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THE AIRPORT NETWORK FLOW SIMULATOR

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16. Abstract

The Airport Network Flow Simulator is a FORTRAN IV simulation of the flow of air traffic in the nation's 600 commerical airports. It calculates for any group of selected airports (a) the landing and take-off (Type A) delays, and (b) the gate departure latenesses (Type B delays) at the selected airports and at all other airports to which these delays propagate by means of scheduled commercial flights. The airports are selected by the user who must input hourly aircraft processing rates for each airport selected. The cost in lost passenger time and aircraft operating expense is also calculated.

A validation process was applied to the simulator, using field data gathered from two air carriers, a large U.S. trunk line carrier and a local service carrier. Results are also reported for sensitivity analysis of the simulated B-delay to slack in gate departure schedules.

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PREFACE

The Airport Network Flow Simulator (ANFS) described in this report is a computer simulation of the propagation of delays through the network of U.S. commercial airports. It was developed for the Federal Aviation Administration, Office of Aviation System Plans, to help it assess the benefits of investments in airport capacity made under the 1976 Amendments to the Airport and Airway Development Act (P.L. 94-353). The outputs of the ANFS, along with that of the Airport Performance Model,(1) a single-airport simulation, will be employed to produce an airport investment handbook for the use of the FAA and of airport managers.

The simulator here described is the outgrowth of previous efforts(2) carried out by the Transportation Systems Center for the Office of Aviation System Plans. The data for validation of the ANFS were gathered and interpreted by Simat, Helliesen and Eichner, Inc. Newton Centre, MA, under contract DOT-TSC-1184.

The validation data were analyzed by Dr. Joseph A. Tanne of Kentron International, Inc., who also devised the linkage algorithm and constructed the Demand Data file of Section 2.1 of this report.

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(1) Hiatt, D., S. Gordon, and J. Oiesen, "The Airport Performance Model," Report No. FAA-ASP-75-5, U.S. Department of Transportation, Transportation Systems Center, Cambridge, MA, April 1976.

(2) Gordon, S., "The Airport Network Flow Simulator," Report No. FAA-ASP-75-6, U.S. Department of Transportation, Transportation Systems Center, Cambridge, MA, May 1976.

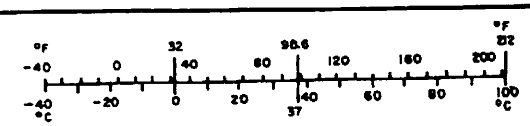
METRIC CONVERSION FACTORS

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



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1. INTRODUCTION

The scheduled air transportation network in the United States comprises over 600 airports and more then 5,000 aircraft. These aircraft make about 20,000 flight legs in a typical day of scheduled service, or an average of about four flight legs per vehicle per day. As a result, the country's commercial airports are interrelated by the flow of traffic. Congestion at one airport will affect other airports to which flights are destined from the congested airport. At least two effects may be distinguished:

(1) Modification of arrival demand at the down-line airports. If flights are delayed in taking off at a congested airport, they may arrive late at their destination, thereby shifting the demand for landing service at the destination airport.

(2) Gate departure delays at the congested and down-line airports. If arrival delays are great enough at a congested airport, the vehicle will be unable to meet its scheduled gate departure time at that airport and, possibly, at succeeding airports in its intinerary.

The first of these effects will modify the demands made upon the down-line ATC terminal facilities as a function of time. The consequent peaking or/and smoothing of the arrival demand profile is of primary interest to the Local and Central Flow Control facilities in the ATC System.

The second of these effects is the major subject of this report. The purpose of the Airport Network Flow Simulator (ANFS) is to model (1) the effect of airport capacity on take-off and landing delays and, (2) the subsequent propagation of those delays as departure latenesses through the air transportation network. The simulation is expected to be of use in evaluating the economic benefits of airport capacity improvement because reducing delays at a major airport can be expected to reduce gate departure delays at downline airports, with consequent saving in passenger waiting time. Preliminary field data, discussed in Appendix A and in the section on validation, suggest that gate departure delays (in aircraft-minutes) can be more than one third of the system-wide take-off and landing delays on an eventful winter day. The corresponding economic losses may reach 25% of the take-off and landing delays. These data indicate, therefore, that a complete benefit/cost analysis of airport capacity improvement should take into account the gate departure latenesses caused by landing and take-off delays. This is what is what done in the ANFS.

A third network effect of airport congestion is that of increased slack time in air carrier schedules. In general, slack ground time built into the arrival and departure schedules of an aircraft will absorb arrival lateness, if any, and prevent it from becoming gate departure lateness. Since ground slack time is unproductive aircraft time it is an index of fleet utilization efficiency, and is therefore related to fleet size. Although ground slack time often serves purposes of scheduling other than delay absorption, the trade-off between ground slack time and network delay is still of interest. For this reason the ANFS allows the user to adjust the ground slack time of all aircraft in the commercial fleet and to calculate the corresponding network delays.

A fourth network effect, not computed by the ANFS, is that of gate arrival latenesses and their effect on missed passenger connections. This is not computed in the ANFS because of the uncertainties in modelling passenger connection times. (They vary from airport to airport, and little data are available.) Another difficulty is that of establishing the cost of missed connections. Nevertheless, it may be possible to incorporate a crude gate arrival lateness economic model into subsequent versions of the ANFS.

1.1 TERMINOLOGY

In order to facilitate discussion an abbreviated terminology will be used throughout this report.(*)

Delays in aircraft operations such as in landing, take-off, turn around and enroute flight will be referred to as A-type delays. Latenesses in meeting arrival and departure schedules will be termed B-type delays. B-delays are a measure of schedule conformity. Our major interest in this report is in landing and take off types of A-delay, and in the consequent gate departure lateness at originating and down-line stations, which are forms of B-delay.

1.2 SCOPE OF THE AIRPORT NETWORK FLOW SIMULATOR

Although the majority of landing and take-off delays are believed** to occur at fewer than ten major airports, little is known about the geographic distribution of the resultant B-delays. In order to explore this distribution, and in order to encompass the entire B-delay effect, the ANFS has been structured to include all airports in the contiguous 48 states receiving commercial service in February 1976, plus selected airports in Canada, Hawaii, Alaska, and Puerto Rico. A total of 665 airports is included in the data base (See Section 2.1). The traffic data base is all scheduled commercial traffic at these airports for a single day, Feb. 16, 1976. This day was selected for validation purposes, but the data base may be regenerated for other days.

Military, general aviation, and non-scheduled commercial flights are not incorporated into the traffic data base, but their effect on runway availability for scheduled flights is allowed for.

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*The terminology here introduced is a slight modification of that first employed by Gordon (Reference (1))

**See Reference (2), p 37.

A-delay is calculated by a first-come-first-served, single runway airport model, using hourly processing rates specified by the user. Delay propagation is based on fixed flight times, and ground service times that were derived from an analysis of airline schedules in the data base. The gate servicing queues are not modelled.

The traffic data base on which the simulation is based is described in Section 2. The other input data to the simulation, dealing with capacity and cost, are also described in Section 2.

The simulation itself is described in Section 3 and its output is described in Section 4.

In order to obtain an estimate of the accuracy of the simulation, data were gathered from two trunk lines and one local service carrier. Both the data base and the delay output of the simulator were compared to these field data, and the results are described in Section 5.

The Appendices give a summary of the contractor's analysis of the field data he gathered on B-delays; a set of program listings; and a guide to the use of the ANFS program.

2. INPUT DATA

The input data required by the ANFS is of three types: demand, capacity and cost. By far the most extensive of these is the demand data, since it encompasses all scheduled domestic flights for an entire day. This demand data base is too large to be supplied by the user, and hence is provided as a separate, computer generated disk file. The capacity data, in contrast, is well within the capability and interest of the user to supply. On any given day serious capacity problems occurring at relatively few airports can cause extensive delays throughout the air network. Hence the user has been given the option of specifying the hourly capacity at up to 32 airports of his choice. Finally, the load factors and cost coefficients for passenger time and aircraft operation have been pre-calculated and stored on disk for input to the ANFS. These data are not too extensive to be modified by hand if the user so desires.

The following three sections describe the demand, capacity and cost input data bases.

2.1 DEMAND DATA

Demand is specified in the file ANFS.DAT as a set of scheduled aircraft itineraries. The file also includes a list of airports (3-letter codes) covered by the itineraries and their time zones. The exact form of the demand file is given in Table 2.1. In this file an event is defined as a gate arrival or gate departure. For each such event the last four items LM, TS, TAU, CECODE of Table 2.1 are recorded in the file. All the events scheduled for a single aircraft in a selected day are grouped together in the file, in order of increasing TS, and constitute the itinerary of the aircraft. Itineraries are strung one after another in the file, the total number of events in all itineraries being NEVNTS.

Each itinerary has the same structure. The first event in the itinerary (K odd) is the aircraft's first scheduled gate departure of the day, which starts at 10:00 GMT (5:00 AM EST).

TABLE 2.1 FORM OF THE DEMAND FILES

NAME	DEFINITION	FORMAT	NUMBER OF ITEMS
NAPTS	Number of airports covered	I10	1
APT(J)	3-letter code of J^{th} airport	20A4	J=1, NAPTS
ZONE(J)	Time zone for J^{th} airport	20I4	J=1, NAPTS
NACFT	Number of itineraries	2I10	1
NEVNTS	Number of events		1
LM(K)	Airport number of K^{th} event	I3,3I6	K=1, NEVNTS
TS(K)	Scheduled time of K^{th} event		
TAU(K)	Minimum time between K^{th} and $(K+1)^{th}$ event		
CECODE(K)	Carrier and equipment code for K^{th} event		

It occurs at airport number LM(K) of the APT list. TAU(K) gives the minimum normal interval to the next event, K even, which is gate arrival. This interval includes taxi time from departure gate to runway, takeoff, flight time to arrival runway, and taxi time to arrival gate. (The method of obtaining TAU is described in Section 2.1.3.)

The 5 digit code word CECODE gives the carrier number in its three most significant digits and the equipment type number in its least significant two digits. For gate arrival events (K even) TS, LM and CECODE have the same meanings as for departure for the given equipment type. (Again, Section 2.1.3 describes the method of obtaining TAU.) The itinerary continues with similar event pairs (K odd, K even), until the aircraft's final gate arrival of the day, which is indicated by TAU equal to 43201. Itineraries need not be arranged in any particular order in the file.

As an example, a printout of the first part of the ANFS.DAT file is given in Appendix B.1. This particular file, it will be observed, covers 665 airports, which are all airports in the contiguous 48 states that received scheduled carrier service on February 16, 1976, plus YUL, YYZ, ADQ, ENA, AKN, JNU, FAI, ANC, HNL, SJU, and OUT. The last is a fictitious airport used to represent all airports not on the APT list. It will be seen also that there are 5,402 aircraft itineraries and a total of 38,222 events, representing 19,111 separate flight legs, in the file. Although the ANFS may run on the full ANFS.DAT file of 38,222 events, it is usually more economic to extract only a portion of the file for a particular segment of traffic, as will be described in Section 2.1.4.

The key to the construction of the demand file, and one of the critical factors in simulator accuracy, is the algorithm that links together the separate legs of the Official Airline Guide (OAG)to produce the complete airframe itineraries of ANFS.DAT. This algorithm is a refinement of that of Reference (4). Because of the importance of this algorithm, it is described fully in the next two sections.

2.1.1 The Linkage Algorithm

In order to trace individual aircraft through a day's journey, an algorithm for linking incoming flights at a given airport with outgoing flights based on a first in-first out approach was employed. The basic assumption is that each airline would attempt to minimize the maximum ground time for its fleet of aircraft so that an outgoing flight at a given airport would utilize the previously arrived aircraft which had been on the ground longer than any other incoming aircraft of the same type available for the outgoing flight.

The actual linkage of incoming flights with outgoing flights at a given airport utilized OAG flight schedule data and was accomplished as follows: first, a listing of all incoming flights on a given day for a given airline and aircraft type at a given airport was constructed, the flights being listed in order of arrival time. This list was then compared with a corresponding list of all flights departing the given airport for the airline on that day with the same scheduled aircraft type, the flights in this list having been arranged in order of departure time. Inasmuch as Greenwich Mean Time (GMT) was used for the arrival and departure times, the times were arbitrarily ordered from 10:00 GMT to 9:59 GMT to cover a 24 hour time period commencing at 5:00 A.M. (local time) in New York.

All shuttle flights (indicated by a non-numeric character in the last digit of the flight number) were then deleted from the lists and the corresponding flight segments were considered to be unlinked flight legs at the given airport. Then all incoming and outgoing flight pairs with the same flight number were deleted from the lists and linked as long as the departure time for a given flight did not precede the arrival time for the incoming flight with the same flight number within the indicated 24 hour period.

Now the arrival and departure times for the remaining flights in the lists were compared. It was assumed that a given incoming aircraft, departing on a flight leg having a different flight number than the incoming flight, would spend at least 30 minutes on the ground. Thus, a minimum ground time adjustment factor of 30 minutes (40 minutes for DC10, L1011 and 747 type aircraft) was added to the arrival time of each incoming flight before the actual comparison of arrival and departure times. Starting with the first arrival time (i.e., the first arrival time after 10:00 GMT), the arrival times were compared in a one-to-one fashion with corresponding departure times until the end of the arrival list was reached, or until a departure-arrival time pair was found with the departure time preceding the arrival time or until the end of the departure list was reached.

If the end of the arrival time list was reached, with each arrival time preceding its corresponding departure time, then the given correspondence between arriving and departing flights was clearly on a first in first out basis, minimizing the maximum ground time for the given aircraft fleet, and the flights were linked as indicated.

If, however, a given departure time preceded its corresponding arrival time, then the arrival time was compared with succeeding departure times until a departure time was found which did not precede the arrival time. The given departure time was then put in correspondence with that arrival time and the next arrival time in the list was compared with the next departure time and the one-to-one correspondence was continued as long as each departure time did not precede its corresponding arrival time. This correspondence procedure was terminated when the end of either the arrival or departure time list was reached.

If the end of the departure time list was reached, and the last departure time preceded the arrival time it was being compared with, the given arrival time was made to correspond with the first departure time (implying a linkage of the arriving aircraft with a flight departing on the succeeding day).

The actual arrival-departure linkages were then constructed by starting with the last arrival-departure correspondence for which the arrival time succeeded the first departure time it was compared with (or for which the end of the departure list was reached and an arrival time was corresponded with the first departure time) and linking the incoming and outgoing flight legs in a one-to-one fashion. When the end of either list was encountered, the next flight leg was the first flight in the list. This procedure was continued until all the flights in either list were accounted for. If the lists were unequal in length (more incoming or outgoing flights), the remaining flight legs in the longer list were considered to be unlinked flight stages.

Thus, the linkage of incoming and outgoing flights by a comparison of arrival and departure times is basically a two-stage process. In the first stage a starting arrival flight and corresponding departure flight are determined. In the second stage the actual linkages are constructed by proceeding in a one to one matching of succeeding arrival and departure flights, cycling back to the beginning of a list when the last element is reached, and terminating the process when all the elements in the shorter list have been accounted for. In addition, inasmuch as it was desired to trace a given aircraft for only one day's itinerary, all linkages which would link an incoming flight to one departing on the next day (i.e., during the next 24 hour time period starting at 10:00 GMT) were not used, the corresponding incoming and outgoing flight stages being considered as unlinked at the given airport.

To illustrate the above procedure suppose we had the following flights for some airline arriving and departing an airport with a given aircraft type on a given day:

Flight #	Arr. Time	Dept. Time	Flight #
0050	10:20	10:30	0050
005*	11:00	12:00	0053
0054	11:20	12:30	0055
0055	13:00	14:00	0057
0056	13:20	14:30	006*
0058	16:00	15:00	0059
0060	16:20	16:30	0061

First of all, arriving flight 005* and departing flight 006* (shuttle flights) would be eliminated from their respective lists and these flight stages would be considered unlinked flight segments. Then arriving flight 0050 would be linked with departing flight 0050 and arriving and departing flights numbered 0055 would be eliminated from the above lists and considered as unlinked flight legs since the departure time precedes the arrival time. The remaining flight segments are now:

Flight #	Arr. Time	Dept. Time	Flight #
0054	11:20	12:00	0053
0056	13:20	14:00	0057
0058	16:00	15:00	0059
0060	16:20	16:30	0061

Arriving flight 0054 would now be made to correspond with departing flight 0053, flight 0056 with flight 0057, but flight 0058 would not be put in correspondence with flight 0059 since the departure time for flight 0059 precedes the arrival time for flight 0058. Thus, flight 0058 would be compared with the next sequential departing flight and would be paired with flight 0061 since the departure time for flight 0061 does not precede the arrival time for flight 0058. Since the end of the departure list has now been reached flight 0060 is joined with flight 0053 and the flight stages are linked in a one-to-one sequential fashion starting with the flight 0060 to 0053 linkage, resulting in the following set of linkages.

Arr. Flight #	Dept. Flight #
0060	0053
0054	0057
0056	0059
0058	0061

Inasmuch as the first linkage of flight 0060 to flight 0053 implies a linkage of an arriving flight with one departing on the following day, this linkage is deleted from the final list of linked segments and these flight legs are considered as unlinked segments.

2.1.2 The Original Linkage Algorithm

The flight leg linkage algorithm described in the preceding discussion is a modified version of an algorithm documented on pages 7-9 of Ref. (4). The original algorithm did not omit shuttle flights from the linking prodedure and assumed that the number of arriving flights was equal to the number of departing flights. If there were more arriving or departing flights, the excess flights at the end of the longer list were deleted before the linkage procedure was initiated. In addition, the original algorithm did not delete linkages between arriving flights and flights departing on the next day.

The present algorithm was developed from the original one by a series of refinements, as described. Because of the importance of the linkage procedure to simulator accuracy, the effect of each refinement was checked against actual airframe linkages, with the results reported in Section 5.

2.1.3 Construction of the Complete Demand File ANFS.DAT

Given the individual linkages of flight legs, as obtained by the linkage algorithm, construction of the complete demand file ANFS.DAT was relatively straightforward.

First, complete itineraries were extracted by locating a departure flight leg that was not paired with any incoming flight leg at the airport. It was then traced to its destination airport where the outgoing leg to which it was linked (if any) was added to the itinerary. This process continued until no outgoing leg was available. The itinerary thus formed was removed from consideration and the process repeated until all flight legs had been placed in itineraries.

The completed itineraries were then put into the form described in Table 2.1. All the airports were numbered arbitrarily from 1 through NAPTS, thus providing the LM values for the itineraries. The TS values were taken directly from the itinerary data, in seconds GMT.

The TAU values, however, were the result of a search process. The TAU value for a gate departure is intended to be the undelayed time from the gate departure to the following event, gate arrival at the end of the leg. The "undelayed" time varies with route chosen, takeoff runway, takeoff weight (which affects takeoff time), ascent time, and flight time, aircraft type and power setting, head/tail winds, approach route and taxi routing at both origin and destination airports. The scheduled block times given in the OAG allow for all these factors, on average, plus an average traffic delay expected on the given flight based on the airline's previous experience. Therefore OAG block times cannot be taken to be undelayed times. However, late night and early morning flights, for example, probably have little or no traffic delay built into their OAG shedules. It was assumed, therefore, that among all scheduled flights by a given aircraft type between two airports, at least one OAG block time is an "undelayed" time. This undelayed time would necessarily be the minimum of all similar times, and was searched out and entered as the TAU value for all flights by the given aircraft type between the two airports. The same process was employed to determine the gate turn-around time at an airport for a given aircraft type, which was entered as the TAU value for gate arrival events of the appropriate aircraft type and airport (except for the last TAU of each itinerary, which was coded as 43201, as described previously).

The carrier/equipment code, finally, was taken from the OAG information for the flight legs of the itinerary. The 2-letter carrier code was replaced by an assigned three digit number, multiplied by 100, and added to a two-digit number assigned to the aircraft type, the result being the five-digit CECODE entered with each event. Although the same carrier/equipment code applies to all events in an itinerary, it was entered repeatedly for each event in order to reduce simulation run time. The three-digit carrier code and two-digit equipment codes correspond to positions in the carrier list and equipment list in Appendix B-3, Cost Data Program.

2.1.4 Extraction of the Demand File

The complete demand file ANFS.DAT fills over 150,000 36-bit words. In many applications one is concerned with the effect of only one airport on the rest of the system. Therefore only itineraries that contain that one airport need be retained in the data base. Accordingly, a short program was constructed to extract from ANFS.DAT only itineraries involving a single airport, which the user specifies. The resultant file(s), FLIGHT.DAT, are in exactly the same format as described above for the full demand file, but are substantially smaller. For example, the file resulting when only ORD related traffic is extracted is about 21% of the full demand file. The extracted airport is the first one in the new APT and zone lists.

2.2 CAPACITY DATA

The airport capacity data, although available on disk, can be made up and entered via cards by the user. A sample input is shown in Appendix B-2. These data must be in the format of Table 2.2. The first card image contains four parameters needed to control the simulation and printout. The use of these control parameters is more conveniently discussed in Section 3. following. The next cards come in pairs, one pair being required for each airport the user wishes to specify, plus one pair for the airport ALL, which controls all airports in the demand data base not specified on the preceding cards. The user may input data for up to 32 airports, or for no airports at all, but must always provide for airport ALL at the end of the data set.

For each airport he selects, the user provides, on the first card, the airport three-letter code and the runway service interval, in seconds, for 24 hours commencing at 00:00 hour, local time, and ending at the 23:00 hour, local time. The runway service time is defined as the minimum allowable number of seconds between operations at the airport and is equal to 3600 divided by the airport processing rate in operations/hr. Although this minimum varies with aircraft type, arrival/departure mix, and other factors, the ANFS can accomodate only a single number for any given hour. Hence the user must select the number carefully so as to

TABLE 2.2 FORM OF CAPACITY DATA

Parameter Card (I8,10I6)

EXPFAC	Traffic expansion factor (percent)
PLEVEL	Printout delay level (aircraft-minutes)
MAXGT	Maximum ground turn-around time (min)
KSLACK	Ground time slack parameter (min)

For each of up to 32 airports, plus the airport "ALL"

CARD 1. (1X, A4, 24I3)

APT	Airport 3-letter code
SIG(I)	Runway service interval by local hour I, I = 1, 24 (seconds)

CARD 2. (1X, I4, 24I3)

KGA	Non-scheduled traffic as percent of all traffic
GFAC(I)	Percent of non-scheduled traffic occurring in local hour I, I = 1, 24

be representative of the hour's aircraft type mix, arrival/departure ratio, and runway configuration(s).

On the second card for each airport the user provides the ratio of non-scheduled traffic to all traffic for the day, in percent, followed by the breakdown of non-scheduled traffic throughout the hours 00:00 -23:00 local time. This breakdown must be expressed as the percentage of the day's total non-scheduled traffic that occurs in each of the 24 hours. (As a check, the 24 hourly percentages should add to 100.)

For each airport specified, including all those covered under airport ALL, the ANFS will calculate the landing delays, take off delays, and gate departure delays (B-delays) by GMT hour. It will also calculate the B-delays at all airports, as well as the costs of passenger time and aircraft operating time for all delays. If the user is interested in the effect of capacity at only a few airports he should input the data for those airports, followed by the cards for airport ALL with 0 seconds service time in each hour. The program will then calculate the landing, take-off and B-delays at the specified airports, plus the B-delays produced in the rest of the system by the specified airports.

2.3 COST DATA

The cost coefficients and subsidiary data used by the simulator were generated by the FORTRAN program listed in Appendix B-3. The data stored in that program came from various sources, which will now be described.

The value of passenger time, PCOST, was taken to be $12.50/hr, in conformity with general usage established by the Federal Aviation Administration.

Aircraft operating costs are of two types: take-off costs (TCOST) and landing costs (LCOST). Take-off costs are the fuel, crew and maintenance costs per hour incurred while waiting to take off after having left the gate. Landing costs are the same items with an adjustment for higher fuel consumption incurred during landing delays. TCOST and LCOST are given as a function of aircraft type in Table 2.3, which was extracted from Appendix B.3. This Table also shows the 3-letter aircraft type designator AC3LC, which corresponds to those used in the Dec 1976 OAG. Types 1 through 57 are non-jet, types 60 through 85 are jets. The costs were based on the size/engine/body information, ACSEB, shown in the third column of the Table, which were assigned to each aircraft type. The three characters in the ACSEB code have the following interpretation:

FIRST LETTER

- H: heavy aircraft, 300,000 lbs or more maximum gross take-off weight (GTOW)
- L: large aircraft, less than 300,000 lbs but more than 12,500 lbs (GTOW)
- S: small aircraft, 12,500 lbs or less (GTOW)
- O: other

SECOND CHARACTER: Number of engines

THIRD LETTER:

- S: standard width body (jet)
- W: wide body (jet)
- P: piston engines
- T: turbo prop engines
- H: helicopter

Having determined the size/engine/body code, the operating costs of Tables 2.4 and 2.5 were extracted from CAB Service Segment Data, (Reference (5)), from an FAA study (Reference (6)) and from an EPA study (Reference (7)). Costs for helicopters are entered as zero, because they are not usually affected by air traffic delays. It is noticed that costs while waiting to take-off (TCOST) are less than those while waiting to land (LCOST) because of different engine settings.

