FAA Air Transportation Center of Excellence
in Operations Research
Research Report RR-97-09

DEVELOPMENT OF AN ON-SITE GROUND OPERATIONS MODEL

FOR

LOGAN INTERNATIONAL AIRPORT

Final Report
December 1997

Bertrand DELCAIRE - Eric FERON
Massachusetts Institute of Technology
Cambridge, MA 02139

Preface

This final report concludes a 10-month research project with the Massachusetts Port Authority (Massport) on the development of a ground operations model of Logan International Airport. This work had two main objectives:

(1) Assessing the current ground operations modeling capabilities of SIMMOD, the simulation software developed by the FAA to model ground and airspace operations.

(2) Inquiring into the potential utilization of a SIMMOD model to support Logan airport *short-term planning*. By short-term planning, we consider the projects including minor modifications of the airport layout and typically concerning the disruption caused by civil works handled by Massport or by changes in the gate management that may affect operations.

This report is divided in five chapters. The first chapter (p. 3) provides an overview of the principles of SIMMOD modeling. The second chapter (p. 19) lists the assumptions that were made in the development of the model for Logan Airport. The third chapter (p. 81) contains the results of a first case study on the use of this model in short-term planning, namely on the assignment of gates to airlines. The fourth chapter (p. 111) concentrates on a second case study that focused on the impact of planned construction in a key area of the taxiway network. We end this report with an evaluation of this software and some proposals as to how it should be handled by NEXTOR (p. 153).

This report documents research undertaken by the National Center of Excellence for Aviation Operations Research, which was supported by the Federal Aviation Administration (Research Grant Number 96-C-001) and by the Massachusetts Port Authority (Massport). This document has not been reviewed by the Federal Aviation Administration (FAA) or Massport. Any opinions expressed herein do not necessarily reflect those of the FAA, Massport or the U.S. Department of Transportation.

Chapter 1:
A general presentation of SIMMOD models

1. Content

This report gives a general perspective on the development of a SIMMOD model for the ground operations of Logan International Airport. We review the major components of the software used and explain how to develop and modify such a model.

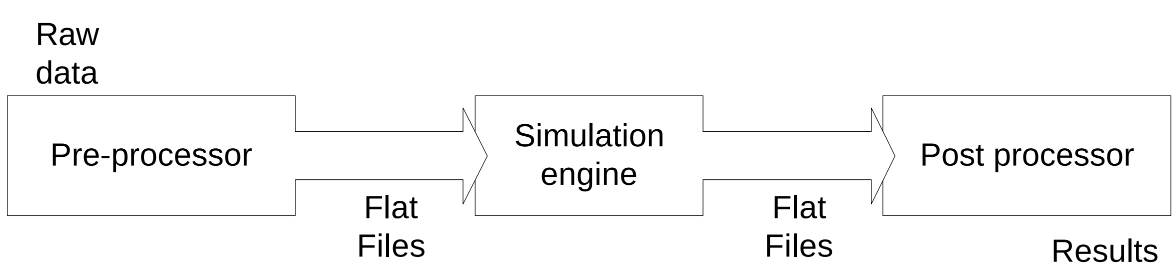
2. Components of the software

The software used in this simulation is SIMMOD 2.2 for Windows. Because of changes in FAA's support, this version uses components of various origin and quality. In any version, it is composed of three major programs:

— The pre-processor, designed to convert raw data into the appropriate input "flat files" used by the simulation engine.

— The simulation engine, that produces output files by simulating the airport thanks to the data contained in the input files.

— The post-processor, that creates animations and reports from these output files.



The core of the software is the simulation engine. It has been improved in 1996 so that the so-called version 2.2 can be considered as quite powerful and flexible. However, both pre and post-processors have not received additional funding from the FAA since 1992. This means that they are plagued with poor DOS graphics.

1. The Pre-processor

The pre-processor is designed to facilitate the construction of the input files for the simulation engine. It can perform three functions:

1.1 Network builder

Without pre-processor, the most time consuming task consists in building the ground and airspace networks on which airplanes will travel. Nodes and links are defined by their coordinates, lengths and direction, this supposes a lot of calculations and measurements.

That is the reason why all versions of SIMMOD contain a network builder. In general, it is possible to superimpose a CAD file over the network and click and drag to create nodes and links.

1.2 Record editor

The second function of the pre-processor deals with the edition of the input files. The operator can edit and modify the data presented in a clear way.

1.3 Events generator

The biggest file in a SIMMOD simulation is the event file listing all the arrivals and departures on the airport. That is the reason why programs have been designed to generate them automatically from the OAG for instance.

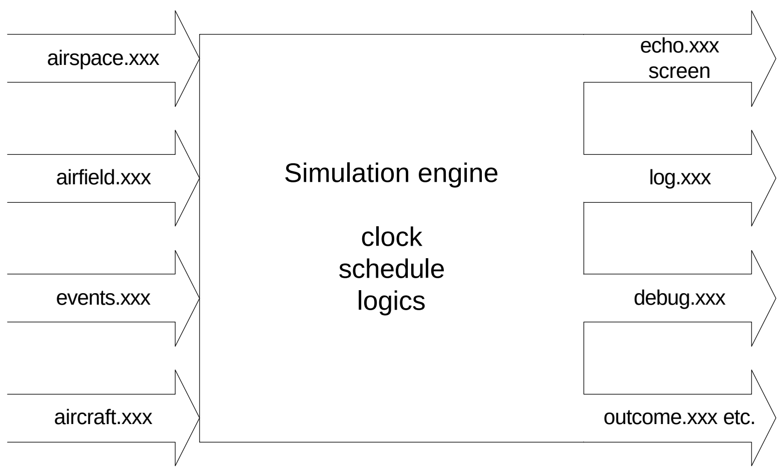
Simple manipulations with Excel are often sufficient to build the event file.

These components are additional layers on the simulation engine and they may introduce undesirable data in the files they generate. For example, LeTech’s network builder assigns 0 as the maximum number of aircraft allowed on a link if it is too short, thus making it impossible for any aircraft to go through. Any data generated by these programs has to be examined in details. It is thus often better to modify the flat files directly with any text editor (Word, Notepad, etc.).

2. The simulation engine

The simulation engine is a program that generates various outputs based on inputs defining the airport and the events happening on it. It contains specific logic to handle all the needed operations of aircraft in the model: circulation along airspace routes, conflict resolution, landings on runways, length of landing, choice of exit, choice of taxiways to get gates, choice of the gate, time spent in the gate, choice of taxiways to get to the departure queue for the appropriate runway, take-off and circulation in the airspace. It is difficult to find rules actually used by FAA towers that can not be modeled in the latest version of SIMMOD.

Typically, we consider the following files:



2.1 Input files

A simulation is fully defined by four input files. These files contain all the information that the simulation engine needs to model the movement of aircraft in the system. The data are grouped under various headings ("records") describing specific parts of the system.

For example, the airspace file for one of the simulations of Logan Airport contains the following numbers:

```
PROCEDURES Def time sep = 55 sec, dist sep = 3.00 miles
1 ARR MIT 22R 1 ;
  1 2 3 ; 50 ; 2.0 ;
2 ARR MIT 4L 103 ;
```

```
  1 2 3 ; 50 ; 2.0 ;
3 ARR MIT 22L 140 ;
  1 2 3 ; 50 ; 2.0 ;
```

This must be read, according to the definition of the PROCEDURES record:

- In the airspace, aircraft are separated by 55 seconds and/or 3 nautical miles by default.
- The first procedure is for arrivals on the airport “MIT” on the runway 22R (that must, of course, be defined somewhere else).
- The landing roll will begin at node No. 1.
- This procedure concerns the 3 groups of aircraft considered in the airspace.
- A separation of 50 seconds and/or 2 miles will be applied between aircraft arriving according to this procedure.

A SIMMOD simulation uses the following 4 files defining to define the system:

- The **airspace.xxx** file contains all records defining the behavior of aircraft in the airspace: classes of aircraft in the sky, structure of the airspace, routes, procedures to take-off and land on various airports.
- The **airfield.xxx** (ground.xxx) file defines the geometry of airports, their runways and departure queues, gates, preferential taxipaths and all other aspects of an operating airport.
- The **events.xxx** file lists all the events that happen during the simulation: not only arrivals and departures, but also changes in weather or configuration used, etc.
- The **aircraft.xxx** file identifies the main aircraft that are currently used and provides technical data on them.

2.2 Output files

The simulation engine can generate a huge amount of data on all the phenomena that happened during the simulation. We generally examine these files in the following order:

- The **echo.xxx** file lists the results of the processing of the input files. If the simulation engine has problem with the input files, it stops at this point and we can identify the problem in this file.

```
Example of echo.xxx:
Finished writing the port plan and interface node data...
Creating 9 departure queues (maximum external route/link
numbers are 33/51
Transferring data for queue #1, QUEUE9, at MIT
Reserving DQ.LNK.BLOCK.ARRAY (1,*) as 1
```

— The **screen** is the second output to examine. During the simulation, information is displayed on the screen and gives clues on what is happening.

