DIMENSION MATRX(8,2),MTRX2(24,2),IDAYS(7),ITOT(24,8)
          L=0
          DO 350 I=1,24
          DO 351 J=1,8
          ITOT(I,J)=0
351       CONTINUE
350       CONTINUE
          DATA ((MATRX(M,N),M=1,8),N=1,2)/1,2,10,11,14,15,
     &    19,27,1,2,3,4,7,1,5,6/
          DATA ((MTRX2(M,N),M=1,24),N=1,2)/0,100,
     &    200,300,400,500,600,700,800,900,1000,1100,1200,
     &    1300,1400,1500,1600,1700,1800,1900,2000.2100,2200,
     &    2300,59,159,259,359,459,559,659,759,859.959,1059,
     &    1159,1259,1359,1459,1559,1659,1759,1859.1959,2059,2159,
     &    2259,2359/
          DO 150 JL=1,2
          READ(20,51)PNUM
51        FORMAT(A4)
150       CONTINUE
40        L=L+1
          READ(20,50,ERR=99,END=100)DAIR,IDGMT,AAIR,IAGMT,IDAYS,
     &    ISUP,IEFDY,IDSDY
50        FORMAT(4X,A3,6X,I4,4X,A3,7X,I4,17X,7I1,I1,7X,I2,2X,I2)
          IF(ISUP.EQ.1) GO TO 40
          IF(DAIR.EQ.'BOS') GO TO 75
          IF(AAIR.EQ.'BOS') GO TO 76
          GO TO 40
75        ITIME=IDGMT
          GO TO 77
76        ITIME=IAGMT
77        ICHK=1
          KCHK=31
          IF(IEFDY.NE.0) ICHK=IEFDY
          IF(IDSDY.NE.0) KCHK=IDSDY
          DO 200 I=1,8
C         TYPE 16,ITIME,ICHK,KCHK
16        FORMAT(1X,'ITIME=',I4,'ICHK=',I2,'KCHK=',I2)
          IF(MATRX(I,1).LT.ICHK.OR.MATRX(I,1).GT.KCHK) GO TO 200
234       N=MATRX(I,2)
          IF(IDAYS(N).EQ.0) GO TO 200
          DO 300 K=1,24
          IF(ITIME.LT.MTRX2(K,1).OR.ITIME.GT.MTRX2(K,2)) GO TO 300
          ITOT(K,I)=ITOT(K,I)+1
          GO TO 200
300       CONTINUE
200       CONTINUE
          GO TO 40
99        TYPE 15,L
15        FORMAT(1X,'ERR=',I5)
          GO TO 40
100       WRITE(23,60)
60        FORMAT(15X,'OAG AIRLINE SCHEDULE FOR DEC.1974 AT BOS')
          WRITE(23,61)
61        FORMAT(3X,'TOTAL NUMBER OF SCHEDULED OPERATIONS FOR SELECTED ',
     &    'DAYS BY TIME(GMT)')
          WRITE(23,62)(MATRX(M,1),M=1,8)
62        FORMAT(1H0,11X,'DEC',1X,I2,7(5X,I2))
          WRITE(23,69)
69        FORMAT(1X,'TIME(GMT)')
          DO 900 M=1,24
          WRITE(23,63)(MTRX2(M,N),N=1,2),(ITOT(M,N),N=1,8)
63        FORMAT(1H0,1X,I4,'-',I4,8(2X,I5))
900       CONTINUE
          STOP
          END
```

I.5.4 JTIMEOPS.F4

```
         DIMENSION MATRX(9,2),MTRX2(24,2),IDAYS(7),ITOT(24,9)
         L=0
         DO 350 I=1,24
         DO 351 J=1,8
         ITOT(I,J)=0
351      CONTINUE
350      CONTINUE
         DATA ((MATRX(M,N),M=1,9),N=1,2)/4,5,6,7,15,16,
      &  24,25,26,7,1,3,4,4,5,6,7,1/
         DATA ((MTRX2(M,N),M=1,24),N=1,2)/0,100,
      &  200,300,400,500,600,700,800,900,1000,1100,1200,
      &  1300,1400,1500,1600,1700,1800,1900,2000,2100,2200,
      &  2300,59,159,259,359,459,559,659,759,859,959,1059,
      &  1159,1259,1359,1459,1559,1659,1759,1859,1959,2059,2159,
      &  2259,2359/
         DO 150 JL=1,2
         READ(20,51)PNUM
51       FORMAT(A4)
150      CONTINUE
40       L=L+1
         READ(20,50,ERR=99,END=100)DAIR,IDGMT,AAIR,IAGMT,IDAYS,
      &  ISUP,IEFDY,IDSDY
50       FORMAT(4X,A3,6X,I4,4X,A3,7X,I4,17X,7I1,I1,7X,I2,2X,I2)
         IF(ISUP.EQ.1) GO TO 40
         IF(DAIR.EQ.'BOS') GO TO 75
         IF(AAIR.EQ.'BOS') GO TO 76
         GO TO 40
75       ITIME=IDGMT
         GO TO 77
76       ITIME=IAGMT
77       ICHK=1
         KCHK=31
         IF(IEFDY.NE.0) ICHK=IEFDY
         IF(IDSDY.NE.0) KCHK=IDSDY
         DO 200 I=1,9
         TYPE 16,ITIME,ICHK,KCHK
16       FORMAT(1X,'ITIME=',I4,'ICHK=',I2,'KCHK=',I2)
         IF(KCHK.EQ.31) GO TO 233
         IF(MATRX(I,1).LT.ICHK.OR.MATRX(I,1).GE.KCHK) GO TO 200
         GO TO 234
233      IF(MATRX(I,1).LT.ICHK) GO TO 200
234      N=MATRX(I,2)