Passenger load data (LOAD and LOADØ) are employed to calculate passenger waiting costs. Passenger load variations by (1) aircraft type, (2) airport, and (3) time of day were obtained from

TABLE 2.3 EQUIPMENT TYPES AND OPERATING COSTS

	AC3LC(1)	ACSEB(2)	TCOST(3)	LCOST(4)
1	ACD	S2T	$80.63/hr.	$96.76/hr.
2	A24	L2T	339.89	385.27
3	A50	S2P	39.67	47.60
4	BBR	S2P	39.67	47.60
5	BNI	S2P	39.67	47.60
6	BNT	S3P	52.83	63.40
7	BTP	S2T	80.63	96.76
8	B18	S2P	39.67	47.60
9	B80	S2T	80.63	96.76
10	B99	S2T	80.63	96.76
11	CES	S1P	13.17	15.81
12	CVR	L2T	339.89	385.27
13	CV2	L2P	260.29	294.13
14	CV4	L2P	260.29	294.13
15	CV5	L2T	339.89	385.27
16	CV6	L2T	339.89	385.27
17	C46	L2P	260.29	294.13
18	DC3	L2P	260.29	294.13
19	DC6	L4P	711.83	784.23
20	DDV	S2P	39.67	47.60
21	DHC	L2P	260.29	294.13
22	DTO	S2T	80.63	96.76
23	FH7	L2T	339.89	385.27
24	F27	L2T	339.89	385.27
25	GGM	S1P	13.17	15.81
26	GGS	S2P	39.67	47.60
27	HRN	L4T	929.52	1027.24
28	LEC	L4T	929.52	1027.24
29	MR4	L2T	339.89	385.27
30	MU2	S2T	80.63	96.76
31	N26	L2T	339.89	385.27
32	PAZ	S2P	39.67	47.60

TABLE 2.3 EQUIPMENT TYPES AND OPERATING COSTS (continued)

	AC3LC (1)	ACSEB (2)	TCOST (3)	LCOST (4)
33	PCB	S2T	80.63	96.76
34	PCH	S1P	13.17	15.81
35	PDS	L4P	711.83	784.23
36	PHP	L2T	339.89	385.27
37	PNV	S2P	39.67	47.60
38	PPS	S2P	39.67	47.60
39	PRP	L2P	260.29	294.13
40	PR4	S2P	39.67	47.60
41	SKV	S2T	80.63	96.76
42	ST2	L2T	339.89	385.27
43	SWM	S2T	80.63	96.76
44	S55	O1H	0.00	0.00
45	S61	O1H	0.00	0.00
46	TB8	S2P	39.67	47.60
47	TS4	S2T	80.63	96.76
48	Y11	L2T	339.89	385.27
49	Y14	L4P	711.83	764.23
50	Y18	L4T	929.52	1027.24
51	402	S2T	80.63	96.76
52	47J	O1H	0.00	0.00
53	601	S2P	39.67	47.60
54	748	L2T	339.89	385.27
55	DHO	S1P	13.17	15.81
56	M20	S1P	13.17	15.81
57	TRK	S1P	13.17	15.81
60	A3B	H2W	494.67	678.00
61	B11	L2S	393.93	500.62
62	B3J	H4S	566.29	807.04
63	DC8	H4S	566.29	807.04
64	DC9	L2S	393.93	500.62
65	D10	H3W	691.27	1075.00
66	D8S	H4S	566.29	807.04

TABLE 2.3 EQUIPMENT TYPES AND OPERATING COSTS (continued)

	AC3LC[1]	ACSEB[2]	TCOST[3]	LCOST[4]
67	D9S	L2S	393.93	500.62
68	D95	L2S	393.93	500.62
69	F82	L2S	393.93	500.62
70	L10	H3W	691.27	1075.00
71	511	L2S	392.93	500.62
72	V10	L4S	544.95	750.00
73	707	H4S	566.29	807.04
74	72S	L3S	469.44	625.00
75	720	L4S	544.95	750.00
76	727	L3S	469.44	625.00
77	735	L2S	393.93	500.62
78	737	L2S	393.93	500.62
79	74L	H4W	887.:87	1472.03
80	747	H4W	887.87	1472.03
81	880	L4S	544.95	750.00
82	990	L4S	544.95	750.00
83	462	H4S	566.29	807.04
84	486	H4W	887.87	1472.03
85	LJT	L2S	393.93	500.62

NOTES (1) AC3LC = Aircraft three-letter code designator
(2) ACSEB = Aircraft size/engine/body code (see text)
(3) T COST = Aircraft operating cost, waiting to take-off
(4) L COST = Aircraft operating cost, waiting to land

TABLE 2.4 AIRCRAFT OPERATING COSTS/HOUR

ACSEB (1)	L COST (2)	T.COST (3)	L/T FUEL RATIO (4)	NOTE
H4W	1472.	888.	.287	(5)
H3W	1075.	691.	.287	(5)
H2W	678.	494.	-	(7)
H4S	807.	566.	.327	(5)
L4S	750.	545.	-	(7)
L3S	625.	469.	.412	(5)
L2S	500.	394.	.415	(5)
L4T	1027.	930.	.500	(6)
L4P	784.	712.	-	(7)
L2T	385.	340.	.500	(6)
L2P	294.	260.	.500	(6)
S2T	97.	81.	.500	(6)
S3P	63.	53.	.500	(6)
S2P	48.	40.	.500	(6)
S1P(4^+)	16.	13.	.500	(6)
S1P(1-3)	11.	9.	.500	(6)

NOTES:

(1) Aircraft size/engine/body code (see p. 2-13 of text.)

(2) Landing operating cost, from Table 2.5, (dollars/hr)

(3) Takeoff operating cost (dollars/hour)

(4) Ratio of fuel consumption rate during takeoff and idle to fuel consumption rate during approach, obtained from Reference (6).

(5) TCOST obtained by applying T/L fuel ratio to fuel and oil and engine maintenance costs of Table 2.5, and adding to other costs of Table 2.5.

(6) TCOST obtained as in Note (5) above, except that a T/L fuel ratio of .5 was assumed. For S type aircraft, the fuel cost component of L COST was assumed to be 1/3 of L COST.

(7) See Note (3) on Table 2.5.

TABLE 2.5 BREAKDOWN OF AIRCRAFT OPERATING COSTS (DOLLARS PER BLOCK HOUR)

	Crew	Fuel And Oil	Maintenance Airframe	Maintenance Engine	Maintenance Burden	Total	Note
H4W	336.	587.	139.	234.	177.	1472.	(1)
H3W	291.	388.	102.	152.	141.	1075.	(1)
H2W	-	-	-	-	-	678.	(3)
H4S	250.	299.	70.	61.	127.	807.	(1)
L4S	-	-	-	-	-	750.	(3)
L3S	219.	218.	55.	46.	86.	625.	(1)
L2S	192.	152.	53.	32.	71.	500.	(1)
L4T	391.	195.	169.	74.	198.	1027.	(1)
L4P	-	-	-	-	-	784.	(4)
L2T	124.	91.	59.	45.	66.	385.	(1)
L2P	97.	68.	38.	41.	51.	294.	(1)
S2T	-	-	-	-	-	97.	(2)
S3P	-	-	-	-	-	63.	(3)
S2P	-	-	-	-	-	48.	(2)
S1P (4+)	-	-	-	-	-	16.	(2)
S1P (1-3)	-	-	-	-	-	11.	(2)
O1H	119.	59.	179.	97.	-	454.	(1)

NOTES:

(1) Reference (4)

(2) Reference (5)

(3) Extrapolated or interpolated from similar types with different number of engines.

(4) Obtained from L4T cost by application of empirical prop/turboprop cost ratio of .76.

Reference (8). The data cover 28 aircraft types, 24 airports and 24 hours, but entries are sparse or missing for many combinations. Only departing loads are available. Moreover, the data are based on a single month's sample at the airports involved: Table 2.6 gives the available data for jets at the 24 airports, averaged over all hours of the day and month. The approximate aircraft seating capacity is also given, (column 3 of the Table). Using the seating capacities a nominal 50% load factor was assumed to derive the passenger loads for aircraft-airport combinations for which no data were available. The complete data base is given in Appendix B-3, where the array LOAD (I,J) gives the load at airport I, numbered as shown in Table 2.6, on aircraft type J. Zeros indicate no data available. The simulator fills in these zeros, as well as the loads for airports not listed, by 50% of the aircraft capacity, LOADØ in the Appendix.

The hourly variation of passenger load at the 24 airports is shown in Appendix B-3 in the array HFACT(I,J), which gives the number of passengers per departing seat at airport I, numbered as shown in Table 2.6, at local hour J, starting at 00.00, normalized to the average number of passengers per seat throughout the day, expressed in percent. For airports not available in Reference (8), the average value of HFACT for MSY, STL, TPA, MSP, SEA, and IAH was taken and stored in HFACT0 in Appendix 3-C. It is believed that the six smaller airports are more representative of the remaining airports in the U.S. than are the other 18 for which data are available.

Since gate departure lateness affects only those passengers that board the aircraft, rather than the total departing load, it is necessary to adjust the load data above by the ratio of boarding to total departing passengers for B-delay calculation. An analysis of the U.S. CAB Service Segment Data for the 2nd Quarter of 1974 yielded a percentage of continuing passengers for 31 airports, as shown in Table 2.7. When the percent continuing passengers is subtracted from 100, the result is the desired ratio of boarding to departing passengers, in percent. For airports not

TABLE 2.6 JET LOADS AT 24 AIRPORTS, MARCH 1974

ACFT #	ACFT TYPE	SEATS AVAIL.	SEATS OCCUPIED					
			1 ORD	2 ATL	3 JFK	4 LGA	5 SFO	6 LAX
60	A3B	251						
61	B11	74	37		30	48		
62	B3J	144	73	42	65		76	79
63	DC8	146	79	91	88		55	62
64	DC9	77	45	46		40	51	55
65	D10	242	88	91	99	99	100	89
66	D85	172	89	78	71		81	116
67	D9S	93	57	60	39	84	33	46
68	D95	139						
69	F28	69						
70	L10	243	77	79	107	67	108	89
71	S11	74						
72	V10	135						
73	707	122	76		74		76	76
74	72S	126	69	75	68	78	47	38
75	720	121	86				55	65
76	727	97	63	65	71	64	52	60
77	73S	103						
78	737	98	59	42	49	59	36	47
79	74L	305						
80	747	348	108	102	142		156	125
81	880	90	76				82	
82	990	109						
83	Y62	186						
84	Y86	234						
85	LJT	8						

TABLE 2.6 JET LOADS AT 24 AIRPORTS, MARCH 1974 (continued)

ACFT #	SEATS OCCUPIED 7 DEN	8 PHL	9 EWR	10 MIA	12 DCA	13 PIT	14 BOS	15 CLE
60								
61		43	42		41	45	45	47
62	79	46	95	18		60	56	
63	75	91	75	64			80	72
64	39	50	50	62	37	46	47	49
65	69	67	101	73		49	118	81
66	77	95	89	33		46	80	62
67	39	53	64	57	70	52	61	60
68								
69								
70		76	84	81		52	73	
71								
72								
73	71	66	83			55	84	70
74	52	69	63	57	66	46	71	51
75	69			56				
76	62	52	64	61	70	51	61	57
77	46							
78	47	57	57		49	45	77	58
79								
80				118		75	89	99
81	66		73			39	76	
82								
83								
84								
85								

TABLE 2.6 JET LOADS AT 24 AIRPORTS, MARCH 1974 (concluded)

	SEATS OCCUPIED									
ACFT	16	17	20	32	22	23	24	-	29	-
#	DTW	MSY	STL	DFW	TPA	MSP	SEA	IND	IAH	MEM
60										
61	40		51					29		
62	40		45	66	40	47	30	47	100	24
63	76	65		74	55		62		41	30
64		27	38	42		30	27	45	75	92
65	84	61		85	80	57	55		76	31
66	98	62		93	46		52		50	44
67	46	48	44	45	52	42	34	41		
68										
69										
70	69	54	81	95	44			95	68	
71										
72										
73	72		65	62				58	38	46
74	62	56	57	57	51	54	43	48	50	44
75						56	64		45	
76	70	51	59	52	49	43	45	47	57	50
77			41	35						
78	70					46	30			26
79										
80	111			117	93	83	90		146	
81			72							
82										
83										
84										
85										

TABLE 2.7 PERCENT CONTINUING PASSENGERS AT MAJOR AIRPORTS

AIRPORT		PERCENT CONTINUING
1	ORD	4
2	ATL	4
3	JFK	3
4	LGA	2
5	SFO	4
6	LAX	7
7	DEN	8
8	PHL	9
9	EWR	3
10	MIA	2
12	DCA	6
13	PIT	12
14	BOS	4
15	CLE	8
16	DTW	7
17	MSY	12
18	LAS	9
19	HNL	5
20	STL	11
21	FLL	3
22	TPA	14
23	MSP	5
24	SEA	8
25	BAL	13
26	CLT	13
27	MKE	17
28	SLC	10
29	IAH	11
30	IAD	15
31	JAX	18
32	DFW	10

Source: U.S. CAB Service Segment Data, 2nd Quarter, 1974.

shown in the table, it was assumed that the continuing passengers were 20% of total passengers. The complete data set of percent boarding is given in Appendix B-3, under the arrays BOARD and BOARDO.

Finally, it will be seen that Appendix B-3 also lists the carrier 2-letter codes under six categories:

STK: Scheduled Trunklines
SLS: Scheduled Local Service, plus New England Airlines.
SIS: Scheduled Intra-State carriers
SIF: Scheduled International, Territorial and Foreign Flag Carriers
SCT: Scheduled Commuter/Taxi Carriers
SHO: Scheduled Helicopter and Other

3. MODELS

The ANFS is a calculation of landing, takeoff, and B-type delays from the demand and capacity data described in the previous section. The models here presented are simply the rules followed in the caluclations. Once the delays are calculated, they are converted to dollars using the input cost coefficients. The rules for the cost calculation are also described in this section. A full listing of the ANFS is given in Appendix B-4.

3.1 TIME

The calculation starts at 10:00 GMT and ends 27 hours later, thus spanning the active flying period from 5:00 AM EST to 3:00 AM HST. The start and stop times are independent of user input, and have been selected so as to insure zero length queues at the start and stop of the calculation. It will be noticed that the stop time 3:00 AM HST (Honolulu) is 8:00 AM EST (New York) of the following day. The demand data base, however, does not include the next day's traffic, so that no new traffic will be introduced in New York after 5:00 AM EST. This confines the delay calculation to a single day's traffic.

In order to avoid the cost of floating point arithmetic, all internal calculations are done in integer seconds. This procedure was found to provide adequate resolution except when a precise value of operations per hour must be achieved by selection of the service interval. A one percent resolution error in service interval produces a one percent error in operations rate, so that for a typical single-runway rate of 60/hr, the resolution error is approximately $\pm$ 0.8%. At a rate of 120/hr, the error is approximately $\pm$ 1.6%. These small capacity errors, however, can correspond to substantial percent errors in delay, a problem that was solved in the validation procedure (Section 5) by interpolating both input and output between runs.

It should be noted that OAG schedules are given in hours and minutes, so that they appear internally in the ANFS as multiples of 60 seconds. The start time (10:00 AM GMT) is expressed internally as 36000 seconds, and the end time (1:00 PM the next day, GMT) is expressed as 133200 seconds.

3.2 SERVICE INTERVAL COMPUTATION

As described in Section 2.2, for each airport of interest the user inputs the airport identifier and a sequence of 24 hourly service intervals, in seconds. This is followed by the percent of all traffic that is non-scheduled, and its distribution, in percent, throughout the 24 hours. These data may be given for up to 32 airports, the remaining airports in the data base being specified under a single fictitious airport ALL.

The service interval input by the user is the average minimum separation time for all aircraft types, both scheduled and non-scheduled. Since the demand data and delay calculation are restricted to scheduled operations only, the simulator converts the input service interval to the equivalent service interval for scheduled operations, as follows: The relations

$$P_T(h) = 1/\sigma_T(h)$$

$$P_T(h) = P_S(h) + P_N(h)$$

$$= 1/\sigma_S(h) + 1/\sigma_N(h)$$

serve to define the processing rates $P_S(h)$, $P_N(h)$, $P_T(h)$ and service intervals $\sigma_S(h)$, $\sigma_N(h)$, $\sigma_T(h)$ for the scheduled, non-scheduled and total traffic components in hour h. The user inputs $\sigma_T(h)$ and the program must calculate $\sigma_S(h)$. The major assumption is that processing rates $P_S(h)$ and $P_N(h)$ are proportional to the hourly demands $V_S(h)$ and $V_N(h)$, i.e.,

$$\frac{P_S(h)}{P_S(h) + P_N(h)} = \frac{V_S(h)}{V_S(h) + V_N(h)}$$

and

$$\frac{P_N(h)}{P_S(h) + P_N(h)} = \frac{V_N(h)}{V_S(h) + V_N(h)}$$

This assumption is equivalent to assuming that the scheduled and non-scheduled demands are both random in time, and that they are served first-come-first-served (FCFS). The value of $V_S(h)$ is obtained from the demand file and its sum over h=1,2,...,24 gives $\bar{V}_S$, the total scheduled demand for the day. Then the program calculates $V_N(h)$ as

$$V_N(h) = \frac{\gamma(h)}{100} * \frac{KGA * \bar{V}_S}{100 - KGA}$$

where KGA and $\gamma(h)$ are the values of the non-scheduled traffic fraction and its distribution throughout the day that were input on the second card of each airport, as described in Section 2. From these, the simulator calculates the desired service interval for scheduled traffic, $\sigma_S(h)$:

$$\sigma_S(h) = \sigma_T(h)\left[1 + \frac{\gamma(h)\ (KGA)(\bar{V}_S)}{V_S(h)\ 100\ (100-KGA)}\right]$$

It was found in practice that the above formula occasionally resulted in excessively long service intervals for scheduled flights. Accordingly, the scheduled service interval was limited in the ANFS to be no greater than the interval for non-scheduled flights.

In the case of airport ALL an additional assumption is made: the ratio of non-scheduled traffic to total traffic is constant throughout the day at the input value KGA/100. This gives

$$\sigma_S(h) = \sigma_T(h)/(1 - \frac{KGA}{100})$$

for all airports not explicitly entered under their three-letter code. It should be noted that this additional assumption applies only to the calculation of service interval, and does not apply to the scheduled demand employed in the simulator for airports under ALL. This scheduled demand for airports under ALL is taken from the OAG for the day and the airport, via the demand file.

3.3 RUNWAY EVENT COMPUTATION

Having calculated the minimum allowable time $\sigma_s(h)$ between completed runway operations for scheduled aircraft, the simulator proceeds to calculate runway events at all airports.

It will be recalled from Section 2. that the demand file contains scheduled <u>gate</u> departures and arrivals, rather than runway operations, the differences being from two to 15 minutes of taxi time, depending on airport layout, runway in use, and type of aircraft. In order to avoid detailed adjustments for these factors, the simulator uses the scheduled gate times as scheduled take-off and landing times. The normal taxi times, therefore, are lumped with flight times, and are taken into account in the minimum normal flight times.

In the description that follows the terms "scheduled departure," "scheduled arrival," and "event", without the word gate, will refer to <u>runway</u> operations as represented by gate arrivals and gate departures in the demand file.

As a first step, the simulator extracts from the itineraries of the demand file all scheduled departures and arrivals at a single airport, and examines them in time order. If any two events are scheduled at less than the minimum runway service interval (for the hour in which the first is scheduled), it reschedules the second event to satisfy the minimum service interval requirement. It then proceeds to the next event at the airport and separates it from the previous, if necessary, by the minimum service interval. This prodecure is carried out for events scheduled within a limited time interval at the airport, and repeated for events at the next airport within the same time interval. When all airports have been adjusted, the time interval is advanced its own duration and the process repeated for all airports.

The reason for use of a time interval has to do with the propagation of delays. When an event in an itinerary is rescheduled (i.e., delayed), the subsequent events for that aircraft may be affected. Specifically, if a departure is delayed, the associated landing may have to be delayed so that the minimum normal flight time is satisfied. Similarly, adjustment of the landing time may require adjustment of the subsequent takeoff time, if any, so that the gate turn-around time is satisfied. The simulator makes all required future schedule adjustments for an aircraft when it reschedules a takeoff or landing event for that vehicle. It is important that none of these future event adjustments affect the events previously rescheduled at other airports. Hence the event calculation at any one airport is restricted to an interval smaller than the shortest TAU in the file, i.e., shorter than the shortest flight or turn-around time in the demand file. Therefore, the propagation of delays from that event calculation will not affect events at other airports within or prior to the interval.

In the initial stages of developing the ANFS it was estimated that the shortest such interval was 5 to 10 minutes. It soon was discovered that gate turn-around times of less than five minutes were occasionally scheduled on some commuter airlines, and, in fact, zero and negative values were found to occur at airports such as Dulles International, because of their mobile lounges. At the expense of some realism, all itineraries were adjusted to have no TAU less than ten minutes, and this value was adopted for the time interval of computation at each airport before passing to the next airport.

3.4 DELAY COMPUTATION

When the computation interval has been advanced to the end time of the simulation, all runway events will have been recalculated to what may be termed their actual times. The simulator then compares these actual times with the original demand file schedules to determine delays by airport.

Landing Delay This is the difference between the actual arrival time and the "ready-to-land" time. The latter is the actual take-off time at the previous airport plus the minimum normal flight time. It will be recalled that the actual take-off and landing times are represented by rescheduled gate times, which is compensated for by the flight times, into which the taxi times have been lumped. The result is representative of the air delay on landing.

Take-off Delay It is assumed that the aircraft actually leaves its gate at a time determined by adding the gate turn-around time to the actual gate arrival time (the latter having been calculated as landing time in the simulator), but not earlier than the scheduled gate departure in the demand file. The actual take-off time was also calculated in the simulation. Subtracting actual gate time from actual take-off time gives take-off delay.

B-Delay This is calculated as actual time of gate departure, described above, minus the gate departure time originally scheduled in the demand file.

Total Delays The delays calculated as above for each event are aggregated and stored by hour for the airport. The total of the three types of delay at all airports is also stored by hour.

3.5 COST COMPUTATION

The delays calculated, as above, for each event at an airport are converted to dollar amounts by use of the input cost parameters. (See Section 2.3.)

First, the number of passengers is calculated using the load level stored in LOAD for the aircraft and airport involved, if the airport is one of the 24 for which data are available, or in LOAD0 if it is not one of the 24 airports. The passenger load is then multiplied by the hourly load factor HFACT/100 for the airport and hour, if the airport is one of the 24 for which data are available, or by the factor HFACT0/100 for the hour if it is not one of the 24 airports. In either case, the result is an estimate of the number of passengers involved in the delay for the particular airport, aircraft type and local hour.

Landing delay cost is obtained by multiplying the landing delay by the passenger load and PCOST, the value of passenger time, and adding the result to the product of landing delay and the landing operating cost, LCOST, for the appropriate aircraft type.

Take-off delay costs are calculated similar to the landing delay costs, except that the operating costs for takeoff, T COST, are used instead of LCOST.

B-delay costs are obtained by multiplying the boarding passenger load BOARD or BOARDØ by P COST and by the B-delay.

Finally, the total costs of each type (i.e., landing, takeoff an B-delay) for all airports are calculated for each hour.

3.6 CONTROL PARAMETERS

The use of the four control parameters, EXPFAC, PLEVEL, MAXGT and KSLACK will now be discussed.

EXPFAC allows for the expansion of traffic by adjusting the service interval. It is assumed that both scheduled and non-scheduled traffic are to be increased by the fraction EXPFAC/100. The service interval $\sigma_s(h)$ is multiplied by EXPFAC/100, thus allowing for servicing (EXPFAC/100) aircraft for each aircraft in the demand data base. This procedure is much simpler than inserting whole aircraft into the demand data base, thus rearranging all schedules, and it gives reasonable average delays for small traffic expansion levels (say, 10% or EXPFAC/100 = 1.10). The process is most accurate for saturation conditions, and less accurate when the airport is operating below capacity.