— The **log.xxx** lists all the internal operations performed by the simulation engine. It allows the identification of the problems that have happened with the input files but did not prevent the execution of the simulation.

```
Example of log.xxx:
1 06:30:00; BE 1322_AMIT will roll to the end of MIT runway
33R at node 14; ml=2500, altml=2500, tl=2447 (RWY.300-000)
1 06:31:38; BE 1323_AMIT will roll to the end of MIT runway
33R at node 14; ml=2500, altml=2500, tl=2447 (RWY.300-000)
```

— The **debug.xxx** is even more useful for this kind of operation. It generally states clearly why the simulation engine did not perform the whole simulation. Sometimes it was not able to move the aircraft from its gate to the runway, sometimes the simulation gets in a gridlock that amplifies, etc.

```
Example of debug.xxx:
BEGIN DUMP OF TAXIPATH DATA FOR PROBABLE GRIDLOCK SITUATION AT
NODE 209
ITERATION #1 OF 06/04/1997 AT 14:08:36 (0)  mit/mit0040
LINKS CONNECTED TO THIS NODE, CAPACITIES, AND OCCUPANCIES ARE:
249/1/0  250/2/2  254/1/1  377/1/1  405/1/0  406/1/0  534/1/0
```

— The valuable part of the output files is found in files such as **history.xxx** or **outcome.xxx**. These files provide detailed information on the position of aircraft in the system at every time. It is on them that the pre-processors generate animations or reports. Typical outputs include also the **inprep.xxx** file and the **report.xxx** file.

```
Example of outcome.xxx:[1]
IN UA 1574_AMIT   .11700 32 12 35 0 ARR
HS UA 1574_AMIT   .11700 32 0.
NM UA 1574_AMIT   .11771 31   0.
RL UA 1574_AMIT   .11771 79 0   0.

Example of History.xxx:
IN   .117000 1 32 UA 1574_AMIT 12 35 ARR
NM   .117000 1 32   .000714 31 140.0   0.
RL   .117714 1 79   .000520 78 33L 10
```

[1] IN means that the aircraft enters the simulation. HS means that the aircraft holds at an airspace node because the next sector is full. NM means that it travels at the specified speed on an airspace node. RL means that it begins a landing roll.

```
RL   .118234 1 78   .003838 77 33L 10
```

It must be clear at this point that when we have made sure that the simulation has worked properly, we can used the **outcome.xxx** files to generate animations of the airport and reports.

Thanks to the TRACE function in the events.xxx file, it is possible to require the generation of reports on specific points of the simulation: queues, occupation of runways, etc.

3. The post-processor

When the simulation has been successful, it generates interesting output files listing relevant data for the study. These files can be converted into reports and animations within the post-processor. Animations are especially useful since they allow a visual check of the conclusions that can be reached from the report. They allow also a very simple validation of the simulation: are in deed aircraft following these taxiways? Are they taking this runway? Etc.

The PC post-processor performs the following functions:

3.1 Animation:

The animation program uses a binary file that must first be created. Once this file is created, it is possible to show the animation on any computer that has the animation program without anything else. It is normally possible to display a CAD layout of the airport on the network.

3.2 Statistical report generation:

The pre-processor can generate useful statistical reports.

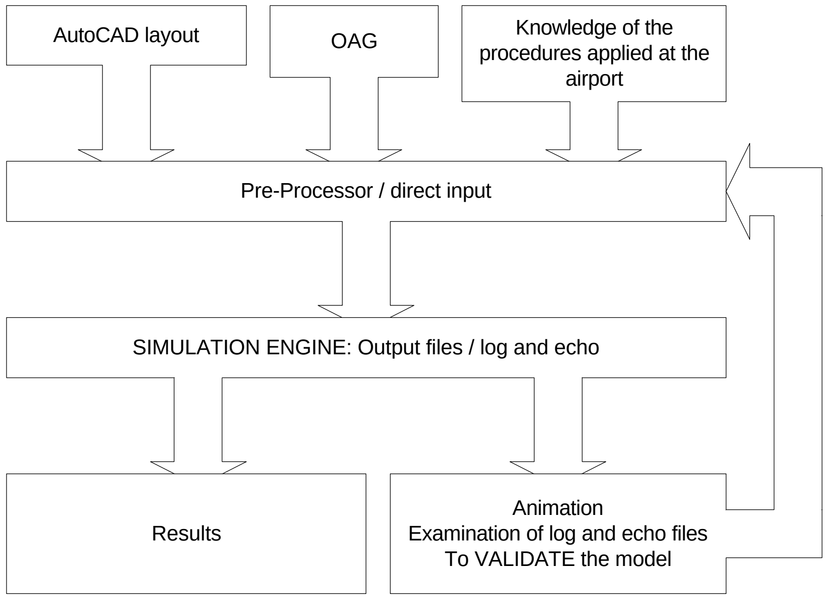
3.3 Graphs generation:

Related graphs should also be available.

In any case, results are most of the time obtained through the manipulation under Excel of the output flat files.

4. Conclusion: the making of a SIMMOD study

The following flowchart sums up the process involved in the creation of a SIMMOD study:



3. How to make a SIMMOD model?

It is now clear that the development of a study is based on the input files. The way by which data is entered into the simulation drives the research for information and the modifications that have to be made to these files in order to simulate a specific feature.

For instance, SIMMOD uses landing and take-off roll probability distribution. This means that data in terms of runway occupancy time or exits used on the airport have to be converted into probabilities of this type to *realistically* simulate the airport.

A **record** describes each part of the system. There are required records and optional ones. Optional records describe more subtle phenomena that happen in the system, like change of plans or deicing. The annex describes the function of all data records.

Records are input following very precise rules given in the *flat files description*. For instance, the Nodes record describing airspace nodes has the following structure:

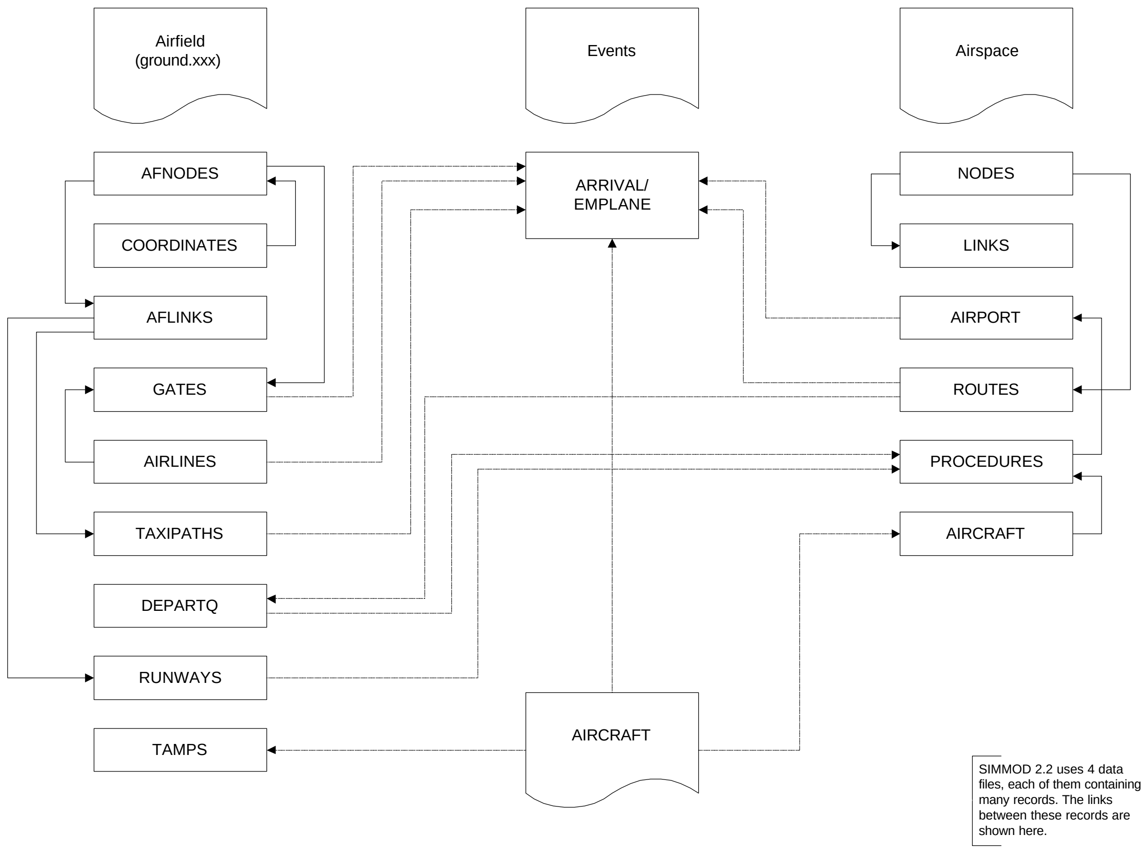
```
NODES com DefSep com MaxNod com
Num Nam Alt Strat Opt Dist Cap HStrat HStck ; Coor com
(and so on for additional records)
```

that must be read, in one of the Boston files:

```
NODES The default separation is 3.0 miles, Max nodes: 30
NodeNo Name Altitude Strategy ArrStrat MIT Cap HoldStrat HoldStak ; x y
3     NODE_3      00100 1 0  3.0   1 1 1 ;     0.203393     1.136553
4     NODE_4      00015 1 0  3.0   1 1 1 ;     0.124343     0.905331
5     NODE_5      00015 1 0  3.0   1 1 1 ;     0.341073     0.761722
```

where	Means	value in the record
com	Comments	The default sep…
DefSep	Default intrail separation	3
MaxNod	Maximum number of nodes	30
Num	Node identification number	3 …
Nam	Node name	NODE_3
Alt	Node altitude, in feet	100
Strat	A value indicating the level I control strategy for aircraft approaching this node	1 [i.e. QFIFO]
Opt	Arrival strategy option flag, zero or one	0
Dist	Initial setting for node intrail separation, in nmiles.	3.0
Cap	Maximum number of aircraft that can be held at this node	1
Hstrat	Holding strategy number at this node	1
HStck	Holding stack type at this node	1 [Holding stack if hold further]
Coor	Node coordinates, in nmiles or longitude/latitude. This field is used only for animation graphics and fuelburn.	.2033 1.13655

It is important to know the links between all these data records because the modification of a record sometimes implies the modification of another record. Between the required records, the links are the following:



For example, routes are assigned to departure queues. Thus, a modification of the route structure must be translated into the departure queues. Then, these departure queues are used to define the procedures. Etc.