         IF(IDAYS(N).EQ.0) GO TO 200
         DO 300 K=1,24
         IF(ITIME.LT.MTRX2(K,1).OR.ITIME.GT.MTRX2(K,2)) GO TO 300
         ITOT(K,I)=ITOT(K,I)+1
         GO TO 200
300      CONTINUE
200      CONTINUE
         GO TO 40
99       TYPE 15,L
15       FORMAT(1X,'ERR=',I5)
         GO TO 40
100      WRITE(3,60)
60       FORMAT(15X,'OAG AIRLINE SCHEDULE FOR JAN,1975 AT BOS')
         WRITE(3,61)
61       FORMAT(3X,'TOTAL NUMBER OF SCHEDULED OPERATIONS FOR SELECTED '
      &  'DAYS BY TIME(GMT)')
         WRITE(3,62)(MATRX(M,1),M=1,9)
62       FORMAT(1H0,11X,'JAN',1X,I2,8(5X,I2))
         WRITE(3,69)
69       FORMAT(1X,'TIME(GMT)')
         DO 900 M=1,24
         WRITE(3,63)(MTRX2(M,N),N=1,2),(ITOT(M,N),N=1,9)
63       FORMAT(1H0,1X,I4,'-',I4,9(2X,I5))
900      CONTINUE
         STOP
         END
```

I.5.5 TOTMAT.F4

```
      DIMENSION OPS(24,60),CLASS(24,6),RATIO(24,2),TOT(5),
     & IMATRX(24,2),PMATRX(68,2),IDEC(31,3),IDAY(7),PTOT(24)
      DATA(PTOT(I),I=1,24)/24*0/
      DATA((IDEC(I,J),I=1,31),J=1,3)/1,2,3,4,5,6,7,8,9,10,
     & 11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,
     & 27,28,29,30,31,1,2,3,4,5,6,7,1,2,3,4,5,6,7,1,2,3,4,5,6,7,
     & 1,2,3,4,5,6,7,1,2,3,4,5,6,7,1,2,3,4,5,6,7,1,2,3,4,5,6,7,
     & 1,2,3,4,5,6,7,1,2,3,4,5,6/
      DATA((OPS(I,K),K=1,60),(CLASS(I,K1),K1=1,6),(RATIO(I,K2),
     & K2=1,2),(IMATRX(I,K3),K3=1,2),I=1,24)
     & /1680*0/
      DATA((PMATRX(J,L),J=1,68),L=1,2)/'747','D10','L10','D8S',
     & 'D8F','B3F','Y62','DC8','707','720','880','V10','CVL',
     & 'MR4','VIS','A24','Y18','Y11','748','HLO','JET','B11','DC9',
     & 'D9S','72S','727','73S','737','F28','CV3','CV4','CV5',
     & 'CV6','DC6','D6A','D6B','FH7','LEC','LJT','B18','B99',
     & 'DC3','DTO','F27','N26','SKV','T88','DHC','SWM','PHP',
     & 'PR4','PRP','ACD','A50','BBR','BTP','B80','DOV',
     & 'PAP','PAZ','PNV','TC4','TS4','BNI','BCH','CES','PCH',
     & 'PCB',
     & 1.,1.,1.,1.,1.,1.,2.,2.,2.,2.,2.,2.,2.,3.,
     & 3.,3.,3.,3.,3.,3.,3.,3.,3.,3.,3.,3.,3.,3.,3.,
     & 3.,3.,3.,3.,3.,3.,3.,3.,3.,4.,
     & 4.,4.,4.,4.,4.,4.,4.,4.,4.,4.,4.,4.,4.,5.,5.,5.,5.,5.,5.,
     & 5.,5.,5.,5.,5.,5.,5.,5.,5.,5./
      L=0
      DO 1000 JK=1,24
      IMATRX(JK,1)=L
      IMATRX(JK,2)=L+59
      L=L+100
1000  CONTINUE
C     TYPE 10
10    FORMAT(1X,'TYPE MONTH,DAY,YEAR YOU',
     & ' WISH DISPLAYED(EG.12/02/74):',$)
C     ACCEPT 5,IMON,SL1,IDY,SL2,IYR
5     FORMAT(I2,A1,I2,A1,I2)
C     TYPE 71,IMON,IDY
71    FORMAT(1X,'IMON=',I2,'IDY=',I2)
      IMON=9
      SL1='/'
      IDY=4
      SL2='/'
      IYR=74
      DO 333 II=1,2
      READ(22,51)CCC
51    FORMAT(A3)
333   CONTINUE
      LCT=0
40    LCT=LCT+1
      READ(22,50,ERR=99,END=100)DAIR,IDHR,IDMIN,AAIR,IAHR,
     & IAMIN,ACT,IDAY,ISUP,IEFDY,IDSDY
50    FORMAT(4X,A3,2X,2I2,8X,A3,2X,2I2,6X,A3,13X,7I1,I1,
     & 7X,I2,2X,I2)
      LL=3
      IF(IMON.EQ.12.OR.IMON.EQ.9) LL=2
1115  ICC=IDEC(IDY,LL)
C     TYPE 79,ICC,IDEC(IDY,2)
79    FORMAT(1X,'ICC=',I1,'IDEC(IDY,2)=',I1)
      IF(ISUP.EQ.1) GO TO 40
      IF(DAIR.NE.'BOS'.AND.AAIR.NE.'BOS') GO TO 40
C     TYPE 141,IDAY(ICC)
```

```
141     FORMAT(1X,'IDAY(ICC)=',I1)
        IF(IDAY(ICC).EQ.0) GO TO 40
        IF(IEFDY.GT.IDY) GO TO 40
        IF(IDSDY.NE.0.AND.IDSDY.LT.IDY) GO TO 40
        IF(DAIR.EQ.'BOS') GO TO 75
        ITM=IAHR
        MIN=IAMIN
        JCT=1
        GO TO 76
75      ITM=IDHR
        MIN=IDMIN
        JCT=2
76      OPS(ITM+1,MIN+1)=OPS(ITM+1,MIN+1)+1.
        RATIO(ITM+1,JCT)=RATIO(ITM+1,JCT)+1.
        DO 200 K=1,68
        IF(ACT.NE.PMATRX(K,1)) GO TO 200
        N=IFIX(PMATRX(K,2))
        GO TO 201
200     CONTINUE
        N=6 .