PLEVEL is the total level of all types of delay, in aircraft-minutes, that must accumulate at an airport over the day for that airport to be included in the printout. Setting PLEVEL at, say, 20 aircraft-minutes of delay will shorten the print out substantially, but not affect the total system delay or cost, which always are printed out and which always include all airports.

MAXGT is the maximum allowable gate turn around time. It was found that the search process used to derive gate turn-around times (See Section 2.1) occasionally resulted in long turn-around times, because only a few aircraft of the given type were scheduled to pass through the airport. In such cases it is possible that none of the aircraft were scheduled to turn around in minimum time, so that the search yielded excessively long turn-around times. It was found that a limit of MAXGT = 60 minutes was effective in avoiding the problem. It should be noted also that a lower limit on turn-around times is set by the computation interval (See Sec. 3.3).

KSLACK allows the user to increase the gate turn-around time of all aircraft at all airports by an amount of KSLACK minutes. The value KSLACK = 9 has been adopted for the ANFS as a result of the validation tests described in Section 5. In general, however, the gate turn-around time is not allowed to exceed either the amount of ground time actually scheduled for the aircraft, or the amount MAXGT + KSLACK. Because of these limits the reduction observed in the system-wide average of ground slack time is usually less than the increase KSLACK in ground time that is input.

4. OUTPUT

The ANFS output consists of (1) a repetition of the demand and service interval data inputs for the airports specified by the user, (2) the delays for all airports in the data base for which the total delay exceeds the control parameter PLEVEL, and (3) a summary of system-wide delays. A sample output is given in Appendix B-5.

4.1 INPUT DATA

Demand and capacity information are printed out for each airport specified on the capacity input cards (See Section 2.2) including the airport ALL. If the user specifies capacity data for no airport except ALL, only the latter will be printed. If he specifies an airport not in the demand data base, the message "INPUT AIRPORT XXX NOT IN DATA BASE" will be printed out, and the data input for that airport will be ignored. Similarly, the program will ignore airports beyond the first 32 that are identified as being in the data base, as well as any inserted after the airport ALL.

For each input airport the output shows the scheduled and non-scheduled volumes by local hour. The volumes are based on the demand data base and the non-scheduled parameters KGA and GFAC (See Section 2.2). The effect of EXPFAC is not included in the volumes that are printed out.

Following the volumes, the output shows the service intervals by local hour for scheduled and total traffic components, which are the values of $\sigma_S(h)$ and $\sigma_T(h)$, $h = 1,2,...,24$, described in Section 3.2. The service intervals printed out include traffic expansion due to EXPFAC, i.e., they have been multiplied by EXPFAC/100.

At the end of the demand and service interval printout the heading appears: "MEAN GROUND SLACK TIME (minutes)." The number printed out is the average, for all aircraft in the demand data base, of the difference between the scheduled ground time and the minimum gate turn-around time (TAU) stored in the data base, after the latter has been adjusted for MAXGT as described in Section 3.6. Increasing the input parameter KSLACK will reduce the average ground slack time, but not in a one-to-one ratio.

4.2 AIRPORT DELAYS AND COSTS

If the 24-hour total of landing, take off and B-delay for an airport equals or exceeds the number of aircraft-minutes input in the parameter PLEVEL, the program will print out the following for the airport: (See Appendix B-5)

Landing delay by GMT hour, followed by the total landing delay for the day and total cost of landing delays for the day. Delays are in aircraft-minutes, costs are in dollars.

Take off delay and cost, in the same format as landing delays.

A-delay and cost, which is defined as the sum of the landing and take off delays and costs, in the same format.

B-delay and cost, which pertain only to gate departure lateness, in the same format as above.

The airport is identified by its 3-letter code, as given in the OAG, preceded by the internally assigned airport number.

4.3 SYSTEM DELAYS AND COSTS

After the outputs for individual airports, the heading "TOTAL DELAY IN HOURS" is printed, followed by the hourly delays in aircraft-hours for the entire system of airports in the data base. The delays are broken out by landing, takeoff, A-delay and B-delay, with totals for the day shown in the right most column. This is followed by the heading "TOTAL COST IN THOUSANDS OF DOLLARS" and the costs corresponding to the total delays.

5. VALIDATION

The ANFS was validated in two stages, corresponding to the two most critical areas in the modelling process.

First, the linkages produced by the flight schedule generator were compared to airframe itineraries obtained from two trunk line carriers. This process was intended to verify the accuracy of the flight schedule generator of the ANFS.

Second, the B-delays calculated by the ANFS were compared with the B-delays actually experienced by a large trunk line carrier on February 16, 1976. The airport capacity in the ANFS was adjusted to make the actual and the simulated landing delays equal at the selected airport for the carrier. This process was intended to verify the relation between A-delay and B-delay as calculated in the ANFS.

The two stages are described in the next two sections. Appendix A describes more fully the data on which the validation is based, and gives a further analysis of the B-delays experienced by two carriers on selected days.

5.1 VALIDATION OF THE FLIGHT SCHEDULE GENERATOR

As described in Section 2.1, the flight schedule generator links together Official Airline Guide (OAG) flights arriving at a specific airport with flights of the same carrier and equipment type leaving that airport. This is done for all airports in the OAG. The resultant strings of legs, or aircraft itineraries, are intended to resemble the itineraries of real airframes. In order to check the generated itineraries, two types of test were performed: single linkage tests and multiple linkage (i.e., itinerary) tests.

5.1.1 Single Linkage Tests

Airframe itineraries were obtained from a large trunk line carrier for September 3, 1975. The ANFS schedule file (ANFS.DAT) was generated for that day and the flight linkages for the carrier were extracted. They were then compared, on an airport-by-airport basis, with the collected data. Linkages generated between incoming and out going flights that bore the same flight number were considered correct. Those between flights with different flight numbers were counted correct if the two flights were found in the trunk line data and if they did, indeed, belong to the same airframe as indicated in the data.

The results of the tests are given in Table 5.1.1. The rows in the Table correspond to versions produced by successive modifications of the basic algorithm described in Section 2.1. The versions are as follows:

Version #0: Basic Algorithm (See Section 2.1)

Version #1: All shuttle flights (distinguished in the OAG by origin, destination, and flight number) were changed to single-leg flights. Further, all single leg and shuttle flights were excluded from the comparison.

Version #2: Linkages between early arrivals (00:00 to 09:00 GMT) and late departures were eliminated.

Version #3: Linkages were eliminated for which the departure time was less than the arrival time plus thirty minutes (40 minutes for L1011, 747 and DC10). The original algorithm generated such linkages on the assumption that the departures were diurnally cyclic, i.e., repeated on the next day.

Version #4: Linkages of flights with the same flight number that were severed by the previous modification were restored, provided the unadjusted arrival time did not exceed the departure time.

As a result of the above four modifications to the original algorithm, about 94% of the linkages generated were correct (i.e., found to have a counterpart in the data). Approximately 59% of these were linkages between similar flight numbers.

TABLE 5.1.1 RESULTS OF SINGLE LINKAGE TESTS

VERSION	TOTAL LINKS IN TEST	LINKS WITH SAME FLT NO	LINK WITH DIFFERENT FLT NOS RIGHT	LINK WITH DIFFERENT FLT NOS WRONG	% CORRECT (ALL CASES)
0	1219	602	392	225	81.5
1	1150	602	392	156	86.4
2	1091	602	395	94	91.4
3	879	466	350	63	92.8
4	1007	594	350	63	93.7

It should be noted, however, that a complete itinerary has, typically, four or five legs and three or four linkages. If the chance of any single linkage being correct is .94, then one might expect $(.94)^3$ or $(.94)^4$ probability of a complete itinerary being correct. These fractions are .83 and .78 respectively. The tests of correctness for complete itineraries are described next.

5.1.2 Itinerary Tests

A second set of itineraries were obtained from another trunk line carrier for February 16, 1976. These data contained 1,391 flight legs. Once again, an ANFS schedule file was generated for the same day, and all flights of the given carrier were extracted. Some 1,374 flight legs and 321 itineraries were obtained. Each of the 321 itineraries was compared with the field data, starting with the first leg of the itinerary. If a similar leg was found in the data, then the next leg in the field data itinerary was compared with the next leg in the generated itinerary, etc. When a mismatch occurred, or when the end of either itinerary was reached, the comparison was stopped. All generated legs that had been matched successfully with the data were counted as correct, and all remaining legs (if any) in the generated itinerary were counted as incorrect. Proceeding in this way, all itineraries were checked, and the total number of correct legs and itineraries tabulated. (Table 5.1.2)

The interpretation of Table 5.1.2 is as follows: An itinerary was considered totally correct if all its legs were correct (i.e., found, in order, in the field data). It was considered partially correct if some, but not all, of its legs were correct. Finally, it was counted as "incorrect" if none of its legs were considered correct. Because of the rules stated above, an itinerary was considered incorrect if, and only it, its first leg was not found in the field data. This could occur only if the OAG schedule for the first leg had no counterpart whatever in the data.

The percentage of "incorrect" itineraries is about 19%, a rather high discrepancy. It appears that a substantial number

TABLE 5.1.2 RESULTS OF ITINERARY TESTS

NUMBER OF LEGS GENERATED	1374
NUMBER OF ITINERARIES GENERATED	321
NUMBER OF CORRECT LEGS	818
NUMBER OF TOTALLY CORRECT ITINERARIES	130
NUMBER OF PARTIALLY CORRECT ITINERARIES	131
NUMBER OF INCORRECT ITINERARIES	60
NUMBER OF LEGS IN INCORRECT ITINERARIES	206

of flight legs in the OAG did not appear in the data exactly as scheduled, i,e., with the originally scheduled origin, destination, departure time, arrival time and aircraft type. The ANFS schedule generator, of course, can not produce correct linkages employing legs that do not appear in the field data. Hence, the 60 incorrect itineraries should be excluded in determining the accuracy of the flight linkage generator.

When the incorrect itineraries are excluded, the linkage generator accuracy may be estimated as K:

K = (number of correct itineraries)
÷(total number of itineraries, minus incorrect itineraries)
= 130÷(321 - 60)
= 50%

A more accurate measure would allow for the correct legs in the partially correct itineraries as well:

K = (number of correct legs) ÷ (total number of legs, minus legs in incorrect itineraries)
= 818 ÷ (1374 - 206)
= 70%

The latter figure must be considered a lower bound on the number of correctly linked legs. The true figure is probably greater because some of the partially correct itineraries may have contained legs not in the field data at all, as in the case of the initial leg of each incorrect itinerary. On a random basis (i.e., assuming the spurious legs were randomly distributed among the generated itineraries) one would estimate the probability of any one leg being spurious as 60/.321 or .187. Therefore, the probability of an itinerary being totally correct is .437 if it had 4 legs and .355 if it had 5 legs. The likelihood of a partially correct itinerary would be 1.0-.437-.187 =.376 for 4 legs and (1.0-.355-.187) =.458 for 5 legs. Finally, the likelihood of an incorrect itinerary would be .187. These theoretical estimates are compared to the actual fractions of correct, partially correct, and incorrect itineraries in Table 5.1.3.

TABLE 5.1.3 FRACTIONS OF CORRECT, PARTIALLY CORRECT AND INCORRECT ITINERARIES

	THEORETICAL*		
	4-LEG	5-LEG	ACTUAL
TOTALLY CORRECT	.437	.355	.40
PARTIALLY CORRECT	.376	.458	.41
INCORRECT	.187	.187	.19

*BASED ON A RANDOM DISTRIBUTION OF SPURIOUS LEGS, AND A PROBABILITY OF .187 OF A LEG BEING SPURIOUS

Examination of Table 5.1.3 shows that the actual number of itineraries in each category falls between the 4-leg and 5-leg prediction. Since the average number of legs per itinerary was actually 4.28, one concludes that the observed number of partially correct itineraries may (possibly) have been produced solely by spurious legs in the data. For this reason, 70% must be considered a low estimate to the true percentage of correct legs.

5.2 VALIDATION OF THE DELAY SIMULATOR

The data employed for the itinerary tests described above contained, before editing, over 1400 flight legs executed by about 350 aircraft on February 16, 1976. The data for each leg contained the aircraft tail number, flight number, origin and destination airport codes, scheduled gate departure and arrival times, and actual gate departure and arrival times. These data were edited for airports not in the ANFS data base (e.g., ITO, YVR, GUA), for key punching errors, and for miscellaneous inconsistencies (e.g., departure and arrival at same airport). The editing affected fewer than 2% of the flight legs.

The modified data were employed in two ways, shown in Figure 5.2.1. First, the scheduled departure times were used to drive the simulator, which calculated A- and B- type delays. Then the actual departure and arrival times were used to derive A- and B-type delays for comparison with the simulator output. The comparison was made only for the flights of the given trunk line carrier at selected airports. Before making the comparison, the airport capacity in the simulation was adjusted so that the total simulated landing delay equalled the total actual landing delay over the day. The B-delays were compared to give a measure of simulator performance. The process was carried out for three airports: ORD, DEN, SFO.

5.2.1 Calculation of A-Delay From Field Data

The intent of the A-delay calculation was to isolate L, the landing delay on arrival at the airport of interest.

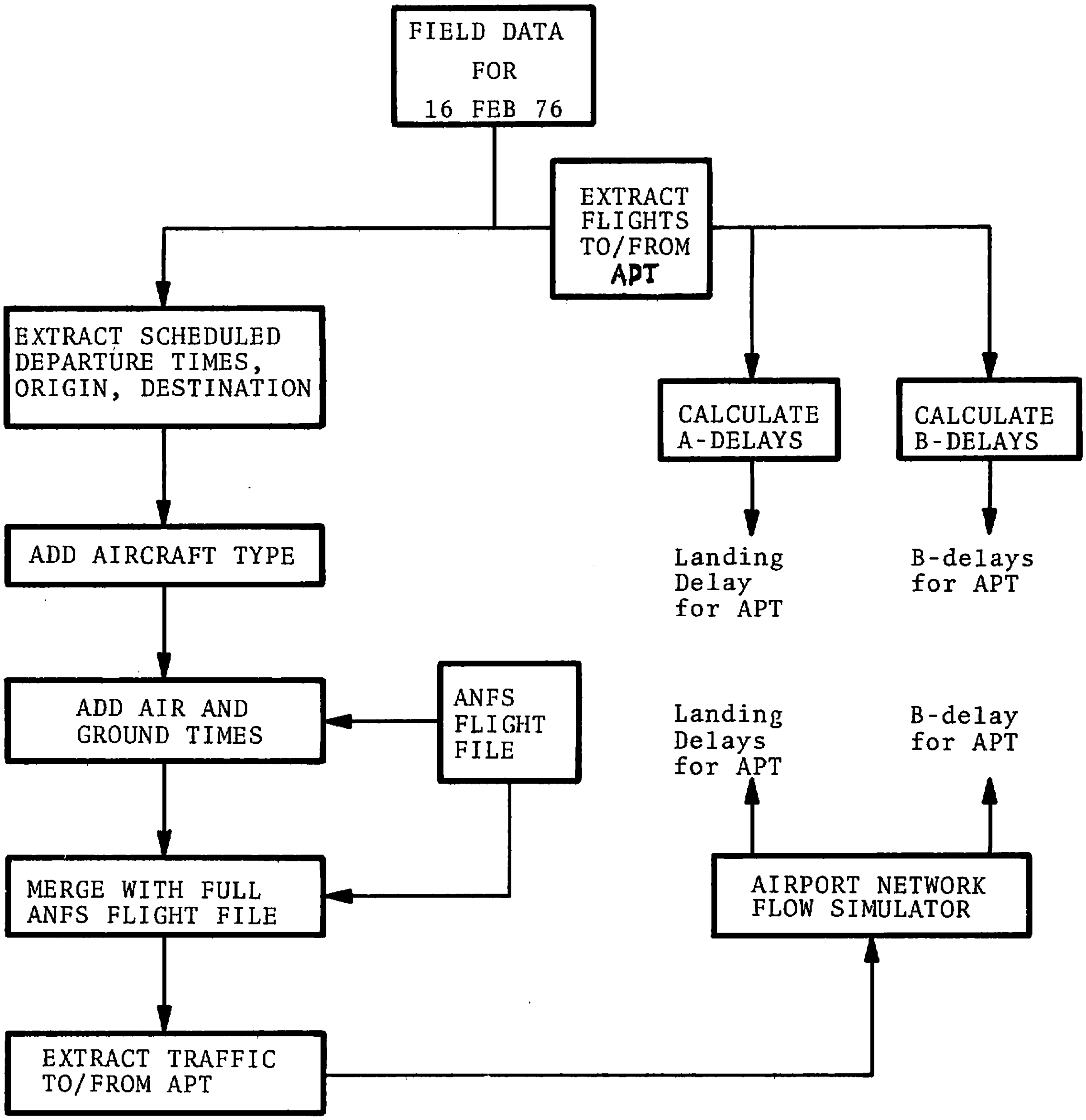


FIGURE 5.2.1 SIMULATOR VALIDATION PROCESS

It was calculated as

L = A -S

A = actual flight time

= (actual gate arrival minus actual gate departure at preceding airport

S = scheduled flight time

= (scheduled gate arrival - scheduled gate departure at preceding airport

When this calculation was made for ORD, several flights appeared to have negative landing delays (See Table 5.2.1). The negative values are possibly due to

(1) Extension of scheduled flight times to allow for delays

(2) Tail winds encountered in flight, or use of a shorter than normal route for departure, arrival or cruise.

On the opposite side of the ledger, the value of L includes delays other than those in landing, such as take-off delays at the preceding airport, enroute delays, and unexpected head winds.

It is not possible, without supplementary data, to distinguish landing delays from the other types included in L. However, a partial correction was made for schedule extension, item (1) above, which tends to make L negative, by using flight times derived from the ANFS flight data base instead of the value of S shown above.

These flight times were obtained by extracting all the scheduled flight times from the Official Airline Guide (OAG) for the test day for each origin/destination pair and aircraft type. The minimum of the scheduled times was selected as the flight time for the origin/destination pair and aircraft type. This was used in place of S in the calculation of L above. The results are shown in Table 5.2.2. It can be seen that the positive delays are increased by about 12% but no change occurs in the negative delays. This would suggest that the negative delays are due to tail winds encountered enroute, but the sample size (six out of 186) is too small to draw any conclusion.

TABLE 5.2.1 A-DELAYS AT ORD CALCULATED FROM FIELD DATA (PRELIMINARY)

GMT HOUR	POSITIVE DELAYS (NO ACFT)	POSITIVE DELAYS (ACFT-MINS)	NEGATIVE DELAYS (NO ACFT)	NEGATIVE DELAYS (ACFT-MINS)
10:	0	0	0	0
11	1	3	0	0
12	1	0	2	-8
13	10	20	3	-16
14	2	0	1	-6
15	18	143	0	0
16	9	24	0	0
17	4	49	0	0
18	17	259	0	0
19	18	178	0	0
20	8	108	0	0
21	9	199	0	0
22	16	270	0	0
23	20	1005	0	0
24	5	124	0	0
25	15	820	0	0
26	18	946	0	0
27	6	299	0	0
28	1	20	0	0
29	2	24	0	0
30	0	0	0	0
	180	4491	6	-30

TABLE 5.2.2 A-DELAYS AT ORD CALCULATED FROM FIELD DATA

GMT HOUR	POSITIVE DELAYS (NO ACFT)	POSITIVE DELAYS (ACFT-MINS)	NEGATIVE DELAYS (NO ACFT)	NEGATIVE DELAYS (ACFT-MINS)
10:	0			
11	1	3	0	0
12	1	0	2	-8
13	10	22	3	-16
14	2	0	1	-6
15	18	149	0	0
16	9	28	0	0
17	4	49	0	0
18	17	279	0	0
19	18	211	0	0
20	8	121	0	0
21	9	212	0	0
22	16	358	0	0
23	20	1121	0	0
24	5	138	0	0
25	15	884	0	0
26	18	1026	0	0
27	6	311	0	0
28	1	20	0	0
29	2	12	0	0
30	0	0	0	0
	180	4944	6	-30

The process of extracting A-delays just described for the ORD data was repeated for the trunk line carrier's flights to SFO and DEN. The results are shown in Tables 5.2.3 and 5.2.4.

5.2.2 Calculation of B-Delay From Field Data

The B-delay employed in validation was taken to be the difference between actual and scheduled gate departure, with the following adjustments:

(1) Flights having no incoming leg to the airport of interest were excluded.

(2) Negative departure lateness (actual gate departure preceding scheduled gate departure) were excluded.

(3) Gate departure lateness at the preceding up-line station were subtracted from gate departure lateness at the airport of interest.

(4) Gate departure times were reduced by the amount that actual ground time exceeded the scheduled ground time, on the assumption that the excess represents aircraft turn-around delay rather than B-delay.

The exclusion in (2) was applied also to delays that were negative after corrections (3) and (4) were made. The results for ORD, SFO and DEN are shown in Table 5.2.5.

The delays shown in the Table may overestimate the actual B-delays on gate departure because they may include delays due to equipment problems or gate availability problems, as well as delays in loading and aircraft checkout. It is not likely that they underestimate B-delays, however, since this would require an error in recording actual or scheduled gate departure, or, perhaps, aircraft maintenance or preparation done at the dock or on the apron after push-back.

TABLE 5.2.3 A-DELAYS AT SFO CALCULATED FROM FIELD DATA

GMT HOUR	POSITIVE DELAYS (NO ACFT)	POSITIVE DELAYS (ACFT-MINS)	NEGATIVE DELAYS (NO ACFT)	NEGATIVE DELAYS (ACFT-MINS)
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	1	0	0	0
15	5	20	0	0
16	3	18	0	0
17	1	11	2	-12
18	5	33	0	0
19	7	52	0	0
20	8	146	0	0
21	4	39	0	0
22	3	35	1	-12
23	5	50	1	-4
24	3	53	0	0
25	11	93	0	0
26	8	103	0	0
27	4	19	1	-4
28	6	42	0	0
29	8	123	0	0
30	7	52	0	0
31	1	4	2	-3
	90	893	7	-35

TABLE 5.2.4 A-DELAYS AT DEN CALCULATED FROM FIELD DATA

GMT HOUR	POSITIVE DELAYS (NO ACFT)	POSITIVE DELAYS (ACFT-MINS)	NEGATIVE DELAYS (NO ACFT)	NEGATIVE DELAYS (ACFT-MINS)
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0	0	0	0
15	1	7	1	-1
16	7	44	1	-1
17	3	18	2	-6
18	8	40	1	-1
19	2	9	0	0
20	9	53	1	-1
21	2	27	1	-5
22	7	26	2	-6
23	0	0	0	0
24	10	66		
25	4	25	1	-5
26	5	37	1	-1
27	5	24	0	0
28	0	0	0	0
29	1	7	0	0
30	0	0	0	0
	64	383	11	-27

TABLE 5.2.5 B-DELAYS AT ORD, SFO AND DEN CALCULATED FROM FIELD DATA

GMT HOUR	ORD		SFO		DEN	
	(NO ACFT)	(ACFT-MINS)	(NO ACFT)	(ACFT-MINS)	(NO ACFT)	(ACFT-MINS)
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	1	19	0	0	0	0
13	5	41	0	0	0	0
14	13	0	0	0	0	0
15	1	0	1	0	0	0
16	18	36	5	1	0	0
17	9	0	3	2	2	0
18	2	8	1	0	7	15
19	16	76	3	10	1	0
20	15	110	6	12	10	6
21	13	159	7	59	3	3
22	7	68	6	2	7	28
23	10	59	3	10	1	6
24	16	602	2	2	11	20
25	9	331	4	24	1	0
26	10	416	8	48	7	18
27	10	327	9	155	5	7
28	4	139	2	0	8	24
29	0	0	4	38	2	12
30	0	0	4	18	0	0
31	0	0	3	2	0	0
	159	2343	71	383	65	133

5.2.3 Calculation of A- and B-Delay by the ANFS

While the field data represents actual flights, the ANFS flight schedule file is based on the OAG schedule for the trunk line on the given day. More over, the field data contains actual airframe itineraries, while the ANFS flight file contains itineraries generated by the linkage algorithm described in Section 1.1. In order to exclude inaccuracies introduced by the flight linkage algorithms, which were evaluated in the preceding Section, the actual aircraft itineraries and departure times for the trunk line carrier were substituted into the ANFS flight schedule file in place of those generated by the linkage algorithm. By this means any discrepancy between actual and simulated B-delays may be attributed primarily to the ANFS ground delay propagation model.