According to these diagrams, here are the tasks to perform to add a new runway to the airport:

1. Create the corresponding ground nodes and links, either thanks to the pre-processor or manually in the input files (records AFNODES, COORDINATES and AFLINKS).
2. Create the runway in itself in the RUNWAY record.
3. Define the corresponding ROUTES (this may require adding airspace LINKS). Create the Departure queue for these routes using this runway.
4. Define the PROCEDURES that use this runway and its departure queues.
5. Add these procedures to the airport plan at the corresponding interface node.
6. Select departures and arrivals to use the corresponding route.
7. Debug the model through the analysis of the output files (echo, screen, debug).

8. Generate the animation and modify the input files in order to achieve an *apparently valid* simulation.
9. Examine the reports and draw conclusions from them.

As a general rule, since it is extremely easy to build a simulation that *looks realistic but is not*, as much time as possible must be spent on the validation of the model (task 7 and 8).

4. Annex: data records input in SIMMOD 2.2

		Description of the data records
1. AIRSPACE		
Required	AIRCRAFT	The AIRCRAFT data record is used to define air traffic control characteristics by groups of aircraft models, weather parameters, link types by speed, holding stack types by times and speeds, and intrail separation distances between aircraft of different groups.
	AIRPORTS	This record is used to define airport characteristics from an airspace perspective. Data input includes ceiling, runway visual range and interface node characteristics including: airport plans and arrival and departure procedures for each interface node.
	LINKS	The LINKS record is used to create airspace links and define aircraft movement on them. User-defined attributes include passing, sequencing, and number of aircraft per link.
	NODES	The NODES record is used to create airspace nodes and define their characteristics. Characteristics include control strategies, holding strategies, separation distances, and maximum aircraft per airspace node.
	PROCEDURES	The PROCEDURES record defines steps a transitioning aircraft follows for approach/landing or takeoff/ascent, including runway occupancy times. Related procedures (using the same runway or closely spaced, parallel, or crossing runways) should be defined together so the simulation will resolve conflicts.
	ROUTES	The ROUTES record is used to create routes, describe their attributes, and set the sequence of flight path nodes through which aircraft travel, including those required to recover from a missed approach.
Optional	FLOW	The FLOW record defines the level III control strategy used to prevent airspace congestion. Level III control places strategic constraints on traffic flow by imposing separation distances and speed limitations on aircraft entering the modeled airspace. This level of control is optional.
	LATENESS	The LATENESS record defines the lateness probability distribution data referenced by the ARRIVAL and EMPLANE records in the Event file. This allows the user to apply a random lateness value to arrival or emplane flights beyond the time specified in the ARRIVAL and EMPLANE Event records. Note: A negative lateness value cannot be entered since simulations cannot run backwards in time.
	METERING	The METERING record is used to assign routes between post nodes and meter nodes. Level II control strategy resolves airspace conflicts by means of a look-ahead to the next node on the aircraft's route, and applying controls to alleviate the conflict. This level of control is optional.
	PATTERN	The PATTERN record is used to create and define the touch-and-go patterns aircraft will travel when touch-and-go is requested by an aircraft. This level of control is optional. Not supported in Simmod 2.2
	PLANS	Defines the route transitions when the airport plan changes. If no inputs are specified in this category, a default PLAN #1 will be generated automatically. Under the default plan, no route transitions will take place, and only one plan may be specified in a SETPLAN event.
	SECTORS	The SECTORS record is used to create and define sectors for the level II control strategy. This record also defines parameters for gathering periodic sector occupancy statistics. This level of control is optional.
	STAGGER	The STAGGER record is used to define the characteristics of the stagger control strategy. This data input file uses nodes, node mates, and the lead/trail separation distance between two aircraft types. This level of control is optional.
	TNGSET	The TNGSET record is used to define the touch-and-go patterns used by an aircraft when touch-and-go has been requested. This record allows an aircraft to perform touch-and-go on multiple patterns. This level of control is optional.
	WINDSETS	This record allows the user to create a list of airspace links that are subject to the same wind effects.
Control	COMMENT , GO, PRINT	

2. AIRFIELD

Required	AFLINKS	The AFLINKS record is used to create airfield links and define aircraft movement characteristics on them. SIMMOD has been modified to only consider an aircraft's model type when determining its movement throughout the airfield, rather than the aircraft's weight.
	AFNODES	This record is used to list the airfield nodes at each airport. A range of nodes may be specified.
	AIRLINES	The AIRLINES record is used to define airlines, their function, and the airports where each airline operates.
	COORDINATES	The COORDINATES record is used to assign a latitude and longitude to airfield nodes. As a minimum, this record must be provided for nodes that mark ends of runways, departure queues, and for either gate or apron nodes if the list of links to the apron node is given on the GATES record.
	DEPARTQ	The DEPARTQ record is used to define an airfield node where aircraft queue to depart on a runway. Additionally, SIMMOD allows the user to set departure queue time thresholds, queue size, routes for each queue, and areas.
	GATES	The GATES record is used to define gates and their characteristics. If STAGING is used, the GATES data record must be input after the STAGING data record.
	RUNWAYS	This record is used to defines runway system characteristics.
	TAMPS	Defines landing and takeoff characteristics for aircraft groups and gate occupancy time distributions.
	TAXIPATH	This record is used to define taxipaths on the airfield. If a flight usually follows a specific path between gate and runway, this path can be defined. By assigning this path name to the flight in the Event file, the program will schedule this flight to follow that specific path. This record must always be included in the input for airfields, but if the user chooses to have the program select the most economical/optimal path for each flight, only the first line is required.
Optional	AFPLANS	The AFPLANS record defines taxipath transitions accompanying airport plan changes. If no inputs are specified in this category a default PLAN #1 will be generated automatically. Under the default plan, no taxipath transitions will take place and only plan 1 may be specified in a PLANS (Airspace file) data record. This level of control is optional.
	BANKS	This optional record is used to define flight banking data characteristics for each airport.
	CHECKPOINTS	This optional record is used to model checkpoints on the airfield.
	CONCOURSE	This optional record is used to reference a group of gates; a concourse; rather than a single gate.
	CONGESTION	This optional data record lists the links that comprise the congestion area, defines the congestion area's threshold level, and lists the gates using the congestion area.
	DCONGESTION	The DCONGESTION record is used to create departure congestion areas. The input includes threshold levels, links that make up each congestion area, and departure queues that use the congestion area. This level of control is optional.
	DEICING	The DEICING record is used to create deicing areas for departing aircraft. User-defined parameters include links entering and exiting the deicing area, aircraft that may enter or queue, time deicing is effective, and designating a secondary deicing area.. This level of control is optional.
	DEPBLOCK	This optional record allows arrivals to block aircraft departing the gate area when the arrival taxis to the gate area. Users may specify a list of gates from which departures are blocked while an arrival taxis to that gate. When the taxiing aircraft reaches its gate, the obstructing condition is removed, allowing blocked aircraft to leave their gate.

DSDPATH	The DSDPATH record is used to more realistically model cul-de-sacs and gate terminal traffic. DSDPATH (Dynamic Single Direction Path) allow users to define a group of links as a path which may have multiple entry and exit points. SIMMOD permits the user to restrict aircraft to taxi in one direction at a time on this group of links. The designated direction of the path depends on the direction of travel of any aircraft already on the links. Oncoming aircraft are held until the possibility of head-on encounters is eliminated. This level of control is optional.
DSTAGING	The DSTAGING record is used to define the ground location where departing aircraft wait when the number of aircraft in a departure queue, plus the number of aircraft converging to that same departure queue, exceeds the user-specified level. In SIMMOD, all aircraft go to a departure staging area unless the TAXICHKPT option is enabled.
EXITS	This optional record is used to define specific runway/gate combinations that force a particular ground group to use a fixed percentage of a runway's length during the landing roll.
GATERWY	This optional record supplements SIMMOD's taxipath optimization logic. Users may use this record to specify taxipaths between concourses (or gates) and runways. This record is used when the gate assignment is not known in advance; SIMMOD references a GATERWY record to find a taxipath or partial taxipath that is suitable for that gate.
GATETOW	This optional record supplements SIMMOD’s taxipath optimization logic. Users may use this record to specify a taxipath between concourses (or gates) and towing areas. In addition, this record is used when a towing area is not specified in Events records. This record must be input if towing is to be enabled.
GATEUSE	This optional record supplements the gate blocking in the GATES record. Users can assign specific gate blocking by aircraft model (or TAMPS group) as well as specify which aircraft models (or TAMPS groups) are affected by the blocking assignment.
GLOBAL	This optional record defines global variable settings used throughout the simulation.
HOLDCYCLE	This optional data record defines holdcycle characteristics. If STAGING is used, the HOLDCYCLE data record must be input before the STAGING data record.
METALINKS	Metalinks are sets of connected airfield ground links. Within a METALINK, one and only one, aircraft is allowed to taxi at any given time. This prevents gridlock, particularly in the gate-to-apron taxipath area, or any other heavily congested areas with low aircraft throughput capacity. This level of control is optional. NOTE: This feature has been superseded by DSDPATH. With a capacity set to unity, DSDPATH provides the same function as METALINKS. Although METALINKS continues to be supported for the benefit of older applications, it is recommended that METALINKS be gradually phased out by substituting DSDPATH in all new applications.
PPBACK	This optional data record is used to list aircraft model numbers that can only push-back. This record must be used in conjunction with the PPTIME record to enable pushback.
PPTIME	This optional data record is used to define the power/push-back probability distribution. Aircraft models that pushback must be input into the PPBACK record.
PROBDIST	This optional data record is used to modify the landing- and takeoff-roll distributions for individual runways, unloading- and boarding-time distributions for individual gates, and deicing-time distributions.
RWYCROSS	This optional record is used to model runway crossings from hold line to hold line. This record is also used to assign specific times and characteristics to each runway crossing.
SLOTWINDOW	Defines the minimum and maximum slot time values to be used with ARRIVAL, EMPLANE, SETSLOT, MULTARR and MULTDEP records in the Events file. This data record is optional.