C203    TYPE 19,N
19      FORMAT(1X,'N=',I1)
C       TYPE 17,ITM,N
17      FORMAT(1X,'ITM+1=',I2,'N=',I1)
201     CLASS(ITM+1,N)=CLASS(ITM+1,N)+1.
        GO TO 40
99      TYPE 15,LCT
15      FORMAT(1X,'ERR=',I5)
        GO TO 40
100     DO 300 JM=1,24
        TOT(0)=CLASS(JM,1)
        DO 301 JN=1,5
        TOT(JN)=TOT(JN-1)+CLASS(JM,JN+1)
301     CONTINUE
        IF(TOT(5).EQ.0) CLASS(JM,1)='*'
        IF(TOT(5).EQ.0) GO TO 300
        DO 302 J1=1,6
        CLASS(JM,J1)=(CLASS(JM,J1)/TOT(5))*100.
302     CONTINUE
300     CONTINUE
        DO 400 LM=1,24
        IF(RATIO(LM,2).EQ.0) GO TO 401
        IF(RATIO(LM,1).EQ.0) GO TO 402
        RATIO(LM,1)=RATIO(LM,1)/RATIO(LM,2)
        GO TO 400
401     RATIO(LM,2)='*'
        GO TO 400
402     RATIO(LM,1)='*'
400     CONTINUE
        DTOT=0
        DO 335 IR=1,24
        DO 336 KR=1,60
        PTOT(IR)=PTOT(IR)+OPS(IR,KR)
336     CONTINUE
        DTOT=DTOT+PTOT(IR)
335     CONTINUE
        TYPE 1111,DTOT
1111    FORMAT(1X,'DTOT=',F5.0)
        DO 337 IS=1,24
        DO 338 KS=1,60
        OPS(IS,KS)=OPS(IS,KS)/DTOT
```

```
338     CONTINUE
        TYPE 1112,OPS(IS,KS)
1112    FORMAT(1X,'OPS(IS,KS)=',1440(F5.3,1X))
337     CONTINUE
        DO 339 IT=1,24
        PTOT(IT)=PTOT(IT)/PTOT
339     CONTINUE
        MCT=0
        ILCT=0
        WRITE(23,80)IMON,SL1,IDY,SL2,IYR
80      FORMAT(30X,'OAG AIRLINE SCHEDULE FOR ',I2,A1,I2,A1,I2,
     &  ' AT BOS')
        WRITE(23,82)
82      FORMAT(1H0,20X,'FOR EACH HOUR(I)(IN LOCAL TIME), THE MIX AS',
     &  ' PERCENT FOR EACH CLASS(J) - M(I,J),I=0,23, J=1,6')
        WRITE(23,83)
83      FORMAT(45X,'J=1 - CLASS H')
        WRITE(23,84)
84      FORMAT(47X,'2 - CLASS A')
        WRITE(23,85)
85      FORMAT(47X,'3 - CLASS B')
        WRITE(23,86)
86      FORMAT(47X,'4 - CLASS C')
        WRITE(23,87)
87      FORMAT(47X,'5 - CLASS D')
        WRITE(23,88)
88      FORMAT(47X,'6 - OTHER')
        WRITE(23,89)
89      FORMAT(1H0,20X,'ARRIVAL/DEPARTURE RATIO BY HOUR(I)',
     &  '(IN LOCAL TIME) ',
     &  '- ADR(I),I=0,23')
        WRITE(23,81)
81      FORMAT(1H0,20X,'FRACTION OF THE',
     &  ' TOTAL NUMBER OF OPERATIONS BY MINUTE(K)',
     &  ' - V(K),K=0,1339')
        WRITE(23,90)
90      FORMAT(1H0,20X,'TOTAL NUMBER OF OPERATIONS BY HOUR(I)'
     &  '(IN LOCAL TIME) - ITOT(I),I=0,23')
        WRITE(23,95)
95      FORMAT(1H0,20X,'PERCENTAGE OF OPERATIONS OCCURING',
     &  ' DURING THE FOUR HIGHEST V(K) FOR EACH HOUR(I)',
     &  '(IN LOCAL TIME) - CON(I),I=0,23')
        DO 500 IL=1,24
        IF(CLASS(IL,1).EQ.'*') WRITE(23,65)ILCT,(IMATRX(IL,M),M=1,2)
65      FORMAT(1H1,3X,'HOUR(',I2,'):',I4,'-',I4,
     &  10X,'NO OPERATIONS TOOK PLACE DURING THIS HOUR')
        IF(CLASS(IL,1).EQ.'*') GO TO 566
        WRITE(23,60)ILCT,(IMATRX(IL,MM),MM=1,2),ILCT,
     &  (CLASS(IL,K),K=1,6)
60      FORMAT(1H1,3X,'HOUR(',I2,'):',
     &  I4,'-',I4,10X,'M('I2,'): ',
     &  '1=',F5.1,'%, 2=',F5.1,'%, 3=',F5.1,'%, 4=',F5.1,
     &  '%, 5=',F5.1,'%, 6=',F5.1,'%')
        IF(RATIO(IL,2).EQ.'*') GO TO 555
        IF(RATIO(IL,1).EQ.'*') GO TO 551
78      FORMAT(1H0,29X,'ADR(',I2,')=',F5.0,2X,'(THE # OF',
     &  ' DEPARTURES FOR THIS HOUR,NO ARRIVALS)')
        WRITE(23,61)ILCT,RATIO(IL,1)
61      FORMAT(1H0,29X,'ADR(',I2,')=',F5.2)
        GO TO 566
555     WRITE(23,77)ILCT,RATIO(IL,1)
```

```
77        FORMAT(1H0,29X,'ADR(',I2,')=',F5.0,2X,'(THE #',
     &   ' OF ARRIVALS FOR ',
     &   'THIS HOUR,NO DEPARTURES)')
          GO TO 566
551       WRITE(23,78)ILCT,RATIO(IL,2)
566       WRITE(23,9998)
9998      FORMAT(1H0)
          JP=1
          DO 501 J=1,30
          IF(CLASS(IL,1).EQ.'*') GO TO 578
          MCT1=MCT+1
          WRITE(23,62)MCT,OPS(IL,JP),MCT1,OPS(IL,JP+1)
62        FORMAT(45X,'V(',G4,')=',F7.5,10X,'V(',I4,')=',F7.5)
578       MCT=MCT+2
          JP=JP+2
501       CONTINUE
          IF(CLASS(IL,1).EQ.'*') GO TO 579
          WRITE(23,66)ILCT,PTOT(IL)
66        FORMAT(1H0,29X,'ITOT(',I2,')=',F7.5)
          PCON=0
          LRIT=2
          KRIT=60
          DO 222 IRIT=1,4
          DO 223 JRIT=LRIT,KRIT
          IF(OPS(IL,IRIT).GT.OPS(IL,JRIT)) GO TO 223
          SW=OPS(IL,IRIT)
          OPS(IL,IRIT)=OPS(IL,JRIT)
          OPS(IL,JRIT)=SW
223       CONTINUE
          LRIT=LRIT+1
          PCON=PCON+OPS(IL,IRIT)
222       CONTINUE
          C1=PCON
          C2=PTOT(IL)
          CON=(C1/C2)*100.