In order to put the actual itinerary into the form of the ANFS flight file, i.e., a series of events, it was necessary to obtain, for each event: (1) airport number, (2) scheduled event time, (3) minimum time to next event, and (4) carrier/equipment type code. This was done as follows:

(1) The field data contained the airport 3-letter identifier, which gave the airport number via a look-up table

(2) The scheduled event time was taken directly from the data

(3) The minimum flight times and ground times were extracted from the ANFS flight file. In the cases where the ANFS flight file contained no minimum ground or air time for the aircraft, the scheduled ground or air times given in the data were used.

(4) The equipment type code was based on the first two digits of the tail number as given in the field data.

The last item, equipment type code, was employed to extract item (3), the minimum flight or ground times, from the ANFS flight file. As described in Section 1.1, the ANFS flight file contains the minimum flight or ground times for the aircraft types and airports of interest. By identifying the aircraft type in the field data it was simple to extract the appropriate flight or ground time from the ANFS flight file itself.

Having substituted the actual itineraries and scheduled times for the trunk line carrier into the ANFS flight file, a final step was taken before running the simulator. This was to extract from the revised flight file all the scheduled itineraries to, from or through the airport of interest. The file thus obtained for the first test airport, ORD, contained about 800 itineraries and 8000 events. The statistics of the extracted files for all three airports are given in Table 5.2.6. (By comparison, the unextracted ANFS flight file has 152,888 words, 5,402 itineraries, 38,222 events, and 665 airports.)

In running the simulator the minimum inter-operation time at the airport was varied from 20 seconds (corresponding to a capacity of 180 operations per hour) to 80 seconds (corresponding to 45 operations per hour); the non-scheduled traffic profiles employed were fixed for all runs and are given in Table 5.2.7. These profiles are based on References (3) and (4). As described in Section 3, the non-scheduled profiles serve to adjust the effective inter-operation time for scheduled flights.

The cost data and cost models were not included in the validation procedure since no field data were taken on operating costs.

5.2.4 Comparison of ANFS Output with Field Data

The output delays of the simulator as a function of the service interval are shown in Figure 5.2.2 for ORD, in Figure 5.2.3 for SFO, and in Figure 5.2.4 for DEN. The vertical axis shows total landing delay and total gate departure lateness (B-delay) for the trunk line carrier when the service interval was constant through out the day at the value shown on the horizontal axis. These plots show the expected sharp increase of delay with service time.

TABLE 5.2.6 STATISTICS OF VALIDATION FLIGHT FILES FOR ORD, SFO AND DEN

AIRPORT ID		ORD	SFO	DEN
File Size (words)	:	31,552	13,992	10,696
Number of Itineraries in File	:	782	381	291
Number of Events in File	:	7,888	3,498	2,674
Number of Airports in File	:	237	142	153

TABLE 5.2.7 NON-SCHEDULED TRAFFIC PROFILES USED FOR VALIDATION RUNS

LOCAL HR	ORD	SFO	DEN
0:00	1%	2%	0%
1	1	1	0
2	1	0	1
3	1	0	1
4	1	1	1
5	1	1	1
6	1	2	1
7	5	4	3
8	6	8	5
9	6	6	8
10	6	5	7
11	5	5	8
12	6	8	6
13	6	6	9
14	6	6	5
15	6	6	6
16	7	3	6
17	7	5	8
18	7	6	10
19	7	7	7
20	6	7	3
21	4	5	2
22	2	3	2
23	1	3	0
	100	100	100
NON-SCHED AS % OF TOTAL	9	13	41

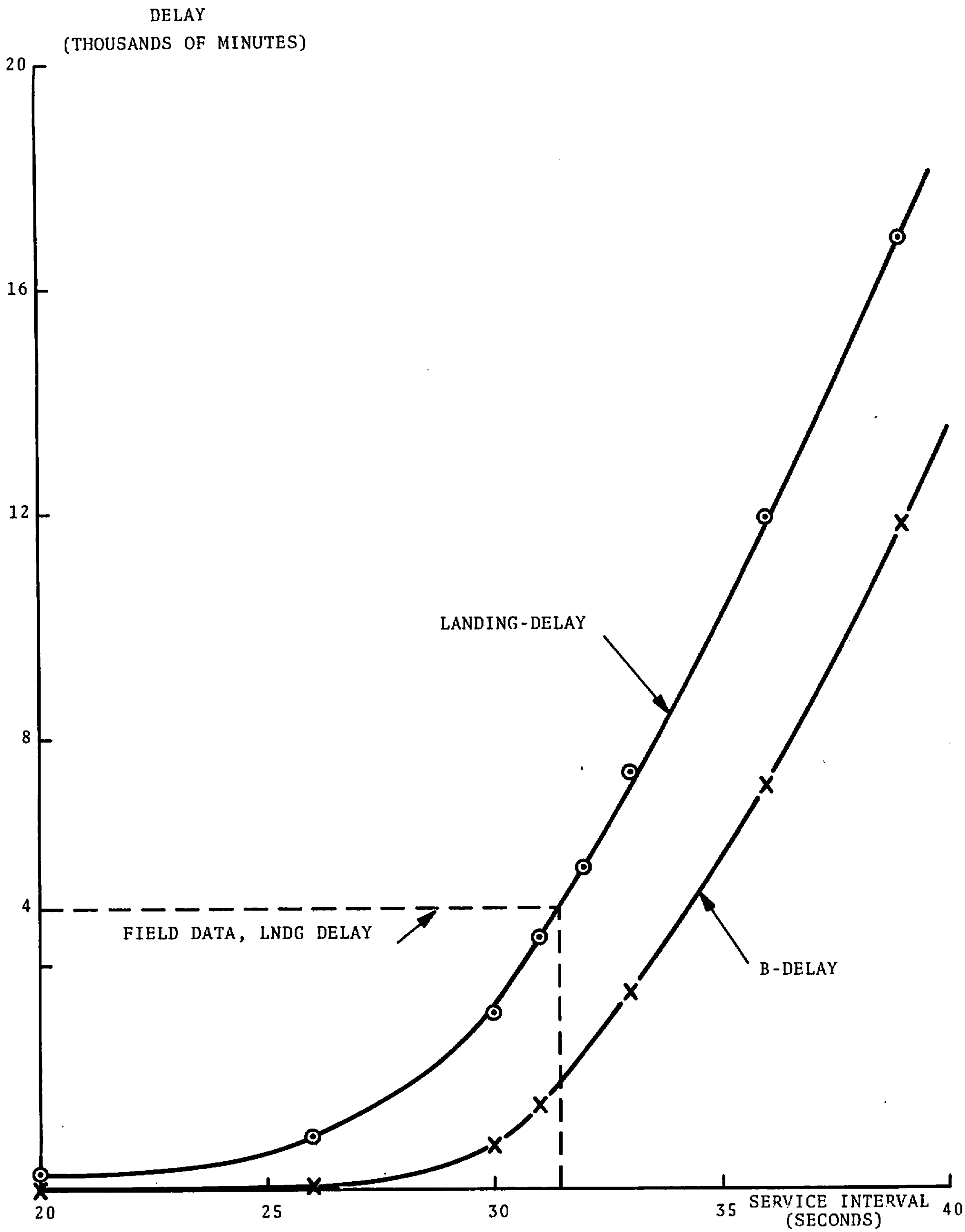


FIGURE 5.2.2 - ORD SIMULATION

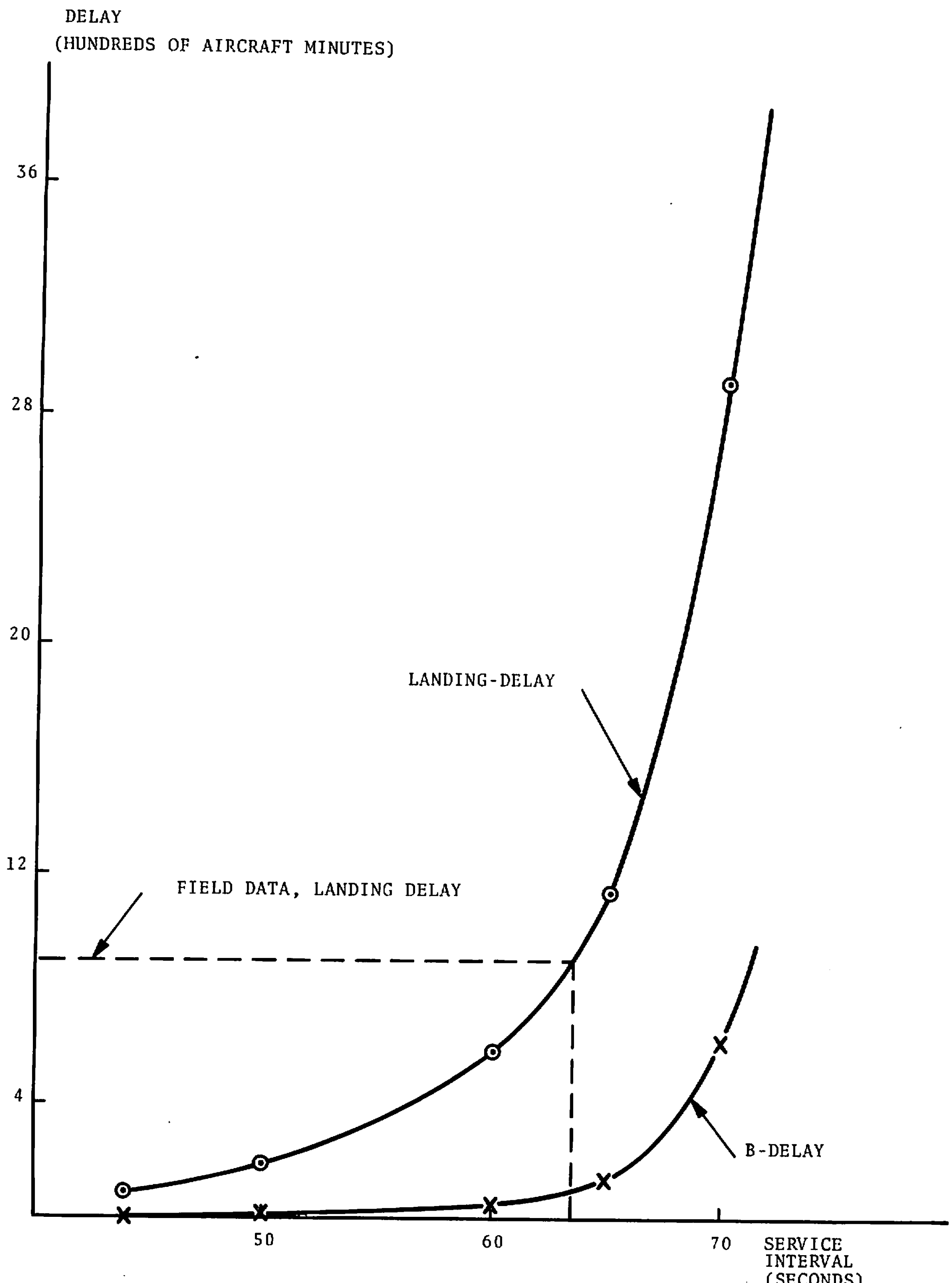


FIGURE 5.2.3 - SFO SIMULATION

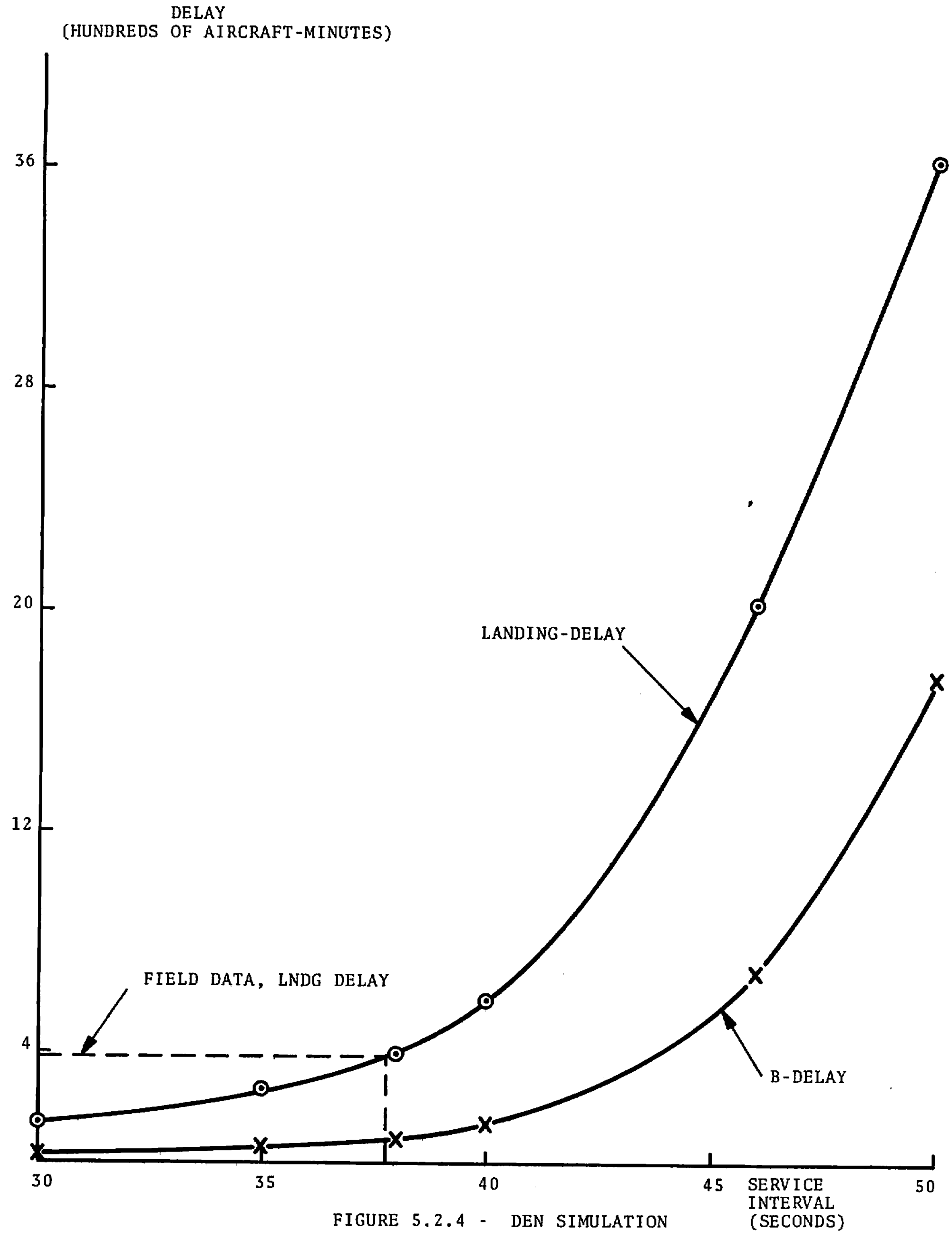


FIGURE 5.2.4 - DEN SIMULATION

By selection of service interval, the total simulated landing delay was made to match the landing delay calculated from the field data and given in Tables 5.2.2 through 5.2.4. For ORD the appropriate value is about 3.15 seconds, for SFO it is 63.6 seconds, and for DEN it is 38.0 seconds, as may be seen in Figures 5.2.2, 5.2.3 and 5.2.4. Table 5.2.8 shows the simulated landing delay and B-delay by hour for the three test airports when the service intervals are set as above.

When the landing delays are plotted as a function of hour along with the landing delays from the field data, the results are as shown in Figure 5.2.5, 5.2.6 and 5.2.7. The match at ORD is better than that at SFO or at DEN. This may be attributed to the larger sample size at ORD, about 180 flights of the trunk line carrier, compared to the other two airports which had 90 and 64 flights. It will also be noticed that the total aircraft-minutes of landing delay at ORD was about 5.7 times that at SFO and 13 times that at DEN.

The ANFS B-delays and the field data for B-delays are plotted in Figures 5.2.8, 5.2.9 and 5.2.10. Good agreement between the simulation and the field data is apparent for ORD. The SFO comparison shows similarity of profile, but the total delay obtained in the simulation is about 30% of that shown in the field data. DEN shows a better agreement between total dealy (65% of field data) that does SFO, but the profile match is poor. Once again it appears that the agreement between simulation and field data improves with the sample size at the airport.

Several explanations are possible for the lower B-delay estimate of the ANFS: (1) The field data may include several anomalous points; 27% of the delay in the SFO field data is due to a single flight. (2) The actual processing rates may not have uniform throughout the day, as was assumed in the ANFS runs; the effect of varying processing rate is probably greater on B-delay than on landing delay. (3) The ANFS ground turn-around times may allow too much ground slack time, which absorbs B-delay.

TABLE 5.2.8 SIMULATED LANDING AND B-DELAYS BY HOUR

GMT HOUR	LANDING DELAY (ACFT-MIN)			B-DELAY (ACFT-MIN)		
	ORD	SFO	DEN	ORD	SFO	DEN
12:00	0	0	0	0	0	0
13	15					
14	12			1		
15	318	13	2	0		
16	89	43	28	71		
17	22	33	15	7		
18	275	30	151	4	3	13
19	310	27	17	75	4	42
20	252	112	40	80	0	5
21	274	60	5	108	26	13
22	436	69	4	137	12	0
23	902	47	0	97	14	0
24	465	6	37	344	0	0
25	569	31	45	185	0	0
26	977	94	37	372	2	6
27	202	105	4	300	20	6
28	25	102	0	68	14	2
29	0	101	0	0	11	0
30	0	13	0	0	5	0
31	0	1	0	0	0	0
ANFS	5095	887	391	1852	111	87
DATA	4944	893	383	2343	383	133