	STAGING	This optional data record is used to define a staging area where aircraft wait for a gate to become available. Staging checkpoints are now modeled in the CHECKPOINTS card.
	TAXICHKPT	This optional record is used to specify ground nodes where aircraft can evaluate their taxipath and choose another taxipath if congestion or projected conflicts are likely. Previously, aircraft chose a taxipath at the departure staging area and were unable to reevaluate the decision, even if events made another taxipath optimal.
	TOWING	This optional data record is used to define ground nodes as towing areas. The towing logic can be used by arrivals, departures, and arrival and departure turnarounds. Arrivals, after unloading at a gate, tow to a towing area to release the gate. Departures enter the simulation at a towing area and tow to a gate where they become normal departure events. Arrival turnarounds unload at a gate and then tow to a towing area where they wait until their turnaround departure time. Departure turnarounds start at a towing area, tow to a gate, and depart for the destination airport where they become arrivals that use towing logic. If towing is used in an Events record (ARRIVAL, EMPLANE, MULTARR, and MULTDEP) and the towing identification number is not specified, SIMMOD will look here for the appropriate towing area. Therefore, towing areas must be specified in this record if they are not specified in Events records.
	UTURN	This optional record enables users to model runways where aircraft must make a U-turn. Departures can use this logic when the aircraft's entry point onto the runway does not permit it enough room for takeoff. The departure can taxi until it has enough room for its takeoff roll, make a U-turn, and then depart. Arrivals can use this logic when they pass their runway exit point when landing. An arrival can make a U-turn on the runway after its landing roll and return to its exit point. Aircraft which U-turn on a runway increase the amount of time they occupy the runway. Users should edit their time separation values in the PROCEDURES record (Airspace file) to compensate for the increased runway occupancy time. Failure to do so could result in a high number of missed approaches.
Control	COMMENT , GO, PRINT	

3. Aircraft

This section describes the basic aircraft data requirements. There is one data record.

4. Events

	ARRIVAL	This record is used to define aircraft that enter the simulation en route from an origin point not in the modeled airspace. Depending on the route(s) specified, these aircraft may approach and land at a modeled airport, pass through the airspace on their way to another destination, or land and turn around for a subsequent redeparture.
	EMPLANE	This record defines aircraft that enter the simulation prior to departure from an airport in the modeled airspace. Depending on the route specified, these aircraft may approach and land at another modeled airport or they may exit the airspace toward an onward destination.
	MULTARR	This record is used to define aircraft that enter the simulation en route from an origin point not in the modeled airspace. The MULTARR event is similar to the ARRIVAL event except that: (1) several aircraft are generated randomly over a specified time interval, and (2) there is no provision to turn a MULTARR aircraft into a subsequent redeparture, as in the ARRIVAL event. Depending on the route specified, these aircraft may approach and land at a modeled airport, or they may pass through the airspace on the way to an onward destination. MULTARR flights are not affected by cloning initiated by a SETCLONE event.
	MULTDEP	This record is used to randomly generate departure events over a user-specified time interval.

Network adjustment	CONTROL	If you are running SIMMOD on an IBM mainframe or VAX computer the second record (after RUNTITLE)in the Event file must be a CONTROL record. The following fields control: (1) the total number of replications to be made, (2) the initialization of the random number streams, and (3) the initial iteration number for this run.
	SETAFLINK	This record is used to modify ground link parameters during the simulation.
	SETCLONE	This record is used to modify cloning probabilities for one or more airspace routes at any time during the simulation.
	SETGATE	This record is used to modify the airline(s) permitted to use the specified gate and the arrival unloading and departure boarding distribution(s) at any given time during the simulation.
	SETINJ	This record allows the user to inhibit airspace injections.

	SETLINK	This record is used to modify parameter values for one or more airspace links at any time during the simulation.
	SETMETER	This record is used to modify intrail separation constraints for metering through a post node at any time during the simulation.
	SETNODE	This record is used to modify several parameter values for one or more airspace nodes at any time during the simulation.
	SETPLAN	This record is used to specify the airport plan and runways in use.
	SETPROC	This record is used to inhibit selected arrival and departure procedures at any time during the simulation.
	SETROUTE	This record is used to modify intrail separation constraints along a single route at any time during the simulation.
	SETRWY	This record is used to modify the landing- and takeoff-roll distribution used for a runway at any given time during the simulation.
	SETSECT	This record is used to modify maximum sector occupancy values for one or more airspace sectors at any time during the simulation.
	SETSLOT	This record is used to turn the slot-time logic on or off at an airport during the simulation. SETSLOT logic will try to maximize the number of aircraft that successfully depart within their specified slot window.
	SETTNG	This record is used to control touch-and-go during the simulation. When the touch-and-go flag is on, aircraft will perform touch-and-go and exit out the eject node of the touch-and-go pattern.
	SETWIND	This record is used to define wind characteristics.
	SETWX	This record is used to define weather parameters for an airport.
	SETXNG	This record is used to define runway crossing parameters.
Simulation control	COMMENT	
	END.SIM	This event record is used to end the simulation at a specific time. One event of this type must be in the event stream to terminate the simulation properly.
	ENDSEED	This event record is used to end the simulation seed period. This event may be omitted if no seed period is desired for the simulation run. Otherwise, exactly one ENDSEED event should appear in the event stream.
	PRINT	
	PER.REP	This record is used to control the production of airfield and airspace activity reports.
	RUNTITLE	If you are running SIMMOD on an IBM mainframe or VAX computer the first record in the Event file must be a RUN TITLE record (followed by the CONTROL record).This record names and describes the simulation run in one 70 column record. This must be the first record in the Events file.
	TRACE	This record is used to control the simulation log, report, graphic and fuelburn post-processor files; and certain debugging outputs at various times. It is possible to control individual write statement messages, or groups of related messages, as described below.

Source: flat files' description available online.

Chapter 2: Assumptions of the SIMMOD Models

1. Content

Background of the model

The following chapter reviews the data that have been used to model the ground operations at Logan International Airport under two of the main runway configurations. The model has been developed for the simulation engine SIMMOD Version 2.2.23.11 developed by the FAA, in the version corrected by Eurocontrol (so-called “version f”). This version implements all the records we need according to the way they are described in the version 2.2 Reference Manual (5/96). Please refer to this manual for the exact definition of each record.

This model is aimed at **quantifying the impact of microscopic modifications of the ground operations** at the airport. Since it considers most aspects of these operations, it can be used to answer various questions of interest. With respect to other existing simulation models of the airport, this model is potentially more detailed in its scope; it is thus more useful when considering small details of the operations. It has been specifically tailored to provide results for two case studies on:

(1) The impact of the current locations of airlines at the various terminals;

(2) The impact of construction in the South West corner of the airport.

These two case studies are discussed in the two next chapters.

Purpose of the manual

Like most Operations Research models, specific studies will require additional development and modifications of the current inputs of this model in order to tailor it to the questions asked. The following manual is written to guide the person who will need to maintain and modify this model.

Overview of the other sections

After a short review of the model specifications, we simply follow the structure of the input files needed by SIMMOD:

(1) The **Ground file** “ground.xxx” describes the ground network and the rules that govern aircraft on it.

(2) The **Airspace file** “airspace.xxx” describes what happens in the sky. It is quite short in our case.

(3) The **events file** “events.xxx” lists all the events (arrivals and departures mainly) that happen during the simulation.

Then, since each file is divided into *records* defining specific features of the model, each of these records is detailed in a separate paragraph.

2. Model specifications

The model has been developed under two runway configurations:

(1) The Northwest VFR, "first configuration", using 33L, 33R and 27 (corresponding to FTA's plan 301BV).

(2) The Northeast VFR, "second configuration", using 4R, 4L and 9 (corresponding to FTA's plan 401DV);

It models the following components of the system:

Ground	All runways
	All taxiways
	All gates with airlines associated limited modeling of gates compatibility
	Runway crossings used in the modeled configurations
Airspace	All routes (except diverging routes for the runways not used in the modeled configurations) limited to straight routes from the runways
	Procedures used in the modeled configurations
	No sectors
Schedule	Entire official schedule for a single day of July 1997, performed under VFR conditions

The simulation engine uses input data provided for each of these components to control the behavior of these objects until the end of the schedule. Multiple runs of the simulation are needed to obtain statistically significant results.

The software needs the three files described below and enclosed in appendix in order to run on a Windows 95 PC.