          WRITE(23,93)ILCT,CON
93        FORMAT(1H0,30X,'CON(',I2,')=',F6.2,'%')
579       ILCT=ILCT+1
500       CONTINUE
101       STOP
          END
```

I.5.6 NTOTMAT.F4

```
      DIMENSION IOPS(24,6Ø),CLASS(24,6),RATIO(24,2),TOT(5),
     & IMATRX(24,2),PMATRX(68,2),IDEC(31,3),IDAY(7),PTOT(24),
     & OPS(24,6Ø),ZTOT(24)
      DATA(PTOT(I),I=1,24)/24*Ø/
      DATA((IDEC(I,J),I=1,31),J=1,3)/1,2,3,4,5,6,7,8,9,1Ø,
     & 11,12,13,14,15,16,17,18,19,2Ø,21,22,23,24,25,26,
     & 27,28,29,3Ø,31,1,2,3,4,5,6,7,1,2,3,4,5,6,7,1,2,3,4,5,6,7,
     & 1,2,3,4,5,6,7,1,2,3,4,5,6,7,1,2,3,4,5,6.7,1,2,3,4,5,6,7,
     & 1,2,3,4,5,6,7.1,2,3,4,5,6/
      DATA((IOPS(I,K),K=1,6Ø),(CLASS(I,K1),K1=1,6),(RATIO(I,K2),
     & K2=1,2),(IMATRX(I,K3),K3=1,2),(OPS(I,K4),K4=1,6Ø),I=1,24)
     & /312Ø*Ø/
      DATA((PMATRX(J,L),J=1,68),L=1,2)/'747','D1Ø','L1Ø','D8S',
     & 'D8F','B3F','Y62','DC8','7Ø7','72Ø','8PØ','V1Ø','CVL',
     & 'MR4','VIS','A24','Y18','Y11','748','HLD','JET','B11','DC9',
     & 'D9S','72S','727','73S','737','F28','CV3','CV4','CV5',
     & 'CV6','DC6','D6A','D6B','FH7','LEC','LJT','B18','B99',
     & 'DC3','DTØ','F27','N26','SKV','TB8','DHC','SWM','PHP',
     & 'PR4','PRP','ACD','A5Ø','BBR','BTP','B8Ø','DDV',
     & 'PAR','PAZ','PNV','TC4','TS4','BNI','BCH','CES','PCH',
     & 'PCB',
     & 1.,1.,1.,1.,1.,1.,2.,2.,2.,2.,2.,2.,2.,3.,
     & 3.,3.,3.,3.,3.,3.,3.,3.,3.,3.,3.,3.,3.,3.,3.,
     & 3.,3.,3.,3.,3.,3.,3.,3.,3.,4.,
     & 4.,4.,4.,4.,4.,4.,4.,4.,4.,4.,4.,4.,4.,5.,5.,5.,5.,5.,5.,
     & 5.,5.,5.,5.,5.,5.,5.,5.,5.,5./
      L=Ø
      DO 1ØØØ JK=1,24
      IMATRX(JK,1)=L
      IMATRX(JK,2)=L+59
      L=L+1ØØ
1ØØØ  CONTINUE
C     TYPE 1Ø
1Ø    FORMAT(1X,'TYPE MONTH,DAY,YEAR YOU',
     & ' WISH DISPLAYED(EG,12/Ø2/74):',$)
C     ACCEPT 5,IMON,SL1,IDY,SL2,IYR
5     FORMAT(I2,A1,I2,A1,I2)
C     TYPE 71,IMON,IDY
71    FORMAT(1X,'IMON=',I2,'IDY=',I2)
      IMON=9
      SL1='/'
      IDY=6
      SL2='/'
      IYR=74
      DO 333 II=1,2
      READ(22,51)CCC
51    FORMAT(A3)
333   CONTINUE
      LCT=Ø
4Ø    LCT=LCT+1
      READ(22,5Ø,ERR=99,END=1ØØ)DAIR,IDHR,IDMIN,AAIR,IAHR,
     & IAMIN,ACT,IDAY,ISUP,IEFDY,IDSDY
5Ø    FORMAT(4X,A3,2X,2I2,8X,A3,2X,2I2,6X,A3,13X,7I1,I1,
     & 7X,I2,2X,I2)
      LL=3
      IF(IMON.EQ.12.OR.IMON.EQ.9) LL=2
1115  ICC=IDEC(IDY,LL)
C     TYPE 79,ICC,IDEC(IDY,2)
79    FORMAT(1X,'ICC=',I1,'IDEC(IDY,2)=',I1)
      IF(ISUP.EQ.1) GO TO 4Ø
      IF(DAIR.NE.'BOS'.AND.AAIR.NE.'BOS') GO TO 4Ø
```

```
C       TYPE 141,IDAY(ICC)
141     FORMAT(1X,'IDAY(ICC)=',I1)
        IF(IDAY(ICC).EQ.2) GO TO 40
        IF(IEFDY.GT.IDY) GO TO 40
        IF(IDSDY.NE.0.AND.IDSDY.LT.IDY) GO TO 40
        IF(DAIR.EQ.'BOS') GO TO 75
        ITM=IAHR
        MIN=IAMIN
        JCT=1
        GO TO 76
75      ITM=IDHR
        MIN=IDMIN
        JCT=2
76      OPS(ITM+1,MIN+1)=OPS(ITM+1,MIN+1)+1.
        RATIO(ITM+1,JCT)=RATIO(ITM+1,JCT)+1.