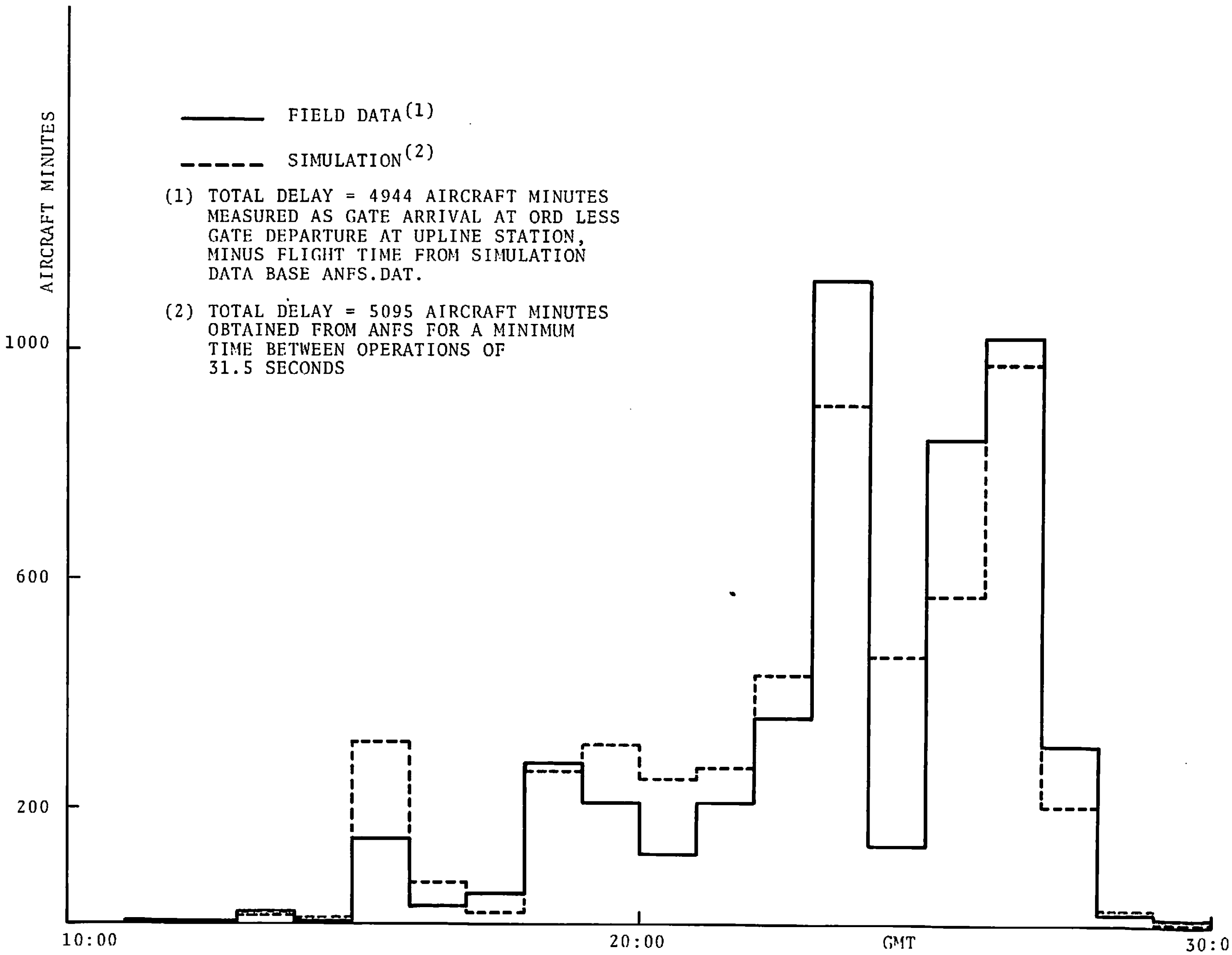


FIGURE 5.2.5 - LANDING DELAY BY HOUR AT ORD - 16 FEB 1976

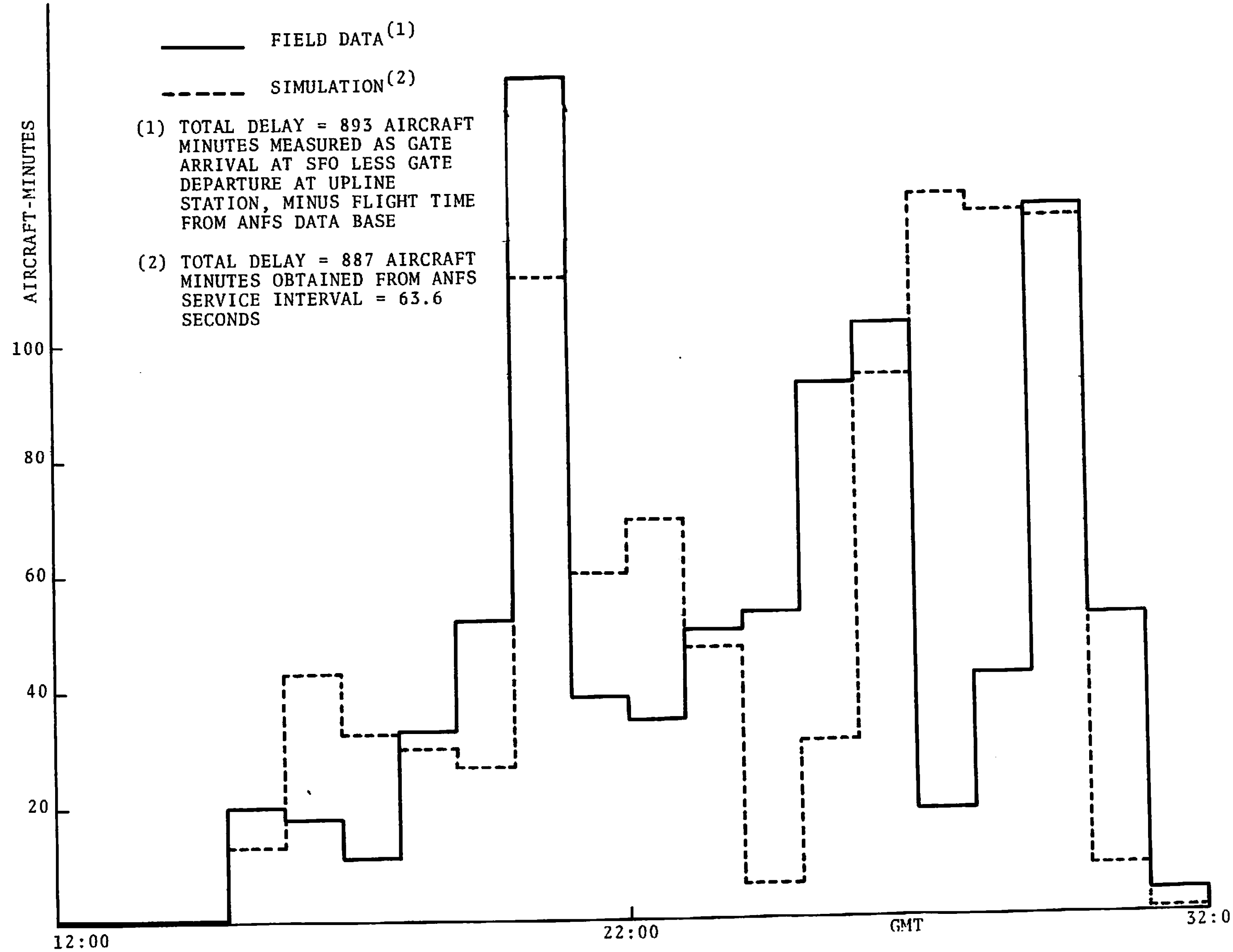


FIGURE 5.2.6 - LANDING DELAY BY HOUR AT SFO - 16 FEB 1976

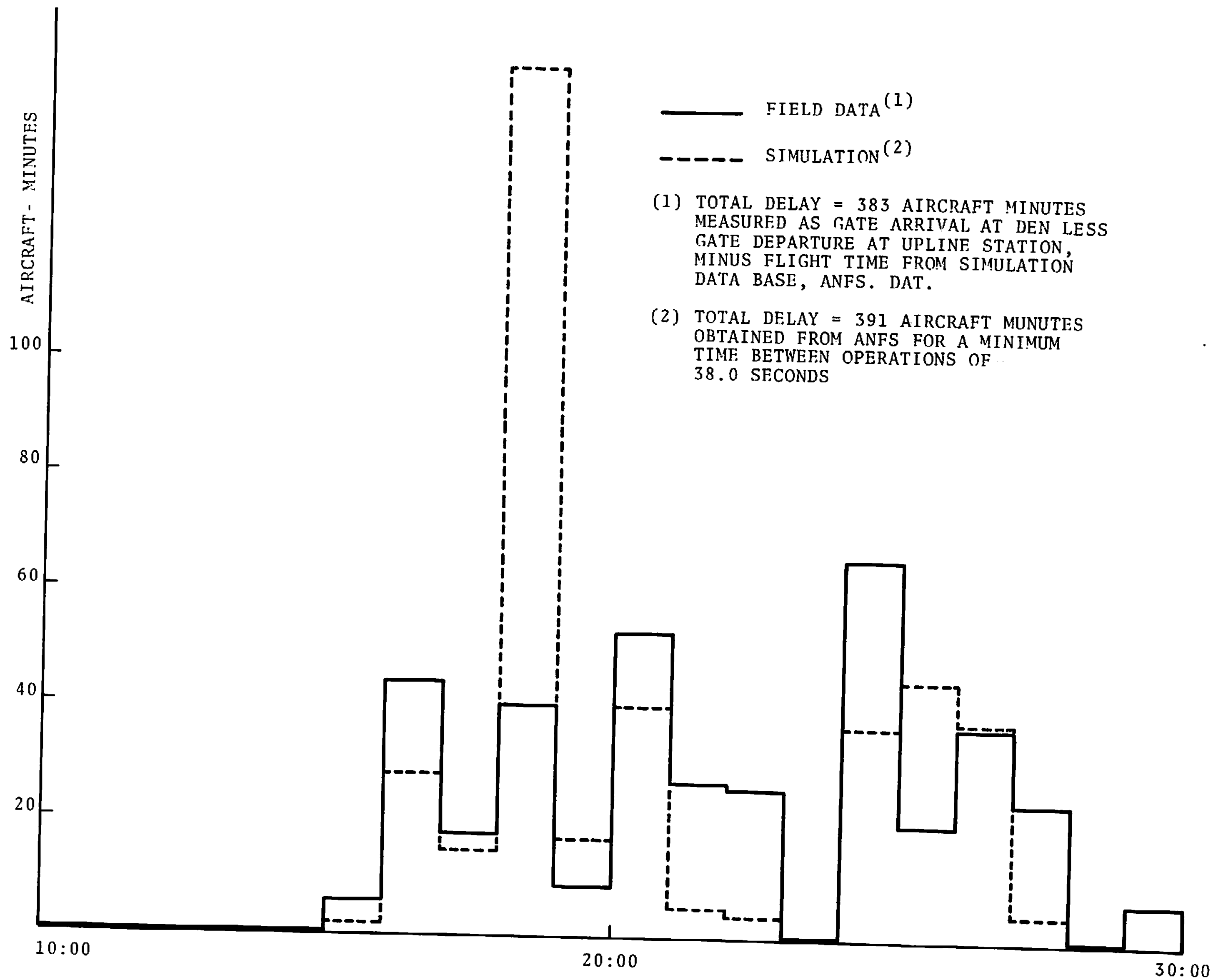


FIGURE 5.2.7 - LANDING DELAY BY HOUR AT DEN - 16 FEB 1976

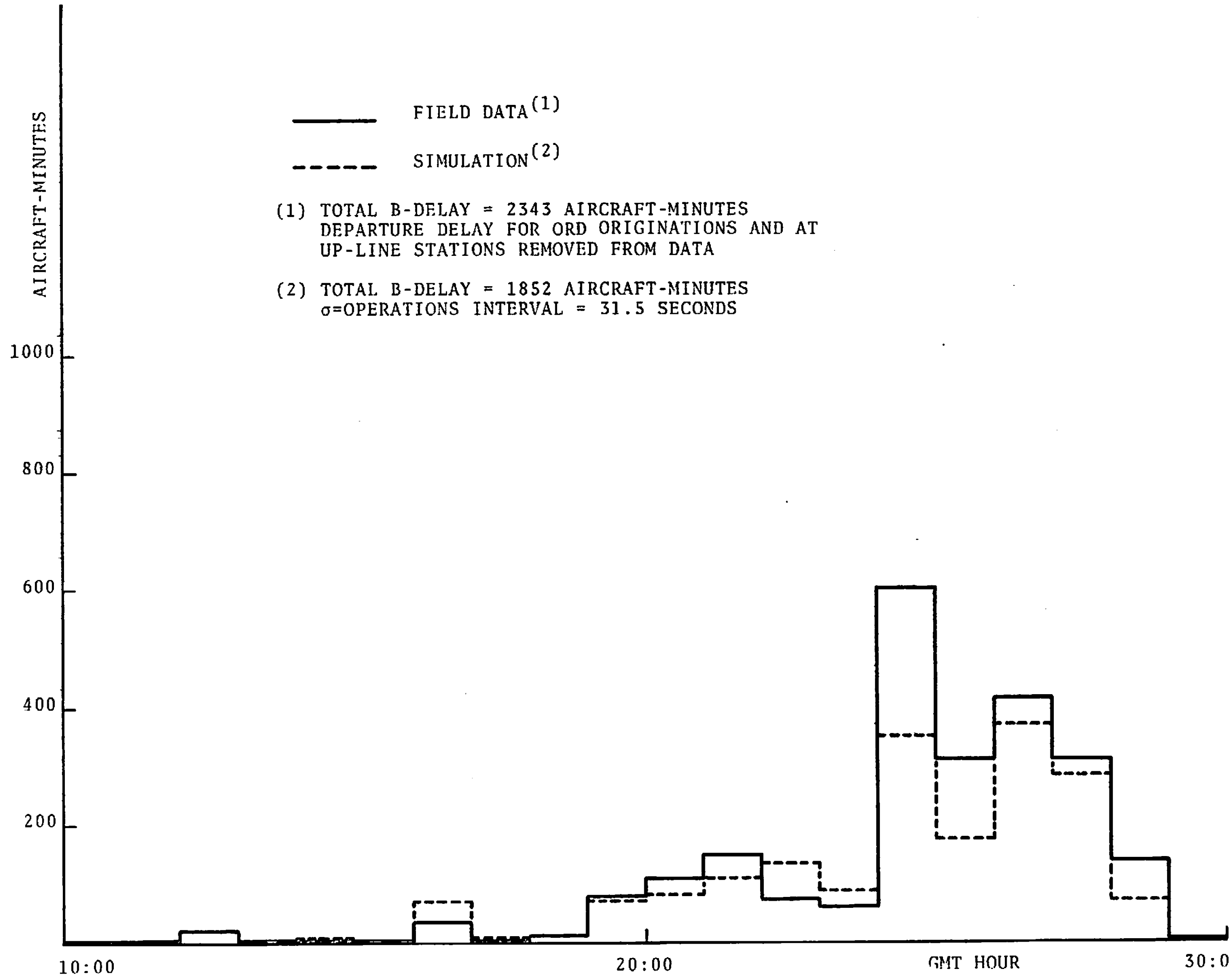


FIGURE 5.2.8 - B-DELAY BY HOUR AT ORD - 16 FEB 1976

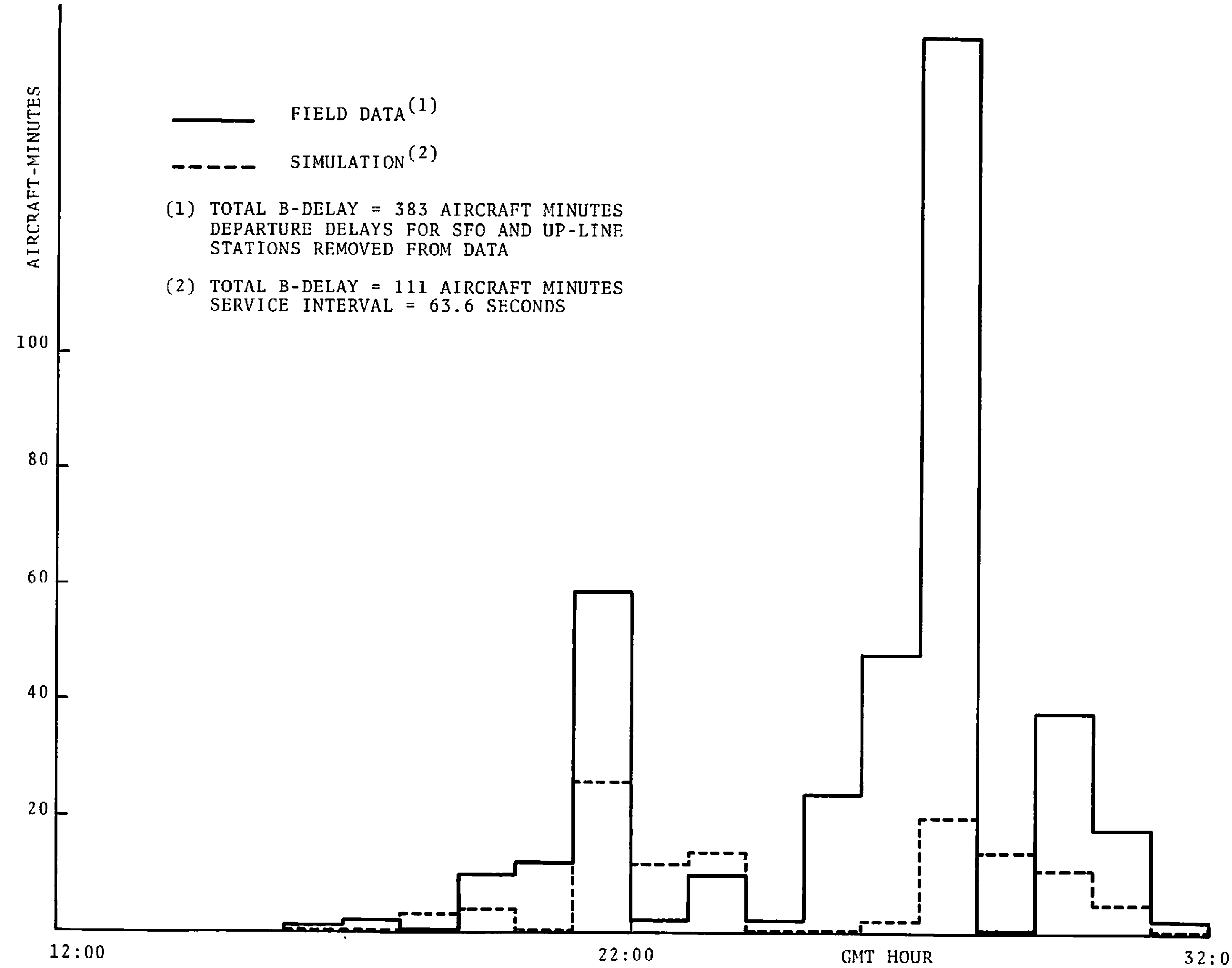


FIGURE 5.2.9 - B-DELAY BY HOUR AT SFO - 16 FEB 1976

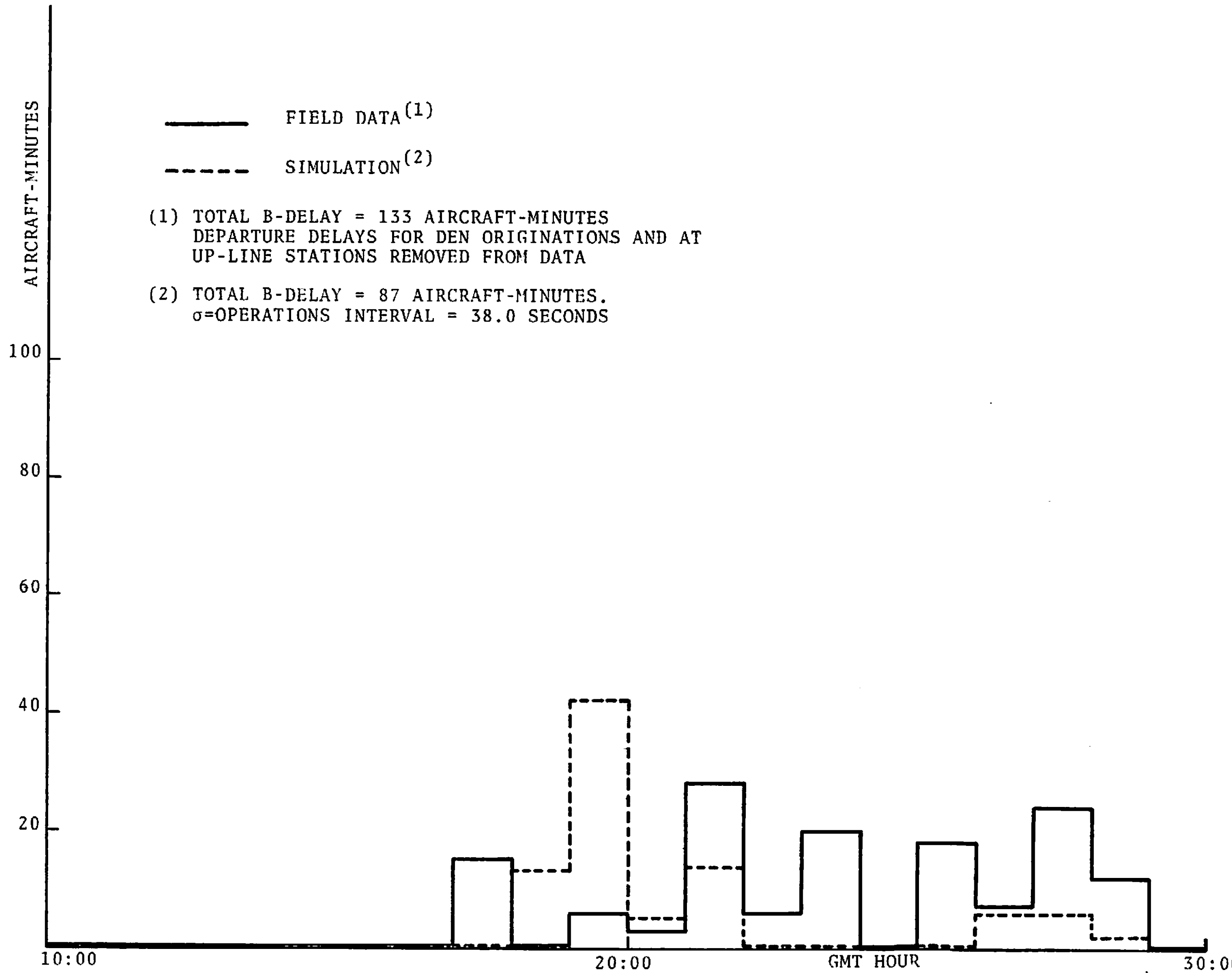


FIGURE 5.2.10 - B-DELAY BY HOUR AT DEN - 16 FEB 1976

5.2.5 Sensitivity of Simulated B-Delay to Gate Slack

The last of these possibilities was investigated. In order to test the sensitivity of simulated B-delay to aircraft turnaround times, the ANFS was run for fixed runway service times, but different gate slack times. Gate slack time is here defined as the difference between scheduled gate time (i.e., scheduled gate departure, minus scheduled gate arrival) and the minimum gate time required to turn around the aircraft. Simulated landing delay and B-delay are plotted vs. mean gate slack time for the three airports in Figures 5.2.11, 5.2.12 and 5.2.13. The gate slack time shown on the abscissa is the average, in minutes, of the ground slack for all aircraft in the traffic data base (i.e., all aircraft to, from, or through the airport of interest). The parameter KS controls the mean gate slack time (See Section 3.2).

The sensitivity of delays to slack time taken from these Figures is summarized in Table 5.2.9. It is seen that the magnitude of the B-delay per aircraft per minute of slack is greatest at ORD and least at DEN. This suggests that ground time is more tightly scheduled at ORD than DEN, with SFO at an intermediate level. At ORD a minute increase in slack per aircraft will produce about .57 minute decrease in B-delay per aircraft, which indicates that about 57% of the through aircraft at ORD are operating with zero slack at the simulated delay levels.

The mechanism that transfers slack time changes into landing delay changes is more indirect. The slack time increase produces a shift in departure runway demand to earlier time at the airport of interest. If the shifted demand increases the peaking at the airport of interest, an increase in landing delay will result. This occurred, as seen in Table 5.2.9, at ORD and SFO. On the other hand, if the shift in landing demand reduces the peaking, then a reduction in landing delay will occur, as seen in the Table for DEN.

The mean gate slack time may be selected at any one airport to make the simulated B-delays in Table 5.2.8 equal the field data. In doing this, however, the sensitivity of landing delays to

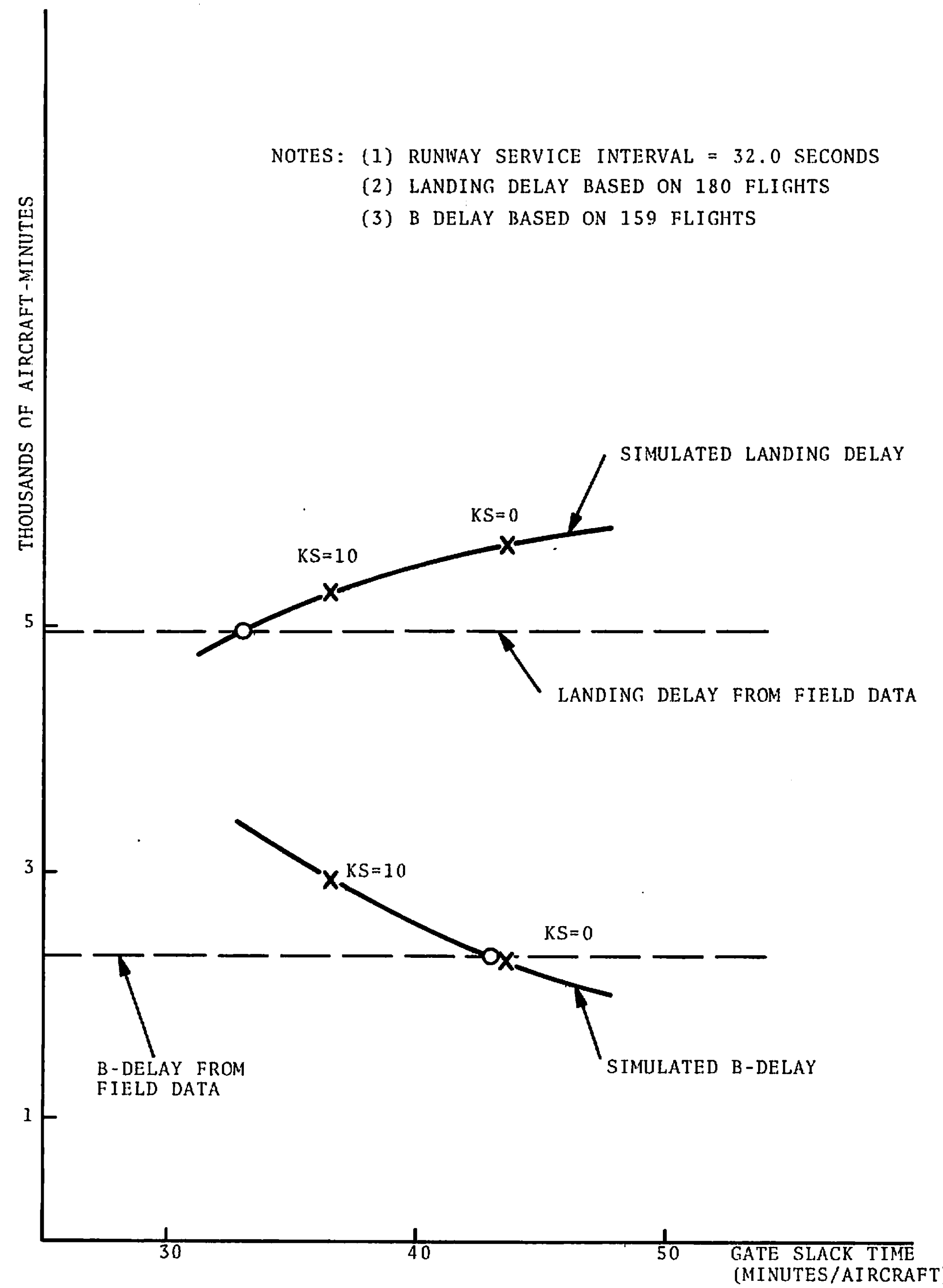
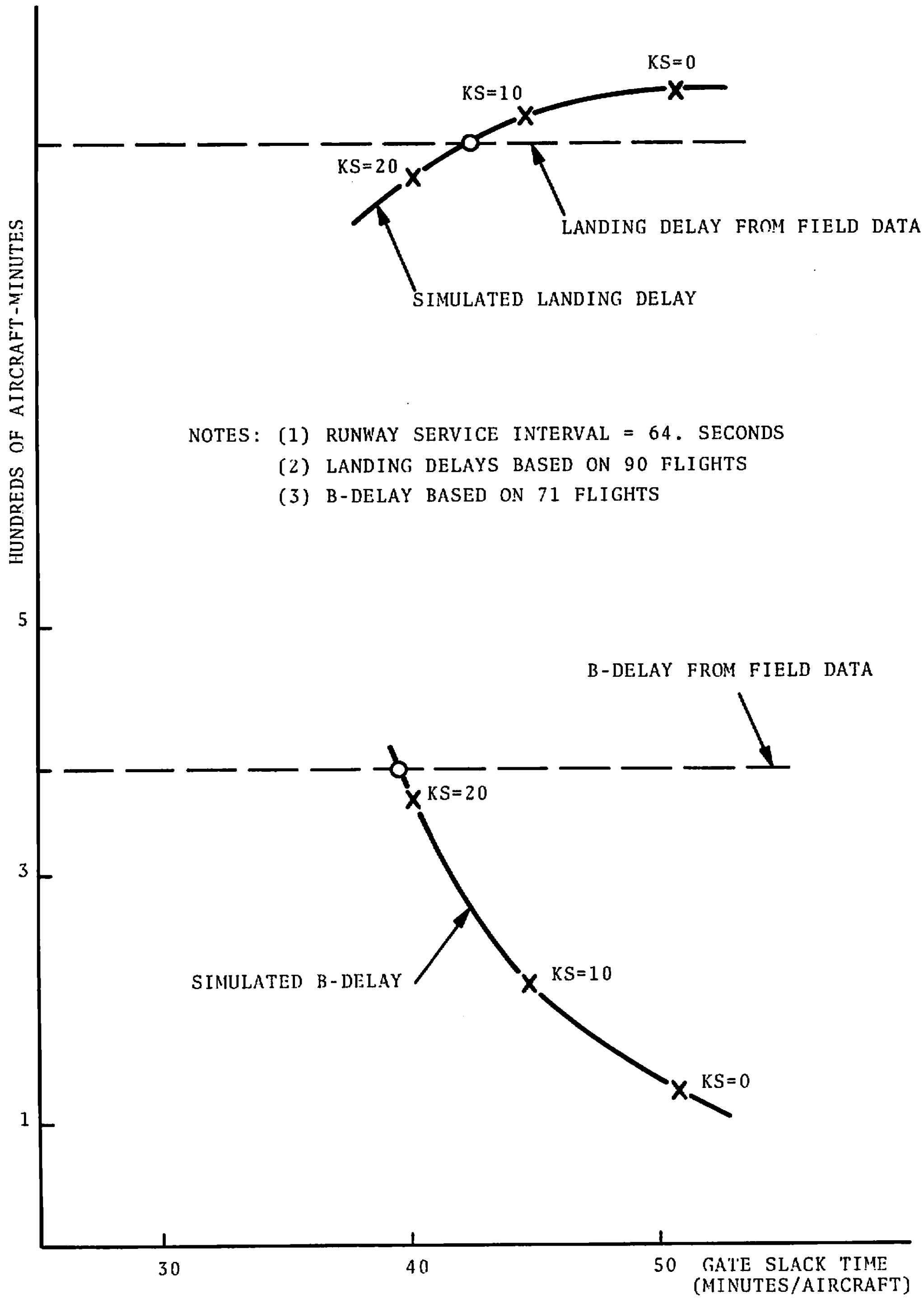