3. The ground network description file "Ground.xxx"

The ground.xxx file defines all the operations on the ground. It includes 1580 lines and looks like this:

```
COMMENT CENTER NM 0:00.0000 0:00.0000
AFNODES In this run, 433 is the largest node number
  MIT 1 3 6 9 10 11 12 13 14 16 18 19 20 21 25 26 27 28 29 30 31 32 33 34
    35 36 37 38 39 40 41 42 43 44 46 47 48 49 50 51 52 53 54 55 56 57
[…] 432 433
COORDINATES This data set has 379 nodes with defined coordinates.
1       786     5612 MIT   N1
3       752     5509 MIT   N3
[…]
431     -1260    -1533 MIT   431
432     -1734     -918 MIT   432
433     -1965    -2858 MIT   433
AFLINKS Taxi Speed = 15 Def Cap = 1 Passing Code = 0 Max 440
1   1   3    198   108 0  1 0 0 0 40 NONE ;
```

```
3    3    6     199  1428 0 10 0 0 0 40 NONE ;
[…]
831   433   121    327   276 0  2 0 0 0 15 NONE ;
832   100   113    184   827 0  6 0 0 0 15 NONE ;
```

TAMPS 5 aircraft groups

```
1 30 15 Heavy aircraft
  0.0 7000.0  1.0 7000.0 ; copy of the landing roll distribution
  0.0 6000.0 1.0 6500.0 ; takeoff roll distance distribution
  0.0 0.0 1.0 0.0 ; arr gate service time
  0.0 0.0 1.0 0.0 ; dep gate service time
  1 2 5 84 ; aircraft models
[…]
5 30 15 Commuters aircraft
  0.0 2300.0 1.0 2300.0 ; landing roll distribution
  0.0 4500.0 1.0 4500.0 ; takeoff roll distance distribution
  0.0 0.0 1.0 0.0 ; arr gate service time
  0.0 0.0 1.0 0.0  ; dep gate service time
  53 59 62 64 67 75 98 99 ; aircraft models
```

PROBDIST 2

```
1 DELAY_DIST
   1 ; 0.0 10.0 1.0 10.0 ;
   2 3 4 ; 0.0 6.0 1.0 6.0 ;
   5 ; 0.0 2.0 1.0 2.0 ;
2 LANDING_ON_33L
   1 2 ; 0.0 5725 0.2 6925 0.6 7665 1.0 9215 ;
   3 ; 0.0 4200 0.03 4215 0.12 5230 0.87 5715 1.0 6925 ;
   4 ; 0.0 4200 0.5 4215 0.56 5230 1.0 5715 ;
   5 ; 0.0 3815 0.65 4215 0.70 5230 0.95 5715 1.0 6925 ;
```

AIRLINES These are the airlines serving the airports in this run

```
1  AA    AIRL
[…]
26 VS    AIRL
27 SN    AIRL
```

GATES There are 85 boarding gates

```
1 217 1 G_A1 MIT 0 YES 0 NONE
 259 ;
 ; ; ;
 ; 0 ; ;
[…]
86 372 1 G_B24 MIT 0 YES 0 AA
 750 ;
 ; ; ;
 ; 0 ; ;
```

GATEUSE We have 7 entries with a maximum of 5 items listed once

```
1 G_C18 MIT TAMPS 3 4 ;
2 G_C27 MIT TAMPS 3 4 ;
3 G_C25 MIT TAMPS 3 4 ;
4 G_C40 MIT TAMPS 3 4 ;
5 G_B42 MIT TAMPS 3 4 ;
6 G_B43 MIT MODEL 2 32 87 51 97 ;
7 G_B43 MIT MODEL 2 GATE G_B42 MODEL 32 87 51 ;
```

PPBACK These are the a/c that can only push back (all)

```
 1 2 5 10 11 12 13 14 15 16 20 22 29 31 32 34 35 40 41 42 47 50 51 53 59
   62 64 67 75 84 85 86 87 89 97 98 99
```

PPTIME there are 5 groups

```
1 ; Heavy aircraft
  0.0 90.0 1.0 180.0 ; power-back time (not used)
  0.0 90.0 1.0 180.0 ; push-back time
[…]
```

5 ; Commuters aircraft
0.0 30.0 1.0 90.0 ; power-back time (not used)
0.0 30.0 1.0 90.0 ; push-back time
RUNWAYS Taxi Speed = 40 mph. Crossing delay = 5
There are 5 runways with 16 links maximum.
1 22R 4L 199 815 0 691 692 1 3 10 37 38 39 117 118 MIT
[…]
5 27 9 256 0 0 97 99 100 101 102 103 104 105 MIT
DEPARTQ There are 10 departure queues, with up to 4 routes
1 0 0 0 0 MIT 5 QUEUE9 215 0
28 41 42 ;
[…]
10 0 0 0 0 MIT 2 QUEUE92 430 0
43 ;
TAXIPATHS There are 53 paths, 32 max links per path, 100 alternate paths,
and 150 nodes per route.
1 PATH1 497 ;
[…]
52 PATH10 827 387 ;
53 PATH11 830 ;
CONCOURSE 13 concourses in this application with up to 23 gates
1 termA1 G_A8 G_A9 G_A10 G_A11 G_A12 ; ;
[…]
13 termC5 G_C20 G_C21 ; ;
GATERWY There are 92 records defined for this run
1 termA1 A127 27 DEP ;
[…]
94 termE2 E24R 9 DEP ;
RWYCROSS 3 crossings
1 DBL33L 5.0 5 5 1 387 76 386 ;
2 CBL27 5.0 5 5 1 388 81 389 ;
3 NBL33L 5.0 5 3 1 384 19 415 ;
CONGESTION I consider 2 set with 28 links serving 14 gates
1 1 1 ; 822 320 308 319 804 805 806 807 808
809 810 317 312 316 315 309 306 304 811
70 71 826 67 199 66 181 819 821 ; G_B28
G_B27 G_B26 G_B23 G_B43 G_B42 G_C41
G_C40 G_C25 G_C27 G_C33 ;
2 1 1 ; 259 260 261 267 269 262 273 274 263
271 272 264 275 276 282 281 280 265 813
277 812 266 279 ; G_A G_A2 G_A3 G_A4 G_A5 G_A6
G_B1 G_B2 G_B3 G_B4 G_B5 G_B6 G_B8 G_B10 ;
DCONGESTION I consider 2 congestion area with all these 28 links and 3 departure queues
1 1 ; 822 320 308 319 804 805 806 807 808
809 810 317 312 316 315 309 306 304 811
70 71 826 67 199 66 181 819 821 ; QUEUE27 QUEUE33L QUEUE33L2 ;
2 1 ; 266 253 812 265 264 263 262 261
260 ; QUEUE27 QUEUE33L QUEUE33L2 ;
DSDPATHS There are 10 paths, 37 max links per path
1 KA 377 250 246 243 240 228 232 233 234
389 223 391 249 247 245 244 242 241 239
238 237 231 230 229 227 226 235 219 225
212 222 221 220 214 211 210 248 ; 5 ;
[…]
10 CROSS 67 199 66 181 819 821 ; 3 ;
TOWING 1 towing area
1 Americawest 322 ;
GLOBAL
1 rc_fudge_time 10 ;

GO

We review each of these records in the next sections.

1. AFLINKS, AFNODES and COORDINATES records

1.1 Logic

The AFNODES record is used to list the airfield nodes at each airport.

The COORDINATES record is used to assign a latitude and longitude to airfield nodes. As a minimum, this record must be provided for nodes that mark ends of runways, departure queues, and for either gate or apron nodes if the list of links to the apron node is given on the GATES record.

The AFLINKS record is used to create airfield links and define aircraft movement characteristics on them. SIMMOD has been modified to only consider an aircraft's model type when determining its movement throughout the airfield, rather than the aircraft's weight.

Under the AFLINKS record, we may define specific taxiways as high-speed runway exits. Planes are allowed to do part of their landing roll on these high-speed exits, based on the angle between the runway and the taxiway. Depending on its change in heading, part of the landing roll can be completed on the high-speed exit:

Change in heading	10°	20°	30°	40°
% roll completed	20%	15%	10%	5%

1.2 Features

The ground network has progressively grown in complexity. The current version has 379 (384 in configuration 2) nodes and 440 (445) links. We show the position of most of the first configuration links in the maps contained in Annex A. The structure of the network is quite straight forward, following aircraft on their taxiways up to each gate.

The major aspect of the network lies in the respective length and speed used on each link. This comes from the fact that the path taken by each aircraft[1] relies only on these values. We thus have to tinker with some lengths and speeds to force aircraft to

[1] Based on a shortest path algorithm.

follow the appropriate path *without changing substantially the travel times.* We thus review here the main assumptions that we made.

Speed. The E&K Airport Machine model uses 5 different taxiway speeds:

- 20 knots as a normal taxi speed;
- 52 knots on an high-speed exit;
- 30 knots on a normal exit;
- 16 knots on a right angle exit;
- 2 knots on acute reverse angle exits.