        DO 200 K=1,68
        IF(ACT.NE.PMATRX(K,1)) GO TO 200
        N=IFIX(PMATRX(K,2))
        GO TO 201
200     CONTINUE
        N=6
C203    TYPE 19,N
19      FORMAT(1X,'N=',I1)
C       TYPE 17,ITM,N
17      FORMAT(1X,'ITM+1=',I2,'N=',I1)
201     CLASS(ITM+1,N)=CLASS(ITM+1,N)+1.
        GO TO 40
99      TYPE 15,LCT
15      FORMAT(1X,'ERR=',I5)
        GO TO 40
C       TYPE 791,((OPS(I,J),I=1,24),J=1,60)
791     FORMAT(1X,'OPS(I,J)=',1440F5.0)
100     DO 300 JM=1,24
        TOT(0)=CLASS(JM,1)
        DO 301 JN=1,5
        TOT(JN)=TOT(JN-1)+CLASS(JM,JN+1)
301     CONTINUE
        IF(TOT(5).EQ.0) CLASS(JM,1)='*'
        IF(TOT(5).EQ.0) GO TO 300
        DO 302 J1=1,6
        CLASS(JM,J1)=(CLASS(JM,J1)/TOT(5))*100.
302     CONTINUE
300     CONTINUE
        DO 400 LM=1,24
        IF(RATIO(LM,2).EQ.0) GO TO 401
        IF(RATIO(LM,1).EQ.0) GO TO 402
        RATIO(LM,1)=RATIO(LM,1)/RATIO(LM,2)
        GO TO 400
401     RATIO(LM,2)='*'
        GO TO 400
402     RATIO(LM,1)='*'
400     CONTINUE
        RTOT=0
        DTOT=770
        DO 335 IR=1,24
        DO 336 JR=1,60
        PTOT(IR)=PTOT(IR)+OPS(IR,JR)
336     CONTINUE
C       TYPE 778,PTOT(IR)
778     FORMAT(1X,'PTOT(IR)=',F8.2)
        RTOT=RTOT+PTOT(IR)
```

```
335     CONTINUE
        TOT1=DTOT/RTOT
        TYPE 66666,TOT1
66666   FORMAT(1X,'TOT1=',F6.2)
C       TYPE 777,RTOT
777     FORMAT(1X,'RTOT=',F9.2)
        F=0
        DO 350 IT=1,24
        DO 351 KT=1,60
        X=OPS(IT,KT)*TOT1
C       TYPE 779,X
779     FORMAT(1X,'X=',F5.2)
        IOPS(IT,KT)=INT(X)
C       TYPE 780,IOPS(IT,KT)
780     FORMAT(1X,'IOPS(IT,KT)=',I5)
        IX=FLOAT(IOPS(IT,KT))
        F=F+X-IX
C       TYPE 781,F
781     FORMAT(1X,'F=',F5.2)
        IF(F.LE.1) GO TO 351
        IOPS(IT,KT)=IOPS(IT,KT)+1
        F=F-1
351     CONTINUE
350     CONTINUE
        DATA(ZTOT(IZ),IZ=1,24)/24*0/
        YTOT=0
        DO 389 IW=1,24
        DO 391 IV=1,60
        Z1=FLOAT(IOPS(IW,IV))
        ZTOT(IW)=ZTOT(IW)+Z1
391     CONTINUE
        YTOT=YTOT+ZTOT(IW)
389     CONTINUE
        DO 340 IU=1,24
        DO 341 IV=1,60
        DIV=FLOAT(IOPS(IU,IV))
        OPS(IU,IV)=DIV/YTOT
341     CONTINUE
340     CONTINUE
        DO 342 KU=1,24
        ZTOT(KU)=ZTOT(KU)/YTOT
342     CONTINUE
        MCT=0
        ILCT=0
799     WRITE(23,80)IMON,SL1,IDY,SL2,IYR
80      FORMAT(38X,'OAG AIRLINE SCHEDULE FOR ',I2,A1,I2,A1,I2,
     &  ' AT BOS')
        WRITE(23,82)
82      FORMAT(1H0,23X,'FOR EACH HOUR(I)(IN LOCAL TIME), THE MIX AS',
     &  ' PERCENT FOR EACH CLASS(J) - M(I,J),I=0,23, J=1,6')
        WRITE(23,83)
83      FORMAT(45X,'J=1 - CLASS H')
        WRITE(23,84)
84      FORMAT(47X,'2 - CLASS A')
        WRITE(23,85)
85      FORMAT(47X,'3 - CLASS B')
        WRITE(23,86)
86      FORMAT(47X,'4 - CLASS C')
        WRITE(23,87)
87      FORMAT(47X,'5 - CLASS D')
        WRITE(23,88)
```

```
88        FORMAT(47X,'6 - OTHER')
          WRITE(23,89)
89        FORMAT(1H0,20X,'ARRIVAL/DEPARTURE RATIO BY HOUR(I)',
     &   '(IN LOCAL TIME) ',
     &   '- ADR(I),I=0,23')
          WRITE(23,81)
81        FORMAT(1H0,23X,'FRACTION OF THE ',
     &   'TOTAL NUMBER OF OPERATIONS BY MINUTE(K)',
     &   ' - V(K),K=0,1339')
          WRITE(23,90)
90        FORMAT(1H0,20X,'TOTAL NUMBER OF OPERATIONS BY HOUR(I)'
     &   '(IN LOCAL TIME) - ITOT(I),I=0,23')
          WRITE(23,95)
95        FORMAT(1H0,23X,'PERCENTAGE OF OPERATIONS OCCURING',
     &   ' DURING THE FOUR HIGHEST V(K) FOR EACH HOUR(I)',
     &   '(IN LOCAL TIME) - CON(I),I=0,23')
          DO 500 IL=1,24
          IF(CLASS(IL,1).EQ.'*') WRITE(23,65)ILCT,(IMATRX(IL,M),M=1,2)
65        FORMAT(1H1,3X,'HOUR(',I2,'):',I4,'-',I4,
     &   10X,'NO OPERATIONS TOOK PLACE DURING THIS HOUR')
          IF(CLASS(IL,1).EQ.'*') GO TO 566
          WRITE(23,60)ILCT,(IMATRX(IL,MM),MM=1,2),ILCT,
     &   (CLASS(IL,K),K=1,6)
60        FORMAT(1H1,3X,'HOUR(',I2,'):',
     &   I4,'-',I4,10X,'M('I2,'): ',
     &   '1=',F5.1,'%, 2=',F5.1,'%, 3=',F5.1,'%, 4=',F5.1,
     &   '%, 5=',F5.1,'%, 6=',F5.1,'%')
          IF(RATIO(IL,2).EQ.'*') GO TO 555
          IF(RATIO(IL,1).EQ.'*') GO TO 551
78        FORMAT(1H0,29X,'ADR(',I2,')=',F5.0,2X,'(THE # OF',
     &   ' DEPARTURES FOR THIS HOUR,NO ARRIVALS)')
          WRITE(23,61)ILCT,RATIO(IL,1)
61        FORMAT(1H0,29X,'ADR(',I2,')=',F5.2)
          GO TO 566
555       WRITE(23,77)ILCT,RATIO(IL,1)
77        FORMAT(1H0,29X,'ADR(',I2,')=',F5.0,2X,'(THE #',