FIGURE 5.2.11 - DELAY VS GATE SLACK TIME, ORD



FIGURES 5.2.12 - DELAY VS GATE SLACK TIME, SFO

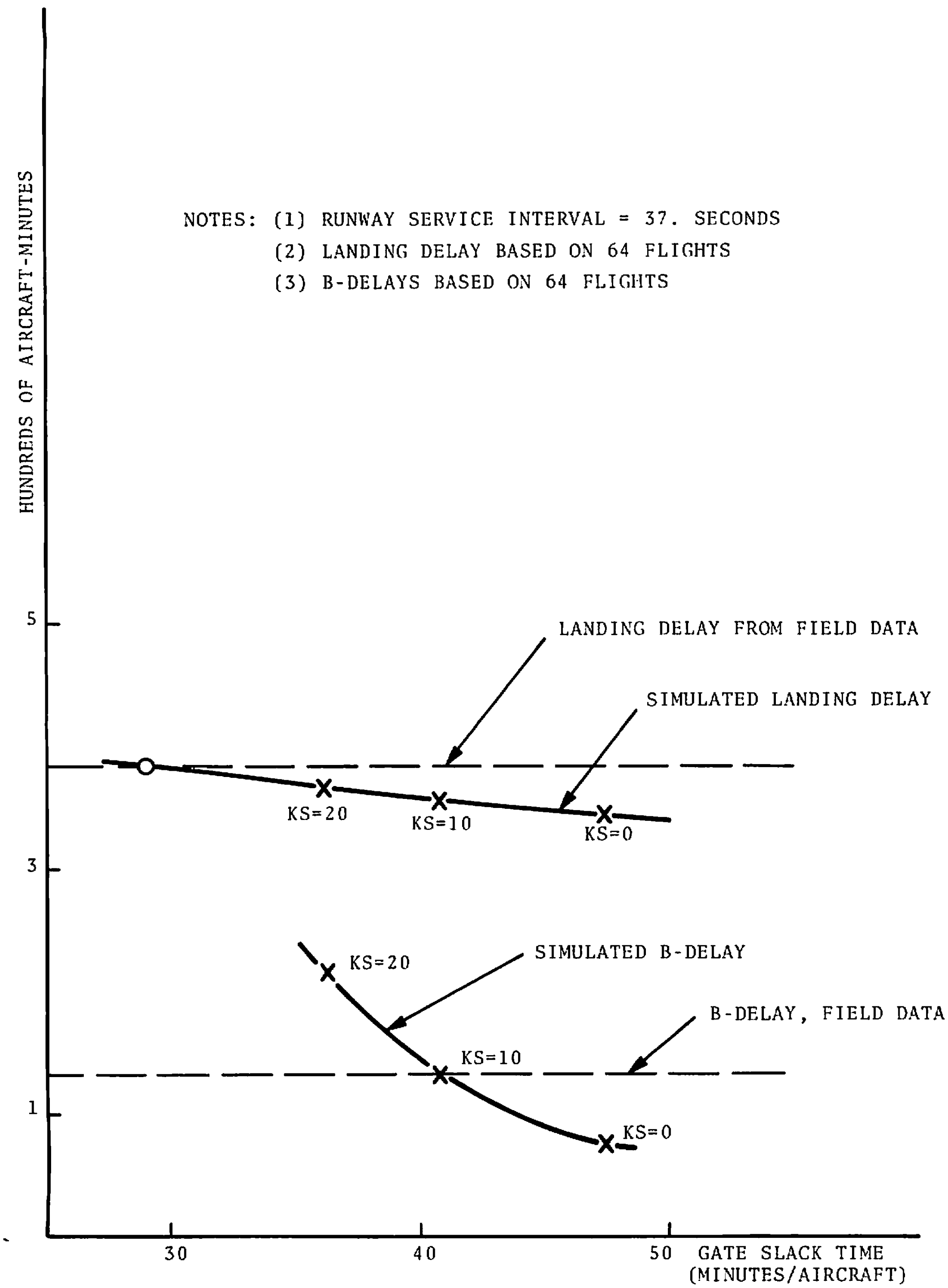


FIGURE 5.2.13 - DELAY VS. GATE SLACK TIME, DEN

TABLE 5.2.9 SENSITIVITY OF DELAYS TO GROUND SLACK TIME

TOTAL DELAY

	ORD	SFO	DEN
LANDING DELAY			
PER MINUTE SLACK	51.4	6.60	-1.77
(PER MINUTE KS)	(-37.0)	(-3.50)	(1.00)
B-DELAY			
PER MINUTE SLACK	-90.3	-23.1	-12.39
(PER MINUTE KS)	(65.0)	(12.3)	(7.0)

DELAY PER AIRCRAFT

	ORD	SFO	DEN
LANDING DELAY/ACFT			
PER MINUTE SLACK	.285	.073	-.028
(PER MINUTE KS)	(-.205)	(-.039)	(+.016)
B-DELAY/ACFT			
PER MINUTE SLACK	-0.568	-0.326	-0.194
(PER MINUTE KS)	(0.410)	(0.173)	(0.109)

changes in service interval σ must be taken into account. In general, the change ΔL in landing delay, and ΔB in B-delay may be related to the change $\Delta\sigma$ in service time and ΔK in slack parameter as follows:

$$\Delta L = \alpha\Delta\sigma + \beta\ \Delta K \quad (1)$$

$$\Delta B = \gamma\Delta\sigma + \delta\ \Delta K \quad (2)$$

The parameters $\alpha,\beta,\gamma,\delta$ were obtained for each airport from Figures 5.2.2-.4 and Table 5.2.9-A. The desired values of ΔL and ΔB were obtained from Table 5.2.8. When equations (1) and (2) were solved, the values obtained for $\Delta\delta$ and ΔK were those shown in Table 5.2.9-B. Only small adjustment are needed in $\Delta\delta$, as expected, while an increment of 7 to 15 minutes is needed in ΔK. Since the ANFS accepts only one K-parameter for all airports, a traffic-weighted average was used for ΔK. Thus

$$\text{KSLACK} = \Delta K = 9.06 \text{ minutes}$$

was obtained as the compromise value. Assuming that the three airports chosen fairly represent all the airports in the system, the value of 9 minutes for the slack parameter may be taken as a permanent adjustment in the ANFS. With this adjustment, the agreement between ANFS and the field data is as shown in Table 5.2.10. The fractional adjustments in the service interval required to make the ANFS landing delay agree exactly with the field data were made by means of Table 5.2.9-A and equation (1), because the simulator input accepts only integer values of the service interval. The corresponding adjustment in B-delay is also shown in the Table. The ANFS error is taken to be the difference between field data B-delay and the adjusted ANFS B-delay, and is shown for the three airports in the last line of the Table. When a traffic-weighted average of the three error magnitudes is taken, the result is 20%, which may be taken as a rough measure of the accuracy of the ANFS B-delay simulation relative to landing delay, when adjustment is made to gate slack time.

TABLE 5.2.9-A CONSTANTS FOR EQUATIONS (1) AND (2)

	ORD	SFO	DEN	
α	1450.	110.	66	$\frac{\text{ACFT-MIN}}{\text{SEC}}$
β	-31.	-5.	+1.1~	$\frac{\text{ACFT-MIN}}{\text{MIN}}$
γ	900.	88.	16.	$\frac{\text{ACFT-MIN}}{\text{SEC}}$
δ	63.	15.	6.7	$\frac{\text{ACFT-MIN}}{\text{MIN}}$
ΔL	-151	6.	-8.	ACFT-MIN
ΔB	491.	272.	46.	ACFT-MIN

TABLE 5.2.9-B SOLUTIONS FOR EQUATIONS (1) AND (2)

	ORD	SFO	DEN	
$\Delta\sigma$	.05	.69	-.25	SEC
ΔK	7.1	14.1	7.45	MIN

TABLE 5.2.10 RESULTS OF ANFS B-DELAY VALIDATION

	ORD	SFO	DEN	UNITS
<u>LANDING DELAY</u>				
SAMPLE SIZE	180	90	65	AIRCRAFT
KSLACK	9	9	9	MINUTES
ADJUSTED SERVICE INT'V'L	31.73	63.72	37.40	SECONDS
ADJUSTED ANFS DELAY	4944.	893.	383	ACFT-MIN
FIELD DATA DELAY	4944	893	383	ACFT-MIN
<u>B-DELAY</u>				
SAMPLE SIZE	159	71	60	AIRCRAFT
KLSLACK	9	9	9	MINUTES
ADJUSTED SERVICE INT'V'L	31.73	63.72	37.40	SECONDS
ADJUSTED ANFS DELAY	2622.	177.	130.	ACFT-MIN
FIELD DATA DELAY	2343	383	133	ACFT-MIN
ERROR	12	-54	-2	PERCENT

5.3 SUMMARY

The linkages of single OAG flight legs produced by the ANFS schedule generator was found to be 94% in agreement with actual airframe linkages for one day, as obtained from a large trunk line carrier. But when complete aircraft itineraries were compared with complete itineraries obtained from a second trunk line carrier, an estimate of 70% correctness was obtained.

Next, the B-delays produced by the ANFS were compared to B-delays extracted from the data of the second carrier and found to be within 12% for ORD, 54% for SFO and 2% for DEN, giving a weighted average error of 20%. This comparison of B-delays is based on (1) adjusting the ANFS runway service intervals at the three airports so that the simulated landing delays agree with those obtained from the data, and (2) a permanent adjustment in the ANFS ground slack time parameter.

REFERENCES

(1) Gordon, Steven, "The Airport Network Flow Simulator," Report No. FAA-ASP-75-6, U.S. Department of Transportation, Transportation Systems Center, Cambridge MA. Interim Report, May 1976.

(2) U.S. Department of Transportation, Federal Aviation Administration, "The National Aviation System, Challenges of the Decade Ahead, 1977-1986."

(3) U.S. Department of Transportation, Federal Aviation Administration, "Profiles of Scheduled Air Carrier Airport Operations, TOP 100 U.S. Airports," 1976.

(4) U.S. Civil Aeronautics Board, Economic Evaluation Division, Bureau of Accounts and Statistics, "Aircraft Operating Cost and Performance Report, Fiscal 1974," February 1975, Washington, D.C.

(5) Federal Aviation Administration, "General Aviation Cost Impact Study," Report DOT-FA-72WA-3118, Final Report, prepared by Batelle-Columbus Laboratory, Columbus, Ohio, June 1973.

(6) Munt, R., E. Danielson and J. Daimen, "Aircraft Technology Assessment: Interim Report on the Status of the Gas Turbine Program," U.S. Environmental Protection Agency, Washington D.C., 1975.

(7) U.S. Department of Transportation, Federal Aviation Administration, Selected Statistics of Published Domestic Air Carrier Schedules, Vol. IV: Estimated Flight Loads, March 1974, pp. 32-55, prepared by Potomac Scheduling Company.

APPENDIX A: SUMMARY OF FIELD DATA ON B-DELAY[1]

Data were collected from two carriers, a large U.S. trunk line carrier and a local service carrier. These data contained scheduled and actual times of gate departure and arrival for all aircraft of the carrier on a single day. This Appendix describes how the data were analyzed in order to obtain estimates of A-delay (landing delay) and B-delay (gate departure lateness).

LOCAL SERVICE CARRIER

The data for this carrier covered service on December 9, 1975. The data were analyzed to obtain an estimate of the relative magnitude of Type-A and Type-B delays. The results are presented in Table A-1. Type-A delay presented in Table A-1 is defined as the difference between actual and scheduled flight durations. Type B-delay presented in Table A-1 is defined as the difference between actual and scheduled departure times.

The Type-A delay may be understated because schedules may include some slack. To estimate the slack in schedules, use was made of the mean nonpositive delay. This is the average "earliness" of flights that arrived on time or early. For the most part, these are flights that encountered little or no Type-A delay. Adjusting for the average slack in schedules, the average Type-A delay amounted to 3.59 minutes. Although the average Type-B delay amounts to 13.89 minutes, this includes some negative Type-B delay--caused by flights departing before schedule. This arises when the aircraft is full or when all passengers with reservations arrive early. It does not make sense to count these early departures as offsets against Type-B delay. Consequently, Type-B delay was recomputed assuming that negative observations are in effect zero. This results in an average Type-B delay of 14.11 minutes.

Some lateness in departure is due to machanical difficulties, loading of baggage, or anticipation of Type-A delay.

(1)The work described in this Appendix was performed under Contract DOT-TSC-1184, carried out by Simat, Helliesen and Eichner, Newton Centre, MA.

The amount of such lateness is estimated by considering only the lateness in depature for each aircraft of the first flight leg of the day. This delay of 4.38 minutes cannot be true Type-B delay. Consequently, after adjusting for this factor, the average Type-B delay is 9.28 minutes, which is more than twice the Type-A delay. Even if all of the 4.38 minutes represented gate delay taken in anticipation of flight delays (for example, because of flow control procedures), then Type-A delay would amount to 8.42 minutes--still less than Type-B delay. This analysis shows that even under conservative conditions (underestimation of Type-B and overestimation of Type-A delays), Type-B delays exceeded Type-A delays on December 9, 1975, for this particular local service carrier. This conclusion fails to generalize, of course, to other carriers or to other days.

TRUNK LINE CARRIER

The data for the trunk line carrier covered its flights on February 16, 1976. They were analyzed according to the techniques employed for the local service carrier data. Table A-2 presents the results of this analysis. As before, the best estimate of real (but unobservable) Type-A delay is given by line 1 minus line 4, or 10.39 minutes/flight. Similary, the best estimate of real Type-B delay is given by line 5 minus line 9, or 5.06 minutes/flight. The delays, once again, are of the same order of magnitude as those for the local service carrier, even though the day analyzed was not a terribly poor one. However, the trunk line carrier's Type-B delays are less than its Type A-delays, as contrasted to the local service carrier's Type-B delays, which are greater than its Type-A delays. This result is expecte and due to longer average length of haul of the trunk line. Table 2 was constructed after deleting two outlying points corresponding to Type-B delays of 244 and 350 minutes. The most likely explanations of these points are that they represent errors in the data or the operation of flights that would have been cancelled had they not been required to transport the flight crew or the aircraft to some other point.

TABLE A-1

ANALYSIS OF DELAYS OF LOCAL SERVICE AIRCRAFT ON DECEMBER 9, 1975

	TYPE OF OBSERVATION (1)	NUMBER OF OBSERVATIONS (2)	MEAN (MINS.) (3)	STANDARD DEVIATION (MINS.) (4)
1.	Type-A Delays	300	1.45	4.55
2.	Negative Type-A Delays	100	-3.04	2.08
3.	Zero Type-A Delays	42	0.00	0.00
4.	Nonpositive Type-A Delays	142	-2.14	2.23
5.	Type-B Delays	300	13.89	26.41
6.	Negative Type-B Delays	21	-3.14	1.98
7.	Zero Type-B Delays	69	0.00	0.00
8.	Type-B Delays with Negative Delays Counted as Zero	300	14.11	26.28
9.	Type-B Delays for Aircraft on First Flight Leg of Day	30	4.83	9.59

TABLE A-2

ANALYSIS OF DELAYS OF TRUNK LINE
AIRCRAFT ON FEBRUARY 16, 1976
(EXCLUDING OUTLYING DATA POINTS)

	TYPE OF OBSERVATION (1)	NUMBER OF OBSERVATIONS (2)	MEAN (MINS.) (3)	STANDARD DEVIATION (MINS.) (4)
1.	Type-A Delays	1419	5.88	14.73
2.	Negative Type-A Delays	474	-5.42	5.24
3.	Zero Type-A Delays	96	0.00	0.00
4.	Nonpositive Type-A Delays	570	-4.51	5.19
5.	Type-B Delays	1417	7.55	17.56
6.	Negative Type-B Delays	54	-6.41	11.16
7.	Zero Type-B Delays	690	0.00	0.00
8.	Type-B Delays, with Negative Delays Counted as Zero	1417	7.88	17.28
9.	Type-B Delays for Aircraft on First Flight Leg of Day	317	2.49	6.73

TABLE A-4

SUMMARY OF A- AND B-DELAYS

	LOCAL SERVICE CARRIER	TRUCK LINE CARRIER
DATE OF DATA	12/9/75	2/16/76
NUMBER OF DEPARTURES	300	1419
A-DELAY PER DEPARTURE	3.6 MIN	10.4 MIN
B-DELAY PER DEPARTURE	9.3 MIN	5.1 MIN
RATIO OF B-DELAY/A-DELAY	2.58	0.49

APPENDIX B: PROGRAM LISTINGS

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BDL	BDR	ORD	ATL	JFK	LGA	SFO	LAX	DEN	PHL	EWR	MIA	DAL	DCA	PIT	BOS	CLE	DTW	MSY	LAS
HNL	STL	FLL	TPA	MSP	SEA	BAL	CLT	MKE	SLC	IAH	IAD	JAX	DFW	HVN	GON	HFD	RKD	PWM	BGR
PQI	LEW	AUG	WVL	BHB	PSF	ORH	BED	ACK	HYA	MVY	EWB	PVC	LWM	MHT	EEN	LEB	HIE	LCI	PVD
BID	WST	NPT	BTV	RUT	MPV	VSF	TTN	AIY	WWD	MMU	ARX	TEB	BUF	ROC	ALB	SYR	ISP	HPN	ITH
UCA	BGM	ELM	JHW	ART	IPT	MDT	ABE	AVP	ERI	BFD	PNE	RDG	LNS	MSS	OGS	GFL	PLB	SLK	HZL
FKL	DUJ	PSB	AOO	JST	POU	HAR	SCE	ONH	MSV	JRB	FRG	ILG	EYW	MTH	MCO	PBI	MLB	DAB	PNS
SRQ	TLH	GNV	FMY	AGS	SAV	CSG	MCN	SSI	PGD	VRB	ORL	TIX	OCF	MRK	PFN	APF	VPS	HGR	SBY
ESN	CBE	ODM	ABY	VLD	MGR	AHN	CWG	GSO	SDU	AVL	HKY	INT	FAY	ISO	ILM	OAJ	EWN	RWI	HNC
MEO	SOP	CAE	CHS	GSP	HHH	GRD	FLO	AND	MYR	ECG	MRH	PGV	RIC	ORF	PHF	WOU	CHO	SHD	LYH
ROA	FRQ	HSP	DAN	WGO	CRW	PKB	HTS	CKB	MGW	EKN	BKW	LWB	BLF	DNV	PIA	MDW	CGX	MLI	UIN
SPI	CMI	BMI	MTO	MVN	GBG	SQI	MWA	IND	MIE	HUF	BMG	EVV	FWA	PLY	SBN	DEC	RFD	MGC	VPZ
WMS	ALN	MDH	DET	AZO	GRR	CMX	MOT	LAN	FVC	PTK	IMT	IND	MNM	ESC	JXN	FNT	CMH	DAY	CVG
CAK	TOL	YNG	MFD	BKL	OSU	GQQ	MBS	BEH	PLN	MBL	ISW	MFI	STE	EAU	ASX	HYR	SBM	SUE	CWA
MSN	GRB	JVL	MTW	OSH	RHI	LSE	SSM	APN	MKG	MOB	LIA	PHN	ATW	BTL	EKI	LAF	OKK	BHM	MGM
HSV	MOB	TCL	MSL	DHN	ANB	GAD	AUO	SDF	LEX	PAH	OWB	BWG	FFT	LOZ	HEZ	JAN	GPT	MEI	PIB
HKS	GTR	GLH	TUP	GWO	UOX	BNA	MEM	TYS	CHA	TRI	CKV	CSV	PHT	MKL	BRL	CID	ALO	DSM	SPW
WUK	SUX	DBQ	OTM	MCW	FOD	EOK	FMS	CWI	ICT	LBL	MHK	TOP	SLN	GCK	GLD	HYS	PPF	LWC	EMP
GBD	HUT	OJC	DDC	DLH	RST	HIB	INL	FRM	MKT	OTG	BJI	BRD	TVF	ULM	STP	ONA	EVM	IRK	MCI
MKC	SGF	JLN	TBN	CGI	COU	POF	KNT	MAW	GPZ	JEF	DMO	OMA	LNK	GRI	AIA	BFF	SNY	CDR	EAR
MCK	HSI	OLU	LBF	OFK	AIZ	RLA	BIS	MOT	FAR	GFK	ISN	DVL	JMS	RAP	FSD	HON	MHE	YKN	ABR
ATY	PIR	BKX	LIT	FSM	HOT	FYV	HRO	PBF	TXK	ELD	JBR	SHV	BTR	ESF	MLU	NEW	LFT	POE	LCH
DRI	OKC	TUL	LAW	WDG	MLC	PNC	AXS	ELP	SAT	AUS	CRP	BRO	AMA	LBB	MAF	SPS	BPT	ABI	PRX
HOU	LFK	OCH	GGG	TYR	CLC	GLS	LJN	VCT	PSN	SJT	MWL	ACT	TPL	HCA	BWD	LRD	HRL	MFE	ILE
DRT	CLL	PHX	TUS	YUM	INW	GCN	PGA	FLG	IGM	LHU	PRC	ASE	COS	PUB	GJT	CEZ	DRO	ALS	LAA
GUC	MTJ	HDN	LXV	EGE	SBS	LWS	BOI	WAU	MPB	SUN	PIH	TWF	WCI	GNY	FTC	IDA	BZN	MSO	FCA
BIL	GTF	MLS	GDV	SDY	LWT	GGW	OLF	HVR	BTM	HLN	LOL	RNO	WMC	EKO	ELY	ABQ	GUP	FMN	ALM
SVC	ATS	ROW	RUI	CNM	HOB	CVN	SAF	RTN	TSM	WGS	VEL	BMC	TRT	LGU	OGD	PUC	CNY	WBT	WUO
BDG	WUJ	CDC	SGU	MLF	EAN	CYS	ECS	SHR	RKS	RWL	CPR	RIW	WRL	COD	JAC	LAR	GCC	SAA	WJA
DGW	DTA	RIF	LRU	SAN	PSP	OAK	ONT	SJC	BUR	CKE	STS	NOT	PAO	UKI	FOB	LVR	PDX	LMT	WFB
MFR	LGB	SMF	WYK	AVX	TWH	SNA	OXR	SBA	PMD	IYK	WIX	GEG	YKM	PUW	ALW	PSC	EAT	RLD	PWT
BFI	OLM	TIW	HQM	MHV	FUL	RAL	ODW	BLI	AST	IPL	ACV	EKA	CEC	CIC	RBL	MYV	COA	RDD	OVE
TVL	JEM	JMC	OBR	FAT	SCK	BKE	LGD	SLE	RDM	WBH	WBY	EUG	BFL	SMX	OTH	BLH	MRY	MMH	BIH
PDT	MOD	MCE	VIS	MWH	SRF	CCR	APC	VLO	SBP	PRB	CLM	WCG	WCF	WBV	YUL	YYZ	ADQ	ENA	AKN
JNU	FAI	ANC	SJU	OUT															
5	5	6	5	5	5	8	8	7	5	5	5	6	5	5	5	5	5	6	8
10	6	5	5	6	8	5	5	6	7	6	5	5	6	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	5	6	5	5
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6
6	6	6	6	6	6	6	6	5	5	5	5	6	5	5	5	6	6	6	6
6	6	6	5	5	5	5	5	5	5	5	6	6	6	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	5	5	5	6	5	5	6	5	5	5	5	6	6
6	6	6	6	6	6	6	6	5	5	6	6	6	5	5	6	6	6	6	6
6	6	6	6	6	6	6	6	5	5	5	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	6	6	6	6
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	7	7	7	6
6	6	6	6	6	6	6	6	6	6	6	6	6	6	7	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	7	6	6	6	6	6	6	6	6	6	6	6
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
6	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
7	7	7	7	7	7	8	7	7	7	7	7	7	7	7	7	7	7	7	7
7	7	7	7	7	7	7	7	7	7	7	8	8	8	8	8	7	7	7	7

```
  7   7   7   7   7   7   7   7   7   7   7   7   7   7   7   7   7   7   7   7
  7   7   7   7   7   7   7   7   7   7   7   7   7   7   7   7   7   7   7   7
  7   7   7   7   8   8   8   8   8   8   8   8   8   8   8   8   8   8   8   8
  8   8   8   8   8   8   8   8   8   8   8   8   8   8   8   8   8   8   8   8
  8   8   8   8   8   8   8   8   8   8   8   8   8   8   8   8   8   8   8   8
  8   8   8   8   8   8   8   8   8   8   8   8   8   8   8   8   8   8   8   8
  8   8   8   8   8   8   8   8   8   8   8   8   8   8   8   5   5  10  10  10
  8  10  10   4  99
    5402    38222
  5 51300 21420   173
  8 72720  1740   173
  8 76500 14760   173
 17 91260  1860   173
 17 93300  3060   173
 75 96360 43201   173
  8 60300 17460   165
  5 78120 43201   165
565 60000  2100   173
  8 62100  1740   173
  8 63900 17520   173
 11 81480  2040   173
 11 93600  4320   173
 32 97920     0   173
 32 98580 11820   173
 34110400  1800   173
 34112200 10380   173
  8123360 43201   173
 34 25800 10380   173
  8 36960  1740   173
  8 63000 14760   173
 17 77760  1860   173
 17 80100  3060   173
 75 83160  2340   173
 75 85500  3840   173
  5 89340 43201   173.
565 58500  2220   165
  8 60780  1920   165
  8 63600 17640   165
 16 81240  2700   165
 16 85800  9000   165
  3 95400  2700   165
  3 98100 12900   165
463111000  2400   165
463113400  6300   165
  7119700 43201   165
  7 59400 18300   165
  5 78000  3660   165
  5 82800 21000   165
  8104160 43201   165
  7 72000 18300   165
  5 90660 43201   165
  5 61200 21900   165
  7 83220  3180   165
  7109200  5820   165
463115020  2400   165
463117600 10620   165
  3128220 43201   165
463 31200 10620   165
  3 41820  2700   165
  3 46800  4800   165
657 51600  7200   165
```

APPENDIX B-2. CAPACITY DATA, CAPCTY.DAT

First page: General sample of CAPCTY.DAT file

Second page: Special form of CAPCTY.DAT for JFK test case.