In our SIMMOD model, we do not need to define the actual speed on runway exits since these exits are used to complete the landing roll. Besides, following our observations of the actual speed on the taxiways, we consider the following typical values:

- 15 knots as a normal taxi speed[2];
- 40 knots on active runways;
- Some lower values when we do not want aircraft to travel on some links, typically on inactive runways. In details, we have the following differences:

Configuration	Corrected speed links
1	35 36 38 39 117 120 121 from 40 to 15 (inactive runways) 50 from 15 to 2 (Exit on 4L, See map 8)
2	178 11 12 13 777 779 from 40 to 15 (Corresponding to 33R, map 3) 258 from 15 to 2 (to force a/c to go on Bravo and not W, map 4) 28 29 30 31 from 40 to 15 (runway 33L, map 3 and 8) and 756 from 60 to 15 (high speed exit on 33L, map 8)

As far as high-speed exits are concerned, we have considered the following:

Runway	High-speed exits
4R	Yankee and Romeo (175, 177, map 3)
27	Echo (124, map 4)
33L	Fox-Trot and Quebec (756, map 8, and 752, map 3)

Length. Some adjustments are easier to achieve through modifications of link lengths than through speed changes. This is specifically the case when we want to direct the

[2] Our observations showed that, on taxiway Kilo, arrivals were moving at an average 25 knots and departures at 15 knots. Since it is not possible to separate these two categories, and since we can assume a slower speed on the aprons, an average 15 or 20 knots for both movements is reasonable.

inbound flow from Kilo to Alpha through specific connecting taxiways (Charlie and not Echo or Sierra, for instance). We changed the following link lengths:

Link	**Length modified from**	**To**
Configuration 1		
84	252	282
62	130	180
72	300	600
236	170	470
Configuration 2		
66	78	108
72	300	320
78	300	400
84	252	372
112	310	340
236	170	310
284	210	330
392	284	404

Capacity. In some very specific instances, we correct the link capacity because a link is only used by small aircraft, such as link 394 in configuration 1. Besides, links leading to the queue for runway 9 have a capacity of 1 aicraft. Link 832 has been closed by putting its capacity down to 0 (second configuration, not on the maps of annex A).

Direction of travel. Finally, we modify some links that must not be used in another direction, such as:

Config.	**Corrected direction of travel links**
1	127 130 arrivals only (Echo, Papa, map 4) 827 from initial to final node only
2	44 DEP only (Kilo in front of terminal C, map 3) 54 ARR only (Alpha in front of gate C19, map 1) 109 from final to initial node only (Whiskey onto 9, map 4) 127 130 arrivals only (Echo, Papa, map 4) 179 from 42 to 429 (to block aircraft going north from taking it, namely Kilo, map 2) 254 arrivals only (short cut on Alpha towards terminal A, map 5) 387 towards runway 9 only (To prevent aircraft from taking Victor, map 4) 391 arrivals only (Alpha in front of gate B16, map 4) 751 departures only (Kilo towards the South West corner, map 7) 781 arrivals only (Echo, map 7) 815 final to initial only (Alpha used to go to term. D and E, not for arrivals traveling south, map 1) 827 from final to initial only

All other nodes and links have the standard properties as defined in the reference manual.

2. TAMPS record

2.1 Logic

This record defines groups of aircraft that share:

- Ground separation requirements;
- Landing and takeoff characteristics;
- Gate occupancy time distributions.

Landing and takeoffs rolls are based on the probability distributions found either in the TAMPS record or defined for each runway in the PROBDIST record (p. 33). Landings start with the nominal aircraft airspeed and end at the runway taxi speed. Takeoffs start at 0 knots and end at the nominal aircraft speed.

2.2 Features

In the current version, we consider 5 classes of aircraft on the ground:

- all heavy aircraft
- jets going to terminal E
- Large jets
- Jets
- Commuters

Different landing roll distributions are actually tailored for each runway so that the only features to note in the TAMPS record are:

- The separation requirements: 30 and 15 seconds
- The takeoff roll distance distribution (that must reflect reasonably well the actual runway occupancy times) and
- The way aircraft are grouped

The record is written:

```
TAMPS 5 aircraft groups
1 30 15 Heavy aircraft
  0.0 7000.0  1.0 7000.0 ; copy of the landing roll distribution
  0.0 6000.0 1.0 6500.0 ; takeoff roll distance distribution
  0.0 0.0 1.0 0.0 ; arr gate service time
  0.0 0.0 1.0 0.0 ; dep gate service time
  1 2 5 84 ; aircraft models
2 30 15 Terminal E aircraft
```

```
  0.0 7000.0  1.0 7000.0 ; copy of the landing roll distribution
  0.0 5500.0 1.0 6000.0 ; takeoff roll distance distribution
  0.0 0.0 1.0 0.0 ; arr gate service time
  0.0 0.0 1.0 0.0 ; dep gate service time
  10 11 12 13 14 15 16 ; aircraft models
3 30 15 Large jet aircraft
  0.0 7000.0 1.0 7000.0 ; landing roll distribution
  0.0 5500.0 1.0 6000.0 ; takeoff roll distance distribution
  0.0 0.0 1.0 0.0 ; arr gate service time
  0.0 0.0 1.0 0.0  ; dep gate service time
  20 22 31 32 34 51 87 ; aircraft models
4 30 15 Jets aircraft
  0.0 7000.0 1.0 7000.0 ; landing roll distribution
  0.0 4800.0 1.0 5200.0 ; takeoff roll distance distribution
  0.0 0.0 1.0 0.0 ; arr gate service time
  0.0 0.0 1.0 0.0  ; dep gate service time
  29 35 40 41 42 47 50 85 86 89 97 ; aircraft models
5 30 15 Commuters aircraft
  0.0 2300.0 1.0 2300.0 ; landing roll distribution
  0.0 4500.0 1.0 4500.0 ; takeoff roll distance distribution
  0.0 0.0 1.0 0.0 ; arr gate service time
  0.0 0.0 1.0 0.0  ; dep gate service time
  53 59 62 64 67 75 98 99 ; aircraft models
```

70 aircraft of the *aircraft.def* file are not assigned in these categories. This appears as a warning in each echo file:

```
WARNING #1  The following 70 aircraft models have not been assigned to an ATC group:
   3  4  6  7  8  9  17  18  19  21  23  24  25  26  27  28  30  33  36  37  38  39  43  44  45  46
   48  49  52  54  55  56  57  58  60  61  63  65  66  68  69  70  71  72  73  74  76  77  78  79
   80  81  82  83  88  90  91  92  93  94  95  96  100  101  102  103  104  105  106  107
```

2.3 Motivation

We have converted the aircraft types that were listed in the OAG schedule into SIMMOD equivalents. Then, the key step was to decide what groups should be built.

In this model, gate service times are not essential since most of the flights are turnaround. Similarly, since we focus on the ground, the actual take-off distances do not need to be extremely accurate. The objective is thus to build classes of aircraft that are consistent *from the point of view of the landing roll distance*.

For airport design, the FAA suggests to use its *Airport Reference codes* that depend on wingspan (in feet) and approach speed (in knots). This is the current assignment, according to the AC 150/5300-13 (ch. 1):

Aircraft approach cat.	A	B	C	D	E
Approach speed	0	91	121	141	166

Class	I	II	III	IV	V	VI
Wingspan	0	49	79	118	171	214

In our case, we first reorganized these wingspan categories to have more homogeneous groups. We came up with the following four groups:

Class	**Aircraft involved**	**SIMMOD codes**
Heavy	B 747 (all series), A 340, A 330, B 777	1 2 5 84
Large	B 757, B 767 (all series), DC-10, L-1011, A 300, A 310	20 22 31 32 34 51 87
Jets	B 727, B 737 (all series), A 320, DC-9 (all series), F 100, MD-80	29 35 40 41 42 47 50 85 86 89 97
Commuters	ATR (all series), DHC-8, Canadair RJ, Saab SF 340, Jetstream 31 and 41, Cessna (all series), Beechcraft 1900	53 59 62 64 67 75 98 99

Since what interests us in the landing roll probability distributions is that aircraft exit where they should, we have to tailor the distributions to the runway exits. This explains that we tailor specific probability distributions for each of the landing runways. They are detailed under the PROBDIST record (p. 33).

However, in connection with this, it is necessary to define the TAMPS classes based on the exits aircraft choose. In terms of exits, *international* aircraft have a specific behavior: in the first configuration, landing on 33 Left, they all exit by the end of the runway to go to terminal E. We thus created a specific class for them. This has lead to the following groups:

Heavy	B747 (all series), A340, A330, B777	1 2 5 84
Terminal E	International jets: A320, B727-200, B757, B767, A300, DC-10, DC-9	10 11 12 13 14 15 16
Large	B757, B767 (all series), DC-10, L-1011, A300, A310	20 22 31 32 34 51 87
Jets	B727, B737 (all series), A320, DC-9 (all series), F100, MD-80	29 35 40 41 42 47 50 85 86 89 97
Commuters	ATR (all series), DHC-8, Canadair RJ, Saab SF 340, Jetstream 31 and 41, Cessna (all series), Beechcraft 1900	53 59 62 64 67 75 98 99

The Heavy class contains only international flights that will thus be sent to terminal E. The terminal E class contains jets and large aircraft that have sometimes equivalents in domestic operations. Then, following figures available in the literature, we have considered the following values (again, the important ones are the takeoff rolls):

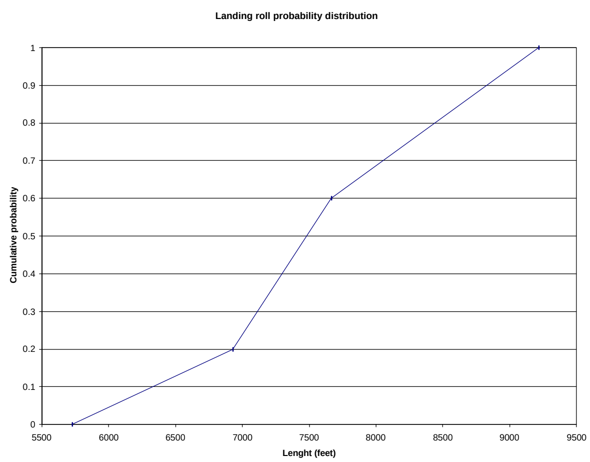
Class	Landing roll (feet)	Take-off roll (feet)
Heavy	7,000	6,000-6,500
Terminal E	7,000	5,500-6,000
Large	7,000	5,500-6,000
Jets	7,000	5,000-5,500
Commuters	2,300 (for 33 Right)	4,500

3. PROBDIST record

3.1 Logic

This optional data record is used to modify the landing- and takeoff-roll distributions for individual runways, unloading- and boarding-time distributions for individual gates, and deicing-time distributions.