     &   ' OF ARRIVALS FOR ',
     &   'THIS HOUR,NO DEPARTURES)')
          GO TO 566
551       WRITE(23,78)ILCT,RATIO(IL,2)
566       WRITE(23,9998)
9998      FORMAT(1H0)
          JP=1
          DO 501 J=1,30
          IF(CLASS(IL,1).EQ.'*') GO TO 578
          MCT1=MCT+1
          WRITE(23,62)MCT,OPS(IL,JP),MCT1,OPS(IL,JP+1)
62        FORMAT(45X,'V(',G4,')=',F7.5,10X,'V(',I4,')=',F7.5)
578       MCT=MCT+2
          JP=JP+2
501       CONTINUE
          IF(CLASS(IL,1).EQ.'*') GO TO 579
          WRITE(23,66)ILCT,ZTOT(IL)
66        FORMAT(1H0,29X,'ITOT(',I2,')=',F7.5)
          PCON=0
          LRIT=2
          KRIT=60
          DO 222 IRIT=1,4
          DO 223 JRIT=LRIT,KRIT
          IF(OPS(IL,IRIT).GT.OPS(IL,JRIT)) GO TO 223
          SW=OPS(IL,IRIT)
```

```
      OPS(IL,IRIT)=OPS(IL,JRIT)
      OPS(IL,JRIT)=SW
223   CONTINUE
      LRIT=LRIT+1
      PCON=PCON+OPS(IL,IRIT)
222   CONTINUE
      C1=PCON
      C2=ZTOT(IL)
      IF(C2.EQ.0) GO TO 579
      CON=(C1/C2)*100.
      WRITE(23,93)ILCT,CON
93    FORMAT(1H0,30X,'CON(',I2,')=',F6.2,'%')
579   ILCT=ILCT+1
500   CONTINUE
101   STOP
      END
```

APPENDIX J — AN ALTERNATE METHOD FOR CALCULATING DELAY

J.1 INTRODUCTION

Appendix D has described the algorithm that this year's model uses to calculate delay for an aircraft. This appendix explains an alternate algorithm that is a candidate for being used in the next version of the model.

J.2 ASSUMPTIONS AND INPUTS

This algorithm, like the previous one, assumes that planes request service only at the beginning of a minute and that planes are serviced on a first-come, first-served basis; but this algorithm embodies a slightly different vision of how the airside system operates. It is assumed that when there is no congestion, it takes a plane c minutes to get through the airside system; c is a constant for an airport and is independent of weather. So if there is no congestion, a plane leaves the system c minutes after it enters; if there is congestion, it leaves r* minutes after the previous plane leaves the system, where r* is the relevant processing time (in terms of minutes per plane). One difference between the view of the airside system expressed in Section D.2 and the present view is that here more than one plane can be simultaneously processed; however, each plane being processed is in a different stage of being processed. Delay is defined to be the difference between when a plane actually leaves the system and when it would have left the system had there been no congestion.

The algorithm requires six inputs. The first comes from the Airside Processing Rate Module; the next four, from the Demand Module; and the last, from the data base for each particular airport.

1. r(W,M,AD) — The processing time in minutes per plane. When there is a queue, this is the number of minutes that elapse between planes leaving the airside system.

2. V(t) — The volume of planes that request service in minute t.

3. W(t) — The weather, either VFR or IFR, in the hour containing minute t.

4. $M(t) = [m_1(t), m_2(t), \ldots, m_5(t)]$ — The mix of aircraft classes that request service in the hour containing minute t; $m_i(t)$ is the percentage of aircraft requesting service in that hour that are of class i.

5. AD(t) — The arrival-departure ratio in the hour containing minute t.

6. c — The amount of time it takes a plane to get through the uncongested airside system (a constant).

J.3 DEFINITIONS

The information in V(t) can be used to number the planes in the order in which they request service; if two planes request service at the same time, then either can be numbered first. We will be interested in three functions:

E(i) the time the $i^{\underline{th}}$ plane enters the airside system;
L(i) the time the $i^{\underline{th}}$ plane leaves the airside system;
D(i) the amount of delay incurred by the $i^{\underline{th}}$ plane.

The function E(i) is known since it can be calculated from the demand profile V(t).

(Note: If the amount of time it takes a departure to pass through the system differs from that taken by an arrival, then the E(i) must be adjusted to make these two times the same. For example, if it takes a departure 8 minutes to pass through the uncongested system and an arrival 10 minutes, then E(i) must either be made 2 minutes earlier for departure or 2 minutes later for arrivals.)