		100		10		60		09																	
ORD	9	28 1	28 1	28 1	28 1	28 1	28 1	28 1	28 5	28 6	28 6	28 6	28 5	28 6	28 6	28 6	28 6	28 7	28 7	28 7	28 7	28 6	28 4	28 2	28 1
JFK	8	32 3	32 1	32 2	32 2	32 1	32 1	32 2	32 3	32 4	32 5	32 4	32 3	32 4	32 3	32 4	32 7	32 7	32 8	32 8	32 7	32 6	32 7	32 4	32 3
SFO	13	64 2	64 1	64 0	64 0	64 1	64 1	64 2	64 4	64 8	64 6	64 5	64 5	64 8	64 6	64 6	64 6	64 3	64 5	64 6	64 7	64 7	64 5	64 3	64 3
ALL	0	00 0	00 0	00 0	00 0	00 0	00 0	00 0	00 0	00 0	00 0	00 0	00 0	00 0	00 0	00 0	00 0	00 0	00 0	00 0	00 0	00 0	00 0	00 0	00 0

		100		10		60		09																	
JFK		60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
	8	3	1	2	2	1	1	2	3	4	5	4	3	4	3	4	7	7	8	8	7	6	7	4	3
ALL		00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
	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

APPENDIX B-3. COST DATA PROGRAM, COST.F4

```
      OPEN(UNIT=6,DEVICE='DSK',ACCESS='SEQOUT',FILE='COST.DAT')
      INTEGER PCOST,TCOST(100),LCOST(100),LOAD(32,100),LOAD0(100),
     1HFACT(32,24),HFACT0(24),STK(10),SLS(9),SIS(13),BOARD(32),
     2SIF(91),SCT(147),SHO(26),AC3LC(100),ACSEB(100),BOARD0
      DATA PCOST/1250/
      DATA TCOST/          8063, 33989,  3967,  3967,  3967,  5283,  8063,
     1  3967,  8063,  8063,  1317, 33989, 26029, 26029, 33989, 33989,
     2 26029, 26029, 71183,  3967, 26029,  8063, 33989, 33989,  1317,
     3  3967, 92952, 92952, 33989,  8063, 33989,  3967,  8063,  1317,
     4 71183, 33989,  3967,  3967, 26029,  3967,  8063, 33989,  8063,
     5     0,     0,  3967,  8063, 33989, 71183, 92952,  8063,     0,
     6  3967, 33989,  1317,  1317,  1317,     0,     0, 49467, 39393,
     7 56629, 56629, 39393, 69127, 56629, 39393, 39393, 39393, 69127,
     8 39393, 54495, 56629, 46944, 54495, 46944, 39393, 39393, 88787,
     9 88787, 54495, 54495, 56629, 88787, 39393,15*0/
      DATA LCOST/          9676, 38527,  4760,  4760,  4760,  6340,  9676,
     1  4760,  9676,  9676,  1581, 38527, 29413, 29413, 38527, 38527,
     2 29413, 29413, 78423,  4760, 29413,  9676, 38527, 38527,  1581,
     3  4760,102724,102724, 38527,  9676, 38527,  4760,  9676,  1581,
     4 78423, 38527,  4760,  4760, 29413,  4760,  9676, 38527,  9676,
     5     0,     0,  4760,  9676, 38527, 78423,102724,  9676,     0,
     6  4760, 38527,  1581,  1581,  1581,     0,     0, 67800, 50062,
     7 80704, 80704, 50062,107500, 80704, 50062, 50062, 50062,107500,
     8 50062, 75000, 80704, 62500, 75000, 62500, 50062, 50062,147203,
     9147203, 75000, 75000, 80704,147203, 50062, 15*0/
C LOAD0(I,J) IS AVG NUMBER OF PAX DEPARTING ON ACFT TYPE J AT APT I.
      DATA (LOAD(1,J),J=1,100)/9*0,4,4*0,28,7*0,19,37*0,37,73,79,45,88,
     189,57,0,0,77,0,0,76,69,86,63,0,59,0,108,76,19*0/
      DATA (LOAD(2,J),J=1,100)/22*0,42,5*0,16,18*0,17,13*0,42,91,46,91,7
     18,60,0,0,79,0,0,0,75,0,65,0,42,0,102,20*0/
      DATA (LOAD(3,J),J=1,100)/60*0,30,65,88,0,99,71,39,0,0,107,0,0,74,6
     18,0,71,0,49,0,142,20*0/
      DATA (LOAD(4,J),J=1,100)/22*0,12,37*0,48,0,0,40,99,0,84,0,0,67,0,
     10,0,78,0,64,0,59,22*0/
      DATA (LOAD(5,J),J=1,100)/14*0,44,8*0,19,37*0,76,55,51,100,81,33,0,
     10,108,0,0,76,47,55,52,0,36,0,156,82,19*0/
      DATA (LOAD(6,J),J=1,100)/23*0,18,3*0,8,33*0,79,62,55,84,116,46,0,0
     1,89,0,0,76,38,65,60,0,47,0,125,20*0/
      DATA (LOAD(7,J),J=1,100)/14*0,18,6*0,5,39*0,79,75,39,69,77,39,5*0,
     171,52,69,62,46,47,0,0,66,19*0/
      DATA (LOAD(8,J),J=1,100)/6*0,5,0,0,22,4*0,20,6*0,5,8*0,15,29*0,43,
     146,91,50,67,95,53,0,0,76,0,0,66,69,0,52,0,57,22*0/
      DATA (LOAD(9,J),J=1,100)/9*0,10,4*0,40,6*0,3,38*0,42,95,75,50,101,
     189,64,0,0,84,0,0,83,63,0,64,0,57,0,0,73,19*0/
      DATA (LOAD(10,J),J=1,100)/61*0,18,64,62,73,33,57,0,0,81,3*0,57,56
     1,51,3*0,118,20*0/
      DATA (LOAD(11,J),J=1,100)/100*0/
      DATA (LOAD(12,J),J=1,100)/6*0,14,0,0,20,4*0,25,7*0,19,7*0,16,16*0,
     122,12*0,41,0,0,37,0,0,70,6*0,66,0,70,0,49,22*0/
      DATA (LOAD(13,J),J=1,100)/9*0,4,4*0,23,6*0,3,38*0,46,60,0,46,49,46
     1,52,0,0,65,0,0,55,46,0,51,0,45,0,75,39,19*0/
      DATA (LOAD(14,J),J=1,100)/14*0,29,7*0,15,37*0,45,56,80,47,118,80,6
     11,0,0,73,0,0,84,71,0,61,0,77,0,89,76,19*0/
      DATA (LOAD(15,J),J=1,100)/14*0,33,11*0,2,33*0,47,0,72,49,81,62,60,
     15*0,70,51,0,57,0,58,0,99,20*0/
      DATA (LOAD(16,J),J=1,100)/14*0,24,45*0,40,40,76,0,84,98,46,0,0,69,
     10,0,72,62,0,70,0,70,0,111,20*0/
      DATA (LOAD(17,J),J=1,100)/15*0,23,12*0,1,33*0,65,27,61,62,48,0,0,5
     14,3*0,56,0,51,24*0/
      DATA (LOAD(20,J),J=1,100)/14*0,14,7*0,11,37*0,51,45,0,38,0,0,44,0,
     10,81,0,0,65,57,0,59,41,3*0,72,19*0/
```

```
      WRITE(6,60000)PCOST
      WRITE(6,60000)TCOST
      WRITE(6,60000)LCOST
60000 FORMAT(13I6)
      DO 1 I=1,32
    1 WRITE(6,60001)(LOAD(I,J),J=1,100)
      WRITE(6,60001)LOAD0
60001 FORMAT(26I3)
      DO 2 I=1,32
    2 WRITE(6,60001)(HFACT(I,J),J=1,24)
      WRITE(6,60001)HFACT0
      WRITE(6,60001)BOARD
      WRITE(6,60001)BOARD0
      WRITE(6,60002)STK
      WRITE(6,60002)SLS
      WRITE(6,60002)SIS
      WRITE(6,60002)SIF
      WRITE(6,60002)SCT
      WRITE(6,60002)SHO
60002 FORMAT(26(1X,A2))
      WRITE(6,60003)AC3LC
      WRITE(6,60003)ACSEB
60003 FORMAT(20(1X,A3))
      END
```

APPENDIX B-4. SIMULATOR, ANFS.F4

```
C  AIRPORT NETWORK FLOW SIMULATOR, VERSION  B
C  THE FOLLOWING FOUR CARDS ARE REQUIRED FOR RUNNING ON THE 10.
      OPEN(UNIT=5,DEVICE='DSK',ACCESS='SEQIN',FILE='FLIGHT.DAT')
      OPEN(UNIT=6,DEVICE='DSK',ACCESS='SEQOUT',FILE='ANFS.OUT')
      OPEN(UNIT=7,DEVICE='DSK',ACCESS='SEQIN',FILE='CAPCTY.DAT')
      OPEN(UNIT=9,DEVICE='DSK',ACCESS='SEQIN',FILE='COST.DAT')
C  THE ABOVE FOUR CARDS SHOULD BE REMOVED WHEN RUNNING ON THE 360.
C  NOTES: ALL TIMES IN SECONDS GMT, UNLESS OTHERWISE NOTED
C          TAU INCLUDES NORMAL SERVICE TIME
C          TAU MUST BE NDLEG FOR THE LAST EVENT OF EACH AIRCRAFT
C          SIG IS MINIMUM INTERVAL BETWEEN INTIATIONS OF SERVICE
C  TS,TAU,TA,LM,IJ,CECODE ARE DIMENSIONED TO NO OF EVENTS, NEVNTS
C  TAX,TAY,MX,MY ARE DIMENSIONED TO MAX NO OF EVENTS AT ANY AIRPORT
C  TA0,APT,ZONE ARE DIMENSIONED TO  NO OF AIRPORTS, NAPTS
C  ML IS DIMENSIONED TO  NO OF AIRPORTS PLUS ONE
C  ALL OTHER DIMENSIONS ARE INDEPENDENT OF NEVNTS AND NAPTS
      INTEGER*2 CECODE(8000),MY(2000),ML(240),LM(8000),IJ(8000),MX(2000)
      INTEGER LCOST(100),TCOST(100), LOAD(32,100),SIG0(24),ZONE(240)
      INTEGER  LOAD0(100),HFACT0(24),HFACT(32,24),COST(4,25),COSTS(4,25)
      INTEGER TA0(240),C(4),APT(240),SIGX(24),SIG(32,25),D(4),OUTP(4,25)
      INTEGER OUTS(4,25),TS(8000),TAU(8000),TA(8000),TAX(2000),TAY(2000)
      INTEGER PCOST,OUT,PLEVEL,SKED,NSKD,TOTL,BOARD(32),BOARD0
      INTEGER GFACX(24),E(4),EQSEB(100),EQ3LC(100),GAFAC(32,25),VOL(24)
      INTEGER T1,T2,TA1,TAMIN,HOUR,ST,TY,TX,TZ,ALL,TSTART,TSTOP,EXPFAC
      INTEGER APTS32(32),XFORM(32),NSVOL(24),NTOTL(24),SIGON(24)
      DATA APTS32  /'ORD ','ATL ','JFK ','LGA ','SFO ','LAX ','DEN ',
     1'PHL ','EWR ','MIA ','DAL ','DCA ','PIT ','BOS ','CLE ','DTW ',
     2'MSY ','LAS ','HNL ','STL ','FLL ','TPA ','MSP ','SEA ','BAL ',
     3'CLT ','MKE ','SLC ','IAH ','IAD ','JAX ','DFW '/
      DATA ALL,OUT,E/'ALL ','OUT','TKOF','LNDG','ADLY','BDLY'/
      DATA SKED,NSKD,TOTL/'SKED','NSKD','TOTL'/
      WRITE(6,6666)
 6666 FORMAT(' THE AIRPORT NETWORK FLOW SIMULATOR'////)
C
C  READ SCHEDULED DEMAND DATA FROM ANFS.DAT
      READ(5,5001)NAPTS
 5001 FORMAT(I10)
      READ(5,5002)(APT(K),K=1,NAPTS)
 5002 FORMAT(20A4)
      READ(5,5003)(ZONE(K),K=1,NAPTS)
 5003 FORMAT(20I4)
      READ(5,5004)NACFT,NEVNTS
 5004 FORMAT(2I10)
      READ(5,5005)((LM(K),TS(K),TAU(K),CECODE(K)),K=1,NEVNTS)
 5005 FORMAT(I3,3I6)
C
C  READ CAPACITY DATA FROM CAPATY.DAT
C  EXPFAC IS TRAFFIC EXPANSION FACTOR IN PERCENT BASED ON 100 FOR
C  UNEXPANDED TRAFFIC LEVEL  (SAME FOR CARRIER AND GA)
C  PLEVEL IS AIRPORT PRINT LEVEL IN ACFT-MINS OF TOTAL DELAY
C  MAXGT IS MAXIMUM GROUND TIME IN MINUTES
C  KSLACK IS REDUCTION IN GROUND SLACK TIME, IN MINUTES
C  KAPT IS AIRPORT 3-LETTER CODE
C  SIGX IS RUNWAY SERVICE TIME IN SEC (SAME FOR CARRIER AND GA)
C  KGA IS DAILY GA OPS AS PERCENT OF TOTAL DAILY OPS
C  GFACX IS GA PROFILE BY HOUR (EACH HOUR'S PERCENT OF DAILY GA OPS)
C  LAST KAPT ENTERED MUST BE ALL
C  IF KAPT IS ALL KGA APPLIES TO ALL REMAINING AIRPORTS AND GFACX
C  IS HOURLY PROFILE FOR SCHED AND NONSCHED AT REMAINING AIRPORTS
      READ(7,7010)EXPFAC,PLEVEL,MAXGT,KSLACK
```

```
 7010 FORMAT(I8,10I6)
      IAPT1 = 0
      NAPTSG = 0
    1 READ(7,7011)KAPT,SIGX
 7011 FORMAT(1X,A4,24I3)
      READ(7,7012)KGA,GFACX
 7012 FORMAT(1X,I4,24I3)
      IF(KAPT.EQ.ALL)GO TO 2
      DO 1003 K=1,NAPTS
      IF(KAPT.EQ.APT(K))GO TO 1005
 1003 CONTINUE
      WRITE(6,6008)KAPT
 6008 FORMAT(/1X,'INPUT AIRPORT ',A4,'NOT IN DATA BASE')
      GO TO 1
 1005 NAPTSG = NAPTSG + 1
      IF(NAPTSG.GT.32)GO TO 1
      SIG(NAPTSG,25) = K
      GAFAC(NAPTSG,25) = KGA
      DO 1008 K=1,24
      GAFAC(NAPTSG,K) = GFACX(K)
 1008 SIG(NAPTSG,K) = (SIGX(K)*EXPFAC)/100
      GO TO 1
    2 DO 3 J=1,24
      IF(SIGX(J).GT.0)IAPT1 = ALL
      IF(KGA.EQ.100)KGA = 95
      SIGON(J) = SIGX(J)*EXPFAC
    3 SIGO(J) = (SIGX(J)*EXPFAC)/(100-KGA)
C
C   READ COST DATA FROM COST.DAT
C   PCOST, TCOST, LCOST ARE CENTS/HR FOR PAX, TAKEOFF, LANDING
C   LOAD(I,J) IS AVG PAX LOAD (LNDG OR TAKNG OFF) ON ACFT TYPEJ, APT I.
C   LOADO IS SEATING CAPACITY OF AIRCRAFT TYPE J
C   HFACT(I,J) IS PAX LOAD IN HR J AS PERCENT OF AVG HOURLY LOAD, APT I
C   (SAME FOR ALL AIRCRAFT TYPES).  HFACTO(J) IS HFACT(I,J) FOR I GT 32.
C   XFORM(J),J=1,32 HOLDS APT NUMBERS L FOR THE 32 APTS OF THE ARRAYS
C   LOAD, LOADO, HFACT, HFACTO .
C   SIG(J,1-24) HOLDS SERVICE TIMES FOR J=1,NAPTSG
C   SIG(J,25) HOLDS APT NUMBER L CORRESPONDING TO J.
      READ(9,9000)PCOST
      READ(9,9000)TCOST
      READ(9,9000)LCOST
 9000 FORMAT(13I6)
      DO 4 I=1,32
    4 READ(9,9001)(LOAD(I,J),J=1,100)
 9001 FORMAT(26I3)
      READ(9,9001)LOADO
      DO 5 I=1,32
    5 READ(9,9001)(HFACT(I,J),J=1,24)
      READ(9,9001)HFACTO
      READ(9,9001)BOARD
      READ(9,9001)BOARDO
C     READ(9,9002)STK
C     READ(9,9002)SLS
C     READ(9,9002)SIS
C     READ(9,9002)SIF
C     READ(9,9002)SCT
C     READ(9,9002)SHO
C9002 FORMAT(26(1X,A2))
C     READ(9,9003)AC3LC
C     READ(9,9003)ACSEB
C9003 FORMAT(20(1X,A3))
```

```
C
C  INITIALIZE
      INTVL = 600
      TSTART = 36000
      TSTOP = TSTART + 97200
      LOUT = 0
      NAPTS1 = NAPTS + 1
      MSLACK = 0
      NSLACK = 0
      NDLEG = 43201
      NAPTSX = NAPTS - 1
      IF(PLEVEL.EQ.0)PLEVEL=15
      MAXGT0 = MAXGT
      KSLAK0 = KSLACK
      KPLVL0 = PLEVEL
      PLEVEL = PLEVEL*60
      MAXGT = MAXGT*60
      KSLACK = KSLACK*60
      MAXGT = MAXGT + KSLACK
      DO 6 L=1,NAPTS
      IF(APT(L).EQ.OUT)LOUT = L
      TAO(L) = 0
      ML(L) = 0
      DO 6 I=1,32
    6 IF(APT(L).EQ.APTS32(I))XFORM(I)=L
      DO 7 K=1,4
      DO 7 J=1,25
      COSTS(K,J) = 0
    7 OUTS(K,J) = 0
C  FILL IN TA(K), LM(K), IJ(K), ML(L), ADJUST SCHEDULE FOR INTVL
      DO 8 K=2,NEVNTS,2
      K1 = K-1
      IF(TAU(K1).LT.INTVL)TAU(K1)=INTVL
      TS(K) = TS(K1) + TAU(K1)
      L = LM(K1)
      ML(L) = ML(L) + 1
      L = LM(K)
      ML(L) = ML(L)+1
      IF(TAU(K).EQ.NDLEG)GO TO 8
      KTAU = TAU(K) + KSLACK
      MTAU =TS(K+1) -TS(K)
      TAU(K) = MIN0(MTAU,MAXGT,KTAU)
      IF(TAU(K).LT.INTVL)TAU(K)=INTVL
      IF((TS(K+1)-TS(K)).LT.TAU(K))TS(K+1) = TS(K) + TAU(K)
      MSLACK = MSLACK + TS(K+1) - TS(K) - TAU(K)
      NSLACK = NSLACK + 1
    8 CONTINUE
      XSLACK = FLOAT(MSLACK)/FLOAT(NSLACK)/60.
      MSAVE = ML(1)
      ML(1) = 1
      DO 9 L = 2,NAPTS1
      MHOLD = ML(L)
      ML(L) = ML(L-1) + MSAVE
    9 MSAVE = MHOLD
      KLMMAX = ML(NAPTS1) - 1
      IF(KLMMAX.NE.NEVNTS)STOP 21
      DO 10 K=1,NEVNTS
      L = LM(K)
      K2  = ML(L)
      ML(L) = K2  + 1
      LM(K) = K2
```

```
      TA(K2)  = TS(K)
   10 IJ(K2)  = K
C     SET ML(L) TO STARTING LOCATION IN TA ARRAY FOR AIRPORT L
      DO 11 L=1,NAPTSX
      L2=NAPTS1-L
   11 ML(L2) = ML(L2-1)
      ML(1) = 1
C     FILL IN LOAD(I,J) AND HFACT(I,J)
C     CHANGE LOAD0 TO BE PAX LOAD AT 50% LOAD FACTOR
      DO 12 J=1,100
      LOAD0(J) = LOAD0(J)/2
      DO 12 I=1,32
      IF(J.GT.24)GO TO 12
      IF(HFACT(I,J).EQ.0)HFACT(I,J) = HFACT0(J)
   12 IF(LOAD(I,J).EQ.0)LOAD(I,J) = LOAD0(J)
C     CALCULATE NEW SIG FROM VOL AND GAFAC
      IF(NAPTSG.EQ.0)GO TO 99
C     PRINT OUT VOLUMES BY APT AND HOUR
      WRITE(6,6667)(I,I=1,23)
 6667 FORMAT(//' LCL HR  0'1114/6X,1214,7X'TOT'//)
      DO 25 J=1,NAPTSG
      L = SIG(J,25)
      K2 = ML(L+1) - 1
      K1 = ML(L)
      NOPS = K2 -K1 + 1
      DO 20 I=1,24
   20 VOL(I) = 0
      DO 22 M=K1,K2
      TY = TA(M)
      I = ((TY/3600) - ZONE(L) + 24)
      LOCLHR = MOD(I,24) + 1
   22 VOL(LOCLHR) = VOL(LOCLHR) + 1
      KGA = GAFAC(J,25)
      KTEMP = 100*(100-KGA)
      MTEMP = KGA*NOPS
      NSTOT = 0
      DO 24 I=1,24
      JTEMP = VOL(I)*KTEMP
      JTEMP = MAX0(JTEMP,1)
      NSVOL(I) = (GAFAC(J,I)*MTEMP)/KTEMP
      NSTOT = NSTOT + NSVOL(I)
      NTOTL(I) = NSVOL(I) + VOL(I)
      SIGX(I) = SIG(J,I)
      LTEMP = (SIG(J,I)*(JTEMP+GAFAC(J,I)*MTEMP))/JTEMP
   24 SIG(J,I) = MIN0(LTEMP,1800)
      WRITE(6,6000)L,APT(L)
      WRITE(6,6668)
 6668 FORMAT(/' HOURLY DEMAND (AIRCRAFT)')
      WRITE(6,6001)SKED,(VOL(I),I=1,24),NOPS
      WRITE(6,6001)NSKD,(NSVOL(I),I=1,24),NSTOT
      NOPTOT = NOPS + NSTOT
      WRITE(6,6001)TOTL,(NTOTL(I),I=1,24),NOPTOT
      WRITE(6,6669)
 6669 FORMAT(/' SERVICE TIME (SECONDS)')
      WRITE(6,6001)SKED,(SIG(J,I),I=1,24)
      WRITE(6,6001)TOTL,(SIGX(I),I=1,24)
   25 CONTINUE
      WRITE(6,6000)LOUT,ALL
      WRITE(6,6669)
      WRITE(6,6001)SKED,(SIG0(I),I=1,24)
      WRITE(6,6001)TOTL,(SIGON(I),I=1,24)
```

```
      WRITE(6,6025)XSLACK
 6025 FORMAT(//' MEAN GROUND SLACK TIME (MINUTES)   ',F5.1/)
      WRITE(6,6026)EXPFAC,KPLVL0,MAXGT0,KSLAK0
 6026 FORMAT(' EXPFAC = ',I5,4X,'PLEVEL = ',I3,4X,'MAXGT = ',I3,
     14X,'KSLACK = ',I2//)
C
C  SET TIME INTERVAL (T1,T2), AND EXAMINE EACH AIRPORT
   99 T2 = TSTART
  100 T1 = T2
      T2 = T1 + INTVL
      DO 200 L=1,NAPTS
      IF(L.EQ.LOUT)GO TO 200
      ISAVE = 0
      DO 103 I=1,NAPTSG
  103 IF(SIG(I,25).EQ.L)ISAVE = I
C  SKIP AIRPORT IF ZERO OR NO SERVICE TIME HAS BEEN INPUT
      IF(ISAVE.EQ.0.AND.IAPT1.NE.ALL)GO TO 200
  105 K1 = ML(L)
      K2 = ML(L+1)-1
      K = 0
C  SELECT M FOR TA GE T1 AND LT T2    PUT TA INTO TAX ARRAY, M INTO MX.
      DO110 M=K1,K2
      TA1 = TA(M)
      IF(TA1.LT.T1.OR.TA1.GE.T2) GO TO 110
      K=K+1
      MX(K) = M
      TAX(K) = TA1
  110 CONTINUE
      IF(K.EQ.0)GO TO 200
      KMAX = K
C PUT TAX INTO TAY ARRAY IN TIME ORDER
      DO 125 KY=1,KMAX
      TAMIN = 1000000
      DO 120 K=1,KMAX
      IF(TAX(K).GE.TAMIN)GO TO 120
      TAMIN = TAX(K)
      KMIN = K
  120 CONTINUE
      MY(KY) = MX(KMIN)
      TAY(KY) = TAMIN
  125 TAX(KMIN) = 1000000
      TY = TA0(L)
C  SELECT SERVICE INTERVAL, SIGX
      IF(ISAVE.GT.0)GO TO 135
      DO 132 J=1,24
  132 SIGX(J) = SIG0(J)
      GO TO 150
  135 DO 137 J=1,24
  137 SIGX(J) = SIG(ISAVE,J)
C  ADVANCE TAY BY MINIMUM SERVICE INTERVAL, RESET TA
  150 DO 160 K=1,KMAX
      LOCLHR = ((TY/3600) - ZONE(L) + 24)
      LOCLHR = MOD(LOCLHR,24) + 1
      ST = SIGX(LOCLHR)
      TY = TY + ST
      IF(TY.LT.TAY(K))TY=TAY(K)
      M=MY(K)
      TA(M) = -TY
      TX = TY
      KIJ = IJ(M) - 1
  155 KIJ = KIJ + 1
```

```
      KTAU = TAU(KIJ)
      IF(KTAU.EQ.NDLEG)GO TO 160
      TX = TX + KTAU
      M1 = LM(KIJ+1)
      IF(TX.LE.TA(M1))GO TO 160
      TA(M1) = TX
      GO TO 155
  160 CONTINUE
      TAO(L) = TY
C     WRITE(6,5000)(TA(M),M=K1,K2)
C5000 FORMAT(10I8)
  200 CONTINUE
C
C  STOP AT 27 HOURS AFTER TSTART
      IF(T2.LT.TSTOP)GO TO 100
C
C  OUTPUT FROM TSTART TO TSTART + 24 HOURS
C
      I1 = TSTART/3600
      I136 = I1*3600
      I2 = I1 + 23
      IX = I1 + 1
      WRITE(6,6060)I1,(I,I=IX,I2)
 6060 FORMAT(/////' HOURLY DELAY (AIRCRAFT-MINUTES)'//1X,'GMT HR'I3,
     111I4/6X,12I4,7X,'TOT'4X,'DOLS'//)
      DO 600 L=1,NAPTS
      DO 400 K=1,25
      DO 400 J=1,4
      COST(J,K) = 0
  400 OUTP(J,K) = 0
      KFLAG = 0
      DO 410 I=1,32
  410 IF(XFORM(I).EQ.L)KFLAG=I
C  CALCULATE DELAYS FOR AIRPORT L
      ML1= ML(L)
      ML2 = ML(L+1) - 1
      DO 500 M=ML1,ML2
      J = IJ(M)
      TX = TS(J)
      HOUR = ((TX-I136)/3600) + 1
      IF(HOUR.LT.1)GO TO 500
      IF(HOUR.GT.24)GO TO 500
      J1=J-1
      KTYPE = CECODE(J)
      KTYPE = MOD(KTYPE,100)
      LOCLHR = ((TX/3600)  -ZONE(L)+24)
      LOCLHR = MOD(LOCLHR,24) + 1
      IF(KFLAG.GT.0)NPAX=(LOAD(KFLAG,KTYPE)*HFACT(KFLAG,LOCLHR))/100
      IF(KFLAG.EQ.0)NPAX=(LOAD0(KTYPE)*HFACT0(LOCLHR))/100
      MTA = TA(M)
      ABSMTA = ABS(MTA)
      IF(MOD(J,2).EQ.0)GO TO 490
C  J ODD, OPERATION IS A DEPARTURE
      IF(J1.GT.0.AND.TAU(J1).NE.NDLEG)GO TO 480
      TY = TX
      GO TO 485
  480 M1 = LM(J1)
      M1TA = TA(M1)
      TY = ABS(M1TA) + TAU(J1)
  485 MAXYT0 = MAX0(TX,TY)
      D(1)= ((ABSMTA - MAXYT0)*EXPFAC)/100
```

```
      D(4)= ((MAXYTO - TX)*EXPFAC)/100
      C(1) =(D(1)*(TCOST(KTYPE) + PCOST*NPAX))/3600
      C(4) =(D(4)*PCOST*NPAX)/3600
      IF(KFLAG.EQ.0)C(4)=(C(4)*BOARD0)/100
      IF(KFLAG.GT.0)C(4)=(C(4)*BOARD(KFLAG))/100
      OUTP(1,HOUR) = OUTP(1,HOUR) + D(1)
      OUTP(4,HOUR) = OUTP(4,HOUR) + D(4)
      COST(1,HOUR) = COST(1,HOUR) + C(1)
      COST(4,HOUR) = COST(4,HOUR) + C(4)
      GO TO 500
C  J  EVEN, OPERATION IS AN ARRIVAL
  490 M1 = LM(J1)
      M1TA = TA(M1)
      TY = ABS(M1TA) + TAU(J1)
      D(2) = ((ABSMTA - TY)*EXPFAC)/100
      C(2) = (D(2)*(LCOST(KTYPE) + PCOST*NPAX))/3600
      OUTP(2,HOUR) = OUTP(2,HOUR) + D(2)
      COST(2,HOUR) = COST(2,HOUR) + C(2)
  500 CONTINUE
C SUM OVER 24 HOURS
      DO 501 K=1,4
      C(K) = 0
  501 D(K) = 0
      DO 503 HOUR=1,24
      OUTP(3,HOUR) = OUTP(1,HOUR) + OUTP(2,HOUR)
      COST(3,HOUR) = COST(1,HOUR) + COST(2,HOUR)
      DO 503 K=1,4
      D(K) = D(K) + OUTP(K,HOUR)
      C(K) = C(K) + COST(K,HOUR)
      COSTS(K,HOUR) = COSTS(K,HOUR) + COST(K,HOUR)
  503 OUTS(K,HOUR) = OUTS(K,HOUR)  + OUTP(K,HOUR)
      DO 510 K=1,4
      OUTP(K,25) = D(K)
      COST(K,25) = C(K)
      OUTS(K,25) = OUTS(K,25) + D(K)
  510 COSTS(K,25) = COSTS(K,25) + C(K)
      IF((OUTP(3,25)+OUTP(4,25)).LT.PLEVEL)GO TO 600
C  CONVERT OUTP DELAYS TO MINUTES AND COST TO DOLLARS AND PRINT OUT
      DO 520 K=1,25
      DO 520 J=1,4
      OUTP(J,K) = OUTP(J,K)/60
  520 COST(J,K) = COST(J,K)/100
      WRITE(6,6000)L,APT(L)
 6000 FORMAT(/1X,I4,1X,A4)
      DO 528 K=1,4
  528 WRITE(6,6001)(E(K),(OUTP(K,J),J=1,25),COST(K,25))
  600 CONTINUE
C
C  CONVERT OUTS DELAYS TO HOURS AND COSTS TO $K AND PRINT OUT
      DO 720 J=1,4
      DO 720 K=1,25
      OUTS(J,K) = (OUTS(J,K)+1800)/3600
  720 COSTS(J,K) = (COSTS(J,K)+50000)/100000
      WRITE(6,6005)
 6005 FORMAT(//1X,'TOTAL DELAY IN HOURS')
      DO 728 K=1,4
  728 WRITE(6,6001)(E(K),(OUTS(K,J),J=1,25))
 6001 FORMAT(1X,A4,1X,12I4/6X,12I4,I10,I8)
      WRITE(6,6006)
 6006 FORMAT(//1X,'TOTAL COST IN THOUSANDS OF DOLLARS')
      DO 738 K=1,4
```

```
  738 WRITE(6,6001)(E(K),(COSTS(K,J),J=1,25))
      STOP
      END
```