We can now state analytical expressions for L(i) and D(i). Let r*(i) be the relevant processing time for plane i; the value taken by this function will be determined in the next paragraph. If there is no congestion, plane i leaves the system at E(i)+c;

i.e., c minutes after it enters the system. If there is congestion, it leaves the system $r^*(i)$ minutes after plane i-1 leaves; this is because when there is congestion, a plane leaves the system every r^* minutes. Therefore we have

$$L(i) = \max\left\{E(i)+c,\ L(i-1)+r^*(i)\right\} \tag{1}$$

Since delay is defined to be the difference between the time a plane actually leaves the system and the time it would have left had there been no congestion, we have

$$D(i) = L(i) - \left[E(i)+c\right] \tag{2}$$

To get an alternate expression for delay, substitute (1) into (2) to get

$$D(i) = \max\left\{E(i)+c,\ L(i-1)+r^*(i)\right\} - \left[E(i)+c\right]\ . \tag{3}$$

The task of this appendix is to rework (3) to put it into a form that will allow delay to be quickly computed.

It is next necessary to give an exact expression for the relevant processing time. If there is no congestion, then plane i leaves the system at $E(i)+c$, which does not depend on the processing time; so we only need an expression for the processing time when there is congestion. Section 2.2.3 argued that the appropriate processing time is the one based on the mix and arrival-departure ratio at the time the plane enters the system and on the weather at the time the plane lands. Therefore, the appropriate mix and arrival-departure ratios are $M[E(i)]$ and $AD[E(i)]$. Since the effect of weather is largely felt through separation standards, the natural time to interpret as "the time the plane lands" is when the previous plane leaves the system. (Recall congestion is assumed.) So the relevant weather is $W[L(i-1)]$. This means that the relevant processing time is

$$r^*(i) = r\left[W[L(i-1)],\ M[E(i)],\ AD[E(i)]\right]. \tag{4}$$

Rewriting (2) as

$$L(i) = D(i)+E(i)+c, \tag{5}$$

substituting i-1 for i, and substituting into (4) gives

$$r^*(i) = r\left[W[D(i-1)+E(i-1)+c],\ M[E(i)],\ AD[E(i)]\right]. \tag{6}$$

It is seen that the relevant processing rate is a function of i, D(i-1), and the known inputs. As will be seen, D(i-1) will always be known whenever the processing rate is used; so we will continue to write the relevant processing rate in the abbreviated form r*(i).

J.4 INTUITIVE DERIVATION OF THE ALGORITHM

The expression for the delay suffered by the $i^{\underline{th}}$ plane is, we claim,

$$D(i)=\max\left\{\begin{array}{l}0,\ D(i-1)+E(i-1)-E(i) \\ +r\left[W[D(i-1)]+E(i-1)+c],\ W[E(i)],\ AD[E(i)]\right]\end{array}\right\}. \tag{7}$$

Inspection reveals that the only unknown in this expression is D(i-1). So the logic of the algorithm is as follows. We know D(1)=0 since it is assumed that there is no congestion when the first plane of the day arrives (at three in the morning, perhaps). D(1) is then used to calculate D(2), D(2) is used to calculate D(3), ..., D(i-1) is used to calculate D(i), etc. In this way, the delay for each plane is calculated.

Start by assuming that there is congestion. The time intervals are shown in Figure J-1.

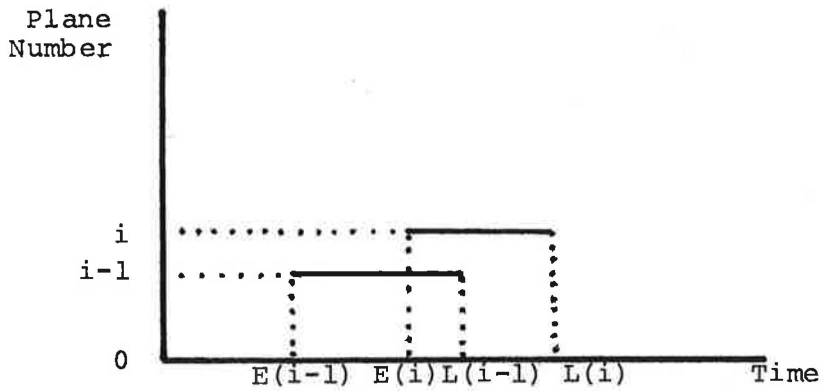

Figure J-1. Aircraft Time Intervals

The i-1st and ith planes are in the system; e.g., the lower line shows that the i-1st plane was in the system from E(i-1) until L(i-1). Now suppose that D(i-1) is known; we will show how one can start with D(i-1), make two adjustments, and end up with D(i).

First, since plane i-1 enters the system before plane i, plane i-1 spends this time waiting but plane i does not. Since this is a portion of delay incurred by plane i-1 but not by plane i, adjust by subtracting this interval E(i)-E(i-1) from D(i-1). After plane i-1 leaves the system, plane i will remain for another r*(i) minutes, so adjust by adding on this interval. In sum, we can now write

$$D(i) = D(i-1) - \left[E(i) - E(i-1)\right] + r^*(i)$$

which we rewrite as

$$D(i) = D(i-1) + E(i-1) - E(i) + r^*(i).$$

This is the correct expression for delay when there is congestion. When there is no congestion, plane i arrives so long after plane i-1 that $E(i-1)-E(i)$ is sufficiently negative to offset $D(i-1)+r^*(i)$. In this case, the expression above is negative, and delay is zero. Hence, equation (7) gives the correct expression for delay.

J.5 MATHEMATICAL DERIVATION OF THE ALGORITHM

The purpose of this section is to prove the following proposition:

<u>THEOREM</u>: $D(i) = \max\left\{0,\ D(i-1) + E(i-1) - E(i) + r^*(i)\right\}$, for $i = 2, 3, \ldots.$

The proof divides into five lemmas. The first lemma proves the intuitively obvious result that the delay is nonnegative.

LEMMA 1: $D(i) \geq 0$.

Proof:

We have

$$\begin{aligned} D(i) &= \max\left\{E(i)+c,\ L(i-1)+r^*(i)\right\} - \left[E(i)+c\right] \\ &\geq E(i)+c - \left[E(i)+c\right] \\ &= 0 \end{aligned}$$

where the first line comes from (3) and the second from the properties of the max operator. Q.E.D.

The next lemma proves that if the time plane i would leave the system were there no congestion is greater than or equal to the sum of the time the i-1st plane leaves the system and the processing time, then delay is zero.

LEMMA 2: If $E(i)+c \geq L(i-1)+r^*(i)$,

then $D(i) = 0$

Proof:

Applying the hypothesis to (1) gives

$$L(i) = E(i)+c,$$

Substituting this into (2) then yields

$$D(i) = E(i)+c - \left[E(i)+c\right]$$
$$= 0. \quad \text{Q.E.D.}$$

The next lemma gives an exact expression for delay when the time that plane i would leave the system were there no congestion is less than or equal to the sum of the time the $i\text{-}1^{\underline{st}}$ plane leaves the system and the processing rate.

LEMMA 3: If $E(i)+c\leq L(i-1)+r^*(i)$, then

$$D(i) = D(i-1)+E(i-1)-E(i)+r^*(i)$$

Proof:

(2) gives

$$D(i) = L(i)-\left[E(i)+c\right]$$

and

$$D(i-1) = L(i-1)-\left[E(i-1)+c\right]$$

Subtracting yields

$$D(i)-D(i-1)=L(i)-\left[E(i)+c\right]-L(i-1)+E(i-1)+c. \tag{8}$$

Applying the hypothesis to (1) gives

$$L(i) = L(i-1)+r^*(i).$$

Substituting this into (8), we obtain

$$\begin{aligned} D(i)-D(i-1)&=L(i-1)+r^*(i)-\left[E(i)+c\right]-L(i-1)+E(i-1)+c \\ &= r^*(i)+E(i-1)-E(i) \end{aligned}$$

which rearranges to the desired expression. Q.E.D.

The next lemma shows that if the expression in the conclusion of Lemma 3 is negative or zero, then delay is zero.

LEMMA 4: If $D(i-1)+E(i-1)-E(i)+r^*(i)\leq 0$,
then $D(i) = 0$.

Proof:

Case I: $L(i-1)+r^*(i)\geq E(i)+c$.

Lemma 3 implies

$$D(i) = D(i-1)+E(i-1)-E(i)+r^*(i)$$

and the hypothesis then implies $D(i)\leq 0$. Lemma 1 then implies $D(i)=0$.

Case II: $L(i-1)+r^*(i)<E(i)+c$. Lemma 2 then implies $D(i)=0$.

Since these two cases exhaust all possibilities and since both imply $D(i)=0$, the proof is completed. Q.E.D.

The next lemma shows that if the expression in the conclusion of Lemma 3 is positive, then delay equals this expression.

LEMMA 5: If $D(i-1)+E(i-1)-E(i)+r^*(i)>0$, then $D(i)=D(i-1)+E(i-1)-E(i)+r^*(i)$.

Proof:

In order to reach a contradiction, assume

$$E(i)+c>L(i-1)+r^*(i). \tag{9}$$

Lemma (2) then implies

$$D(i) = 0 \tag{10}$$

which in turn implies via (2) that

$$L(i) = E(i)+c.$$

Substituting this expression into (8) gives

$$\begin{aligned} D(i)-D(i-1) &= E(i)+c-\left[E(i)+c\right]-L(i-1)+E(i-1)+c \\ &> L(i-1)+r^*(i)-\left[E(i)+c\right]-L(i-1)+E(i-1)+c \\ &= r^*(i)+E(i-1)-E(i) \end{aligned}$$

where the inequality is justified by (9). Rearranging this last expression gives $D(i)>D(i-1)+E(i-1)-E(i)+r^*(i)$

which is positive by hypothesis. This implies $D(i)>0$, which contradicts (10). Therefore, we must reject assumption (9) and conclude that

$$E(i+c) \leq L(i-1)+r^*(i).$$

Lemma 3 now gives the desired result. Q.E.D.

The theorem stated at the beginning of this section is an immediate implication of the last two lemmas. This completes the mathematical proof of the validity of the proposed algorithm.

J.6 CONCLUSIONS

Five concluding remarks are necessary. First, the new algorithm in this appendix does not offer any significant gain in accuracy over the old algorithm in the preceding appendix. The difference in accuracy lies in the definition of delay. The new algorithm defines delay as the difference between when a plane actually left the system and when it would have left had there been no congestion; the old defines delay as the difference between when a plane actually was placed on the runway and when it would have been placed had there been no congestion. The difference between these two definitions amounts to the difference between the processing time when the plane requested service and the processing time when it landed. This difference will usually be zero; when not zero, it will still be only about 10 or 15 seconds. Moreover, the old algorithm could be rewritten to obtain the same delay as the new. Therefore, accuracy is not an important issue in comparing the two algorithms.

Second, the new algorithm is based on a more plausible vision of how the airside system operates; e.g., more than one plane can be simultaneously processed. However, this point should not receive much weight since the actual delay calculations do not differ significantly.

Third, the new algorithm is easier to understand. To see this, compare Figure D-1, which is used to explain the old algorithm, with Figure J-1, which is used to explain the new algorithm. Figure D-1 is a page full of blocks and arrows, whereas Figure J-1 is a simple graph with two horizontal lines. Moreover, the idea behind the new algorithm can be quickly and intuitively explained (as it was in Section J.4).

Fourth, the new algorithm is computationally more efficient. It is expressed in a single mathematical statement. The root reason for the greater efficiency is that knowing the delay for one plane often tells much about the delay for the next plane, and the new algorithm fully utilizes this information.

Fifth, note that the expression D(i-1)+E(i-1)+c that occurs inside the full expression for the relevant processing rate is equal to L(i-1), the time the i-1st plane left the system. Since the time each plane entered the system is known, it is therefore easy to calculate the length of the queue at particular times.