APPENDIX B-5. ANFS OUTPUT, ANFS.OUT

	0	0	0	0	15	0	0	0	0	0	0	0	22	566
10 PHL														
TKOF	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
LNDG	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
ADLY	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
BDLY	0	0	0	0	0	0	0	0	0	0	0	5		
	11	0	0	0	0	33	0	0	0	0	0	0	50	622
13 DCA														
TKOF	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
LNDG	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
ADLY	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
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	15	20	0	18	0	0	0	0	0	0	53	869
14 PIT														
TKOF	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
LNDG	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
ADLY	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
BDLY	0	0	0	0	0	0	0	0	0	0	3	0		
	2	1	19	0	19	0	0	0	0	0	0	0	46	630
16 CLE														
TKOF	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
LNDG	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
ADLY	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
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	18	21	0	0	0	0	0	0	0	0	40	675
17 DTW														
TKOF	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
LNDG	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
ADLY	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
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	30	0	0	0	0	0	0	1	0	32	577
18 MSY														
TKOF	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
LNDG	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
ADLY	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
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	0	21	12	0	0	7	0	0	0	42	301

LNDG	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
ADLY	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
BDLY	0	0	0	0	0	0	0	0	0	0	0	0		
	0	0	0	33	0	0	0	0	0	0	0	0	33	273

TOTAL DELAY IN HOURS

TKOF	0	0	0	0	2	1	0	1	0	0	0	3	
	10	12	12	7	5	0	0	0	0	0	0	0	54
LNDG	0	0	0	0	0	0	0	0	1	1	2	9	
	9	9	11	6	3	0	0	0	0	0	0	0	52
ADLY	0	0	0	0	2	1	1	1	1	1	2	11	
	19	21	23	13	8	1	0	0	0	0	0	0	106
BDLY	0	0	0	0	0	0	0	0	0	0	1	1	
	2	4	5	5	5	4	1	2	0	1	0	0	33

TOTAL COST IN THOUSANDS OF DOLLARS

TKOF	0	0	0	0	3	2	1	2	0	0	1	4	
	15	21	15	11	6	0	0	0	0	0	0	0	81
LNDG	0	0	0	0	0	0	0	0	2	2	4	13	
	16	14	18	10	4	0	0	0	0	0	0	0	85
ADLY	0	0	0	0	3	2	1	2	2	2	5	17	
	32	35	33	21	10	1	0	0	0	0	0	0	165
BDLY	0	0	0	0	0	0	0	0	0	1	1	1	
	1	3	3	4	3	3	0	1	0	0	0	0	21

APPENDIX C: USER'S GUIDE TO ANSF

This Appendix provides information on running the Airport Network Flow Simulator (ANFS) and its associated programs. Although the programs have been constructed and tested on the DEC-10 computer system at TSC, they have been written in ASA Level G FORTRAN IV, and employ few machine-dependent features. Hence they should be transferrable to other computers without extensive revision of the FORTRAN statements. For the sake of clarity, however, the file designation convention employed in this description is that of the DEC-10 system: a program or data file is identified by a file name of up to six characters, followed by a period and a three-character file extension name.

The ANFS and its supporting programs and data files have been recorded on 9 and 7-track magnetic tapes. Together with the sample outputs in Appendix B of the present report, they constitute a complete test case for the airport JFK (John F. Kennedy, N.Y.).

The interrelation of the programs and data files is shown in Figure C-1. FORTRAN IV programs are distinquished by the file name extension .F4, and data files by the extension .DAT. The box labelled TTY represents the user's teletype, or, in the case of some batch job systems, a set of user-supplied punched cards. The arrows indicate the flow of data between FORTRAN programs and data files. Table C-1 provided detailed lists of the data and formats corresponding to the ( ) numbers on the flow lines, and Table C-2 provides definitions for the variables.

The data identified as (1), (2), (3), (4), (6), (7) and (8) described more fully in Section 2. of this report. The ANFS outputs (5) are described in Section 4. and Appendix B-5 of this report.

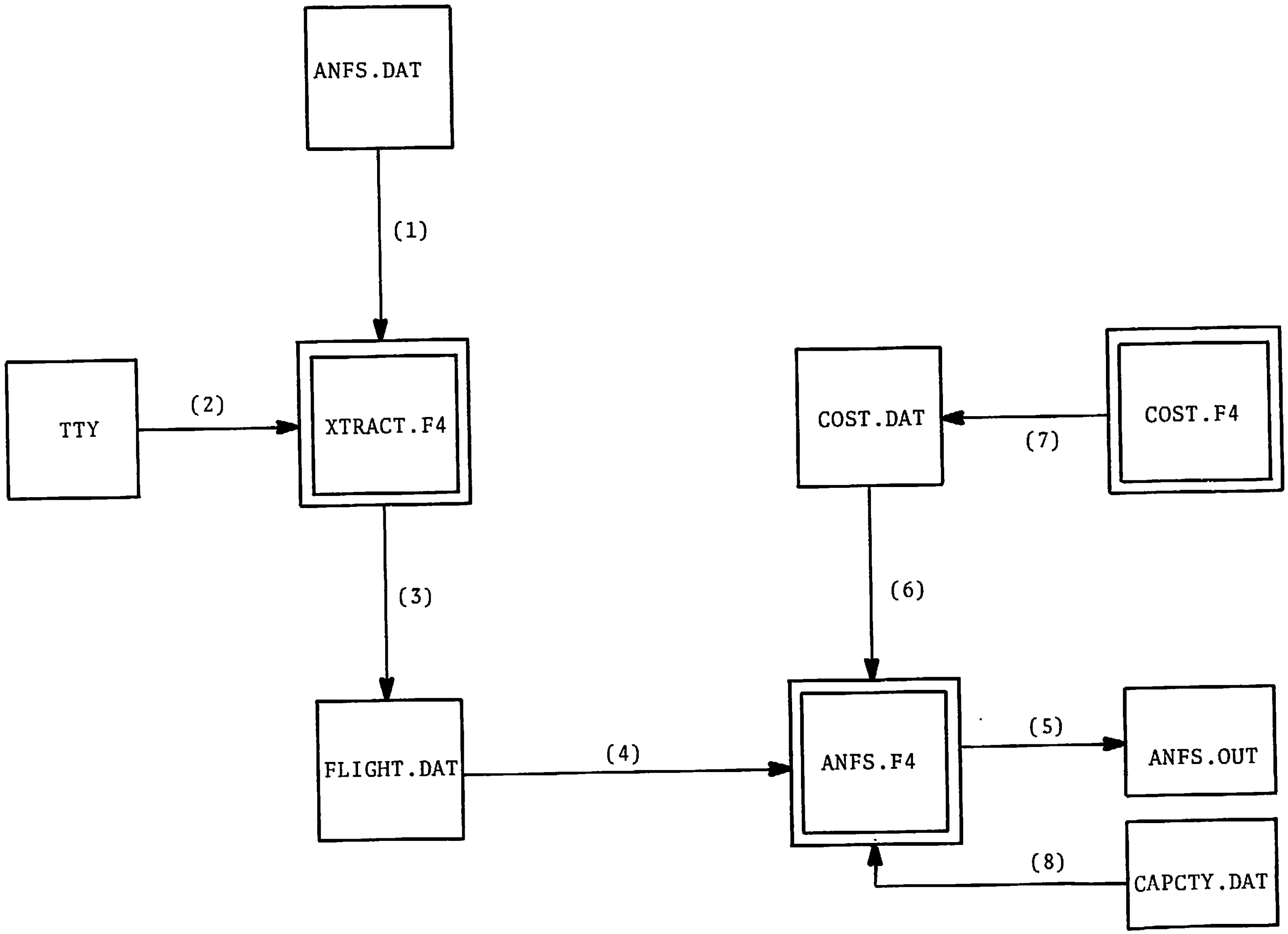

FIGURE C-1. INTERRELATION OF FORTRAN PROGRAMS AND DATA FILES

TABLE C-1: DATA FLOW FOR FIGURE C-1

(1) NAPTS
APT(I), I=1, NAPTS
ZONE(I), I=1, NAPTS
NACFT, NEVNTS
(LM(K), TS(K), TAUCK), CODE(K)), K=1, NEVNTS

(2) IAPT

(3) Same as (1)

(4) Same as (1)

(5) See Appendix B-5

(6) PCOST
TCOST(I), I=1,100
LCOST(I), I=1,100
(LOAD(I,J), J=1,100), I=1,32
LOADϕ(J), J=1,100
(HFACT(I,J), J=1,24), I=1,32
HFACTϕ(J), J=1,24
BOARD(I), I=1,32
BOARDϕ

(7) Same as (6)

(8) EXPFAC

PLEVEL

MAXGT

KSLACK

APT,(SIG(I), I=1,24)
KGA,(GFAC(I), I=1,24)

TABLE C-2. DEFINITIONS OF VARIABLES IN TABLE C-1

(1)	NAPTS	= Number of airports in demand file, ANFS.DAT
	APT(I)	= Three-letter identifier for Ith airport in ANFS.DAT file
	ZONE(I)	= Time zone for Ith airport in ANFS.DAT file, equal to the number of hours difference in time between the airport location and Greenwich
	NACFT	= Number of aircraft in ANFS.DAT file
	LM(K)	= Airport number, I, at which Kth event takes place
	TS(K)	Time at which Kth event is scheduled to take place, seconds from GMT midnight.
	TAU(K)	= Minimum allowable time between event K and event K+1, seconds
	CODE(K)	= Carrier-Equipment code for Kth event (See Section 2.1.3)
(2)	IAPT	= Three-letter identifier for airport for which traffic is to be extracted from the demand file ANFS.DAT

(3) The variables put into the extracted demand file FLIGHT. DAT are the same as the full demand file ANFS.DAT, except that (1) the number of airports NAPTS is fewer (2) the airport identifiers and zones are fewer and in a different order, the first one in the extracted list being IAPT, (3) the number of aircraft NACFT is usually fewer, (4) the number of events NEVNTS is fewer, (5) the event data LM(K), TS(K), TAU(K), CODE(K) are given only for aircraft in the extracted file, which aircraft may be arranged in an order different from their order in ANFS.DAT.

(4) Same as (3) above

(5) See Appendix B-5 and Section 4 of this report.

(6) PCOST = The value of passenger time, ¢/hr

TCOST(I) = Operating cost per hour of take-off delay, aircraft type I

LCOST(I) = Operating cost per hour of landing delay, aircraft type I

LOAD(I,J) = Number of passengers per departure at airport I, aircraft type J

LOADØ = Number of passengers per departure aboard aircraft type, airports other than those specified in LOAD(I,J)

HFACT(I,J)= Hourly load factor, passengers per departing seat at airport I, local hour J, normalized to average load factor for all hours at airport I.

BOARD(I) = Percentage of continuing passengers, relative to departing passengers, for airport I.

BOARDØ = Same as BOARD(I) for airports not covered by index I.

(7) Same as (6) above

(8) See Table 2.2 in text

<u>ANFS.DAT</u> This is the master file of demand described in Section 2.1.3 of this report. It corresponds to the Official Airline Guide flights for February 16, 1976. A sample of the file is given in Appendix B-1; this file follows the formats of Table 2.1. It will be noticed that the zones are listed in the same order as the 665 airports, including the arbitrary zone 99 for the airport OUT. The 5,402 aircraft itineraries are comprised of 38,222 events. Since each flight leg comprises one departure event and one arrival event, the file has 19,111 flight legs. All flights listed in the OAG for the given date that have one or more events at the listed airports are included in the ANFS.DAT file. Creation of the ANFS.DAT

file for a different day is possible by re-running the programs employed to create it.

XTRACT.F4 — This FORTRAN program performs the function described in Section 2.1.4 of this report, i.e., it extracts from ANFS.DAT only those flights that go to, from, or through the airport specified at the user's TTY. This airport input is labelled (2) in Figure C-1.

FLIGHT.DAT — The output of XTRACT.F4, labelled in Figure 1 as (3), is stored in the file FLIGHT. DAT. It has the same format as ANFS.DAT, but is usually much shorter. The first airport in the APT and ZONE lists, more-over, is the airport that the user has inputted to XTRACT.F4 from his TTY, and is the airport for which the extraction was performed.

ANFS.F4 — The ANFS.F4 is the simulator itself, and is described extensively in Section 3. of this report. A listing is given in Appendix B-4.

ANFS.OUT — The output of the simulator is described in Section 4. of this report. A sample for JFK is given in Appendix B-5.

COST.DAT — This file provides cost, passenger load, and airline and equipment information needed in ANFS.F4 to calculate the cost of delays. It is described more fully in Section 2.3 of this report. A sample of COST.DAT is not given, because it is redundant with the FORTRAN program COST. F4 that generates it.

COST.F4 — This program generates COST.DAT, the cost data file used by ANFS.F4. It is decribed in Section 2.3 of this report, and a listing is given in Appendix B-3. The cost and related data are contained in DATA statements of the program. It is necessary to modify these data statements to alter costs, loads, etc.

CAPCTY.DAT — The processing rates, non-scheduled traffic percentage, and non-scheduled traffic hourly pattern are stored in this data file. The format and exact definition of the data are given in Section 2.2 of this report. A sample of CAPCTY.DAT is given in Appendix B-2.

In order to run the simulator, the user should first compile and run XTRACT.F4, entering at the TTY the three-letter code of the airport for which he wishes itineraries extracted. This will produce the proper FLIGHT.DAT file, with the specified airport first on the APT and ZONE lists. Next, the user should create the proper CAPCTY.DAT file. It is recommended that he specify capacity for the airport for which the FLIGHT.DAT file was created, and follow this immediately by the airport ALL showing ϕ for service intervals and non-scheduled traffic. This will allow landing and takeoff delays only at the extracted airport, and B-delays at airports connected to it by traffic.

Finally, the user may compile and run ANFS.F4. It is not necessary to regenerate the COST.DAT file unless the cost data in COST.F4 has been changed.

If it is desired to make a test run, the user should create the FLIGHT.DAT file for John F. Kennedy airport by entering JFK at the TTY when running XTRACT.F4. If the COST.DAT file is that given in Appendix B-3., and if the CAPCTY.DAT is that given in Appendix B-2., second page, then compiling and running ANFS.F4 will yield the output given in Appendix B-5.

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