These distributions are read the following way:



1 ; 0.0 5725 0.2 6925 0.6 7665 1.0 9215 ;

is read:

Probability that

- the landing roll is 5,725 feet or less = 0
- it is between 5,725 and 6,925 feet = 0.2
- it is between 6,925 and 7,665 feet = 0.6-0.2
- it is between 7,665 and 9,215 feet = 1.0-0.6

3.2 Features

We have built 4 distributions. The first one gives the delays aircraft take to cross runways: 10 seconds for heavy aircraft, 6 for jets and 2 for commuters. These estimates have not been confirmed by on-site measurements.

The three next distributions describe the landing roll distributions tailored for runways 33L, 4R and 4L:

```
PROBDIST 4 distributions
1 DELAY_DIST
  1 ; 0.0 10.0 1.0 10.0 ;
  2 3 4 ; 0.0 6.0 1.0 6.0 ;
  5 ; 0.0 2.0 1.0 2.0 ;
2 LANDING_ON_33L
  1 2 ; 0.0 5725 0.2 6925 0.6 7665 1.0 9215 ;
  3 ; 0.0 4200 0.03 4215 0.12 5230 0.87 5715 1.0 6925 ;
```

4 ; 0.0 4200 0.5 4215 0.56 5230 1.0 5715 ;
5 ; 0.0 3815 0.65 4215 0.70 5230 0.95 5715 1.0 6925 ;
3 LANDING_ON_4R
1 ; 0.00 5930 0.10 7130 0.60 8490 1.00 8935 ;
2 ; 0.00 3150 0.06 3820 0.09 4235 0.22 5000 0.81 5925 0.94 7130 1.00 8935 ;
3 ; 0.00 4235 0.15 5000 0.72 5925 0.90 7130 1.00 8490 ;
4 ; 0.00 3150 0.04 3820 0.09 4235 0.71 5000 0.93 5925 1.00 7130 ;
5 ; 0.00 2435 0.30 2800 0.70 3150 0.75 3820 0.95 4235 0.99 5000 1.00 5925 ;
4 LANDING_ON_4L
1 2 3 4 ; 0.00 3150 0.04 3820 0.09 4235 0.71 5000 0.93 5925 1.00 7130 ; like large on 4R (not used!)
5 ; 0.00 1800 0.15 1890 0.40 2870 0.67 3300 0.83 3950 0.95 5640 1.00 7070 ;

These values come from an undated study of the Boston tower that has been used by all the models we are aware of.

4. AIRLINES record

4.1 Logic

The AIRLINES record is used to define airlines and the airports where they operate.

4.2 Features

Since we look at carriers from the operations side, the SIMMOD airlines differ a little from the ones used in the OAG schedule:

- International carriers belong to the "INT" airline except SN and VS that depart from other terminals.
- We neglect *cargo aircraft, charters, corporate and General Aviation*.
- We have separated flights scheduled under the same OAG code when they were managed by different teams, such as US Air shuttle, US Air express and US Air.

This makes the following record:

```
AIRLINES These are the airlines serving the airports in this run
 1  AA    AIRL
 2  USS   AIRL
 3  HP    AIRL
 4  CO    AIRL
 5  DL    AIRL
 6  DLS   AIRL
 7  NONE  AIRL
 8  NW    AIRL
 9  TW    AIRL
10 TWE   AIRL
11 UA    AIRL
12 UAE   AIRL
13 US    AIRL
14 USE   AIRL
15 INT   AIRL
16 JI    AIRL
17 W9    AIRL
18 YX    AIRL
19 J7    AIRL
20 9K    AIRL
21 9L    AIRL
22 BE    AIRL
23 AC    AIRL
24 CP    AIRL
25 NK    AIRL
26 VS    AIRL
27 SN    AIRL
```

Such a list requires the following conversion in the event file:

OAG code	OAG Name	No. ARR	No. DEP	SIMMOD airline used
US	USAir	198	198	Split between USS (72S flights to LaGuardia every hour), US and USE (small aircraft)
DL	Delta	181	181	Split between DLS (72S flights to LaGuardia every hour), DL and BE (small aircraft)
UA	United	70	70	Split between UA and UAE (small aircraft)
AA	American	55	55	AA
9K	Cape Air	36	37	9K
CO	Continental	32	32	CO
NW	Northwest	22	22	NW
TW	Trans World	19	19	Split between TW and TWE
AC	Air Canada	18	18	AC

9L	Colgan Air	10	10	9L
HP	America West	6	6	HP
YX	Midwest	6	6	YX
CP	Canadian airways	4	4	CP
J7	Valujet	4	4	J7, using gate D 1E
JI	Midway	3	3	JI, handled by American at gate B 20
W9	Eastwind	3	3	W9, handled by USAir shuttle at gate A3
NK	Spirit Airlines	2	2	NK, handled by Delta at gate C12
SN	Sabena	1	1	SN, handled by Delta at gate C28
VS	Virgin Atlantic	1	1	VS, handled by United at gate C43
BA	British Airways	3	3	INT (international flights to the international terminal)
LH	Lufthansa	2	2	INT
AZ	Alitalia	1	1	INT
EI	Air Lingus	1	1	INT
FI	Iceland Air	1	1	INT
KE	Korean Air	1	1	INT
OA	Olympic Airways	1	0	INT
SR	Swiss Air	1	1	INT
TP	TAP Air Portugal	1	0	INT

4.3 Elements not modeled

The exact movement of some international aircraft has not been modeled: they arrive at terminal E but depart from the gate of a major company (Virgin at gate C43 for instance). This is not possible for the moment since the TOWING logic is not working.

5. GATES record

5.1 Logic

The GATES record is used to define gates and their characteristics. If STAGING is used, the GATES data record must be input after the STAGING data record. Each gate has the following attributes:

- a node where it is located;
- a capacity;
- unloading-time and boarding-time probability distribution numbers, if used;
- a gate hold strategy (if used, aircraft will hold at the gate if its corresponding departure queue attains a threshold);
- an alternate gate flag (to allow aircraft to seek another gate if it is full);
- a default connect time (banking logic);
- a list of airlines allowed to use the gate;
- a list of links blocked when the aircraft pushes back;
- a staging required flag (to force staging before gate reevaluation…);
- a gate type (pushback only, etc.).

5.2 Features

According to the available layout, we have designed 85 gates on the airport. We considered the following attributes:

- a capacity of one aircraft except for commuter airlines and America West, because of problems with the towing logic (See p. 59);
- no unloading-time or boarding-time distributions;
- no gate hold in configuration 1, gate hold for all gates in configuration 2;
- allowing aircraft to seek other gates ("YES" in each record);
- a list of airlines allowed to use the gate based on the tables below;
- a list of blocked links based on the network structure and interviews;
- Pushback only.

The first 10 gates appear like that:

GATES There are 85 boarding gates
1 217 1 G_A1 MIT 0 YES 0 NONE
259 ; […] ; ; ; […] ; 1 ; ;
2 225 1 G_A2 MIT 0 YES 0 NONE
267 ; […] ; ; ; […] ; 1 ; ;
3 227 1 G_A3 MIT 0 YES 0 USS W9
269 ; […] ; ; ; […] ; 1 ; ;
4 229 1 G_A4 MIT 0 YES 0 USS
271 ; […] ; ; ; […] ; 1 ; ;
5 237 1 G_A5 MIT 0 YES 0 USS
279 ; […] ; ; ; […] ; 1 ; ;
6 241 1 G_A6 MIT 0 YES 0 USS
283 ; […] ; ; ; […] ; 1 ; ;
7 246 1 G_AA MIT 0 YES 0 CO
288 ; […] ; ; ; […] ; 1 ; ;
8 243 1 G_AB MIT 0 YES 0 CO
284 ; […] ; ; ; […] ; 1 ; ;
9 248 1 G_A7 MIT 0 YES 0 CO
290 ; […] ; ; ; […] ; 1 ; ;
10 261 1 G_A8 MIT 0 YES 0 CO
303 ; […] ; ; ; […] ; 1 ; ;

SIMMOD airlines (See p. 42) were affected to gates thanks to the following table:

Terminal	**Gate**	**Airlines**
A	1, 2	NONE
	3	USS W9
	4-6	USS
	A, B, 7-10	CO
	11-12	NONE
	CAPE	9K 9L (4 slots in the gate)
B	1-8	US
	9	US YX
	10	US
	11-13	USE (3 slots at gate 11 and 13, 1 at gate 12)
	14-16	US
	17	HP (2 slots because of towing, See p. 59)
	17A, 18, 18A, 19	DLS
	20	AA JI
	21-29	AA
	42	UA
	43	UA VS
C	12	DL NK
	14	DL
	16	TWE
	17	TW
	18	UA
	19	UAE
	11, 15, 20, 21	BE AC CP (2 slots per gate)
	25, 27	UA
	28	DL SN
	26, 29-34, 36	DL
	40, 41	UA
D	1E	J7

E	1A, 1B, 2A, 2B, 3A, 3B	NW
	4-6, 7A, 7B, 8A, 8B	INT

Listed for the 26 SIMMOD airlines, this makes the following table:

Airline	**No. Gates used**	**Location**
Air Canada (AC)	4 (8)	C: 11 15 20 21
America West (HP)	1 (2)	B: 17
American (AA)	10	B: 20 21 22 23 24 25 26 27 28 29
Business Express (BE)	4 (8)	C: 11 15 20 21
Canadian Airlines (CP)	4 (8)	C: 11 15 20 21
Cape Air (9K)	1 (4)	A: CAPE
Colgan Air (9L)	1 (4)	A: CAPE
Continental (CO)	6	A: A B 7 8 9 10
Delta Airlines (DL)	11	C: 12 14 26 28 29 30 31 32 33 34 36
Delta Shuttle (DLS)	4	B: 17A 18 18A 19
Eastwind (W9)	1	A: 3
International (INT)	7	E: 4 5 6 7A 7B 8A 8B
Midway (JI)	1	B: 20
Midwest (YX)	1	B: 9
Northwest (NW)	6	E: 1A 1B 2A 2B 3A 3B
Sabena (SN)	1	C: 28
Spirit Airlines (NK)	1	C: 12
Trans World (TW)	3	C: 17 18 19
Trans World Express (TWE)	1	C: 16
United Airlines (UA)	5	B: 43 C: 25 27 40 41
United Express (UAE)	1	B: 42
US Air (US)	13	B: 1 2 3 4 5 6 7 8 9 10 14 15 16
US Air Express (USE)	3 (7)	B: 11 12 13
US Air Shuttle (USS)	4	A: 3 4 5 6
Valujet (J7)	1	D: 1E
Virgin Airlines (VS)	1	B: 43
Not affected (NONE)	4	A: 1, 2, 11, 12

The numbers in parenthesis represent the actual number of aircraft that can be accommodated in these gates.

For the moment, we only consider two areas where a pushback blocks other operations on the related gates: the aprons between terminals A and B and the horseshoe between terminals B and C.

Gates	**Links**
Aprons between terminals A and B	
A1	259
A2	259 260 267
A3	259 260 267 269 261
B1	259 260 267 269 261 273 274
A4 B2	259 260 267 269 261 273 274 271 263 262 272

B3 B4 B6	259 260 267 269 261 273 274 271 263 262 272 264 275 276 282 281 280
B8 A5	259 260 267 269 261 273 274 271 263 262 272 264 275 276 282 281 280 277 278 265 279
Horseshoe between terminal B-C	
B27 B26 B23 B43 B42 C41 C40 C25 C27 C33	315 67 320 308 320 319 317 30 306 309 22 70 71 304

6. GATEUSE record

6.1 Logic

This record is used to select which aircraft are allowed to use gates and which are blocking other gates.

6.2 Features

In this model, we have not collected data for all airlines on the ways they use their gates. We have limited ourselves to simply trying and converting these constraints in SIMMOD entries for United airlines. This gives the following record:

GATEUSE We have 7 entries with a maximum of 5 items listed once
1 C_18 MIT TAMPS 3 4 ;
2 C_27 MIT TAMPS 3 4 ;
3 C_25 MIT TAMPS 3 4 ;
4 C_40 MIT TAMPS 3 4 ;
5 B_42 MIT TAMPS 3 4 ;
6 B_43 MIT MODEL 2 32 87 51 97 ;
7 B_43 MIT MODEL 2 GATE B_42 MODEL 32 87 51 ;

Heavy aircraft are not allowed at gates 18, 27, 25, 40 and 42. 41 and 43 are left for heavies. The geometry of gate 43 limits its use to bigger aircraft (record No. 6). When it hosts a 747 (typically the one from Virgin Atlantic), it limits gate 42 to small aircraft (737, etc., record 7).

Although this may seem easy to model, since we faced much larger problems when we tried to implement the basic priority logic on the “horseshoe” apron between terminal B and C, we did not develop these modeling details further.

7. PPBACK and PPTIME records

7.1 Logic

The PPBACK data record is used to list aircraft model numbers that can only pushback. This record must be used in conjunction with the PPTIME record to enable pushback. The PPTIME record is used to define the power/push-back probability distribution. An aircraft takes this time to travel on the first link from the gate.

7.2 Features

In the PPBACK record, we list all the aircraft models that are used in the simulation. In the PPTIME, we enter estimates of pushback duration. The maximum values come from the airport machine model that considers 180 seconds for Heavies, 90 seconds for small and 120 for other aircraft. Since the duration of this operation is quite uncertain, we have added a lower value to add some stochasticity.

We had the opportunity to make a couple of measurements of the pushback time, defined as the time from the start of the pushback until the aircraft moves by itself:

Aircraft	Ground group	Gate	Time (min and sec)	Comments
757	L	B43	3:10 (5:10)	Horseshoe
737-400	J	B1	3:05	
757	L	C41	4:10	Horseshoe
737	J	B42	(5:26)	Horseshoe
DC9-80	J	A	2:34	
747	H	E5	6:50	
757	L	C29	2:54	
727	J	C29	2:55	
DC9	J	A?	2:56	
?	J?	B40	4:59	Horseshoe

These data seem to confirm that 120-180 seconds seems reasonable estimates. We have thus kept the figures used by E&K.

```
PPBACK These are the a/c that can only push back (all)
 1 2 5 10 11 12 13 14 15 16 20 22 29 31 32 34 35 40 41 42 47 50 51 53 59
   62 64 67 75 84 85 86 87 89 97 98 99
PPTIME there are 5 groups
1 ; Heavy aircraft
  0.0 90.0 1.0 180.0 ; power-back time (not used)
  0.0 90.0 1.0 180.0 ; push-back time
2 ; Terminal E aircraft
```

```
  0.0 60.0 1.0 120.0 ; power-back time (not used)
  0.0 60.0 1.0 120.0  ; push-back time
3 ; Large jet aircraft
  0.0 60.0 1.0 120.0 ; power-back time (not used)
  0.0 60.0 1.0 120.0  ; push-back time
4 ; Jets aircraft
  0.0 60.0 1.0 120.0 ; power-back time (not used)
  0.0 60.0 1.0 120.0  ; push-back time
5 ; Commuters aircraft
  0.0 30.0 1.0 90.0 ; power-back time (not used)
  0.0 30.0 1.0 90.0  ; push-back time
```

8. RUNWAYS record

8.1 Logic

This record is used to define runway system characteristics: links involved, heading, displaced threshold, landing and take-off probability distributions. The displaced threshold logic is known to have some problems.

8.2 Features

The current version of the record is the following:

RUNWAYS Taxi Speed = 40 mph. Crossing delay = 5
There are 4 runways with 16 links maximum.
1 22R 4L 199 815 0 691 692 1 3 10 37 38 39 117 118 829 MIT 4
2 22L 4R 199 1199 1155 693 6 759 8 9 33 34 35 36 120 121 122 123 699 700
701 MIT 3
4 15R 33L 135 880 0 706 16 17 28 29 30 31 32 85 86 87 88 MIT 2
5 27 9 256 0 0 97 99 100 101 102 103 104 105 MIT

Under configuration 1, in order to model runway crossing of 4L, it is simpler to suppress runway 33R because SIMMOD does not accept runway crossings on runways.

The only interesting global data is the taxi speed, which is the speed an aircraft will use when it finishes its landing roll on a runway. It only impacts the landing roll time. The links that we consider here define the 5 runways:

Runway 22R/4L, displaced threshold of 815 feet in the primary direction

Links	From node	To node	Taxiway at final node
691	340	341	N-2 and N
692	341	1	Threshold
1	1	3	N-1
3	3	4	15L
10	6	12	15R, T
37	12	37	Q
38	37	38	F
39	38	39	C
117	39	102	E (S)
118	102	103	W

Runway 22L/4R, displaced threshold of 1199 feet (1155 in the opposite direction)

Links	From node	To node	Taxiway at final node
693	339	140	N, N-3
6	140	381	Threshold
759	381	9	R
8	9	10	15L

9	10	11	Y
33	11	400	15R, J
34	400	34	F
35	34	35	H
36	35	36	C
120	36	105	P
121	105	106	E
122	106	402	9
123	402	214	Threshold
699	214	107	S
700	107	115	X - X (nothing)
701	115	116	B

Runway 33R/15L

Links	**From node**	**To node**	**Taxiway at final node**
178	142	10	4R
11	10	13	Y
12	13	392	Hold line
777	392	6	4L
13	6	394	Hold line
779	394	14	N

Runway 15R/33L, displaced threshold of 880 feet

Links	**From node**	**To node**	**Taxiway at final node**
706	21	20	L and X - X
16	20	18	Z
17	18	19	N
28	19	399	4L, T
29	399	30	Q
30	30	31	4R, J
31	31	32	F
32	32	33	G
85	33	76	D
86	76	77	27
87	77	78	C
88	78	79	Threshold 33L

Runway 27/9

Links	**From node**	**To node**	**Taxiway at final node**
97	86	85	D, D-2
99	85	88	D-1
100	88	401	15R/33L
101	401	81	C
102	81	89	E
103	89	90	22L/4R
104	90	91	W
105	91	92	S

9. DEPARTQ record

9.1 Logic

The DEPARTQ record is used to define an airfield node where aircraft queue to depart on a runway. Additionally, SIMMOD allows the user to set departure queue time thresholds, queue size, routes for each queue, and areas.

Dynamic rerouting between departure queues is apparently not working. However, departure staging areas can be defined in this record.

9.2 Features

We consider 10 departure queues affected to various routes (See the ROUTES record, p. 64). The valuable parts of the record are the following:

```
DEPARTQ There are 10 departure queues, with up to 4 routes
1 0 0 0 0 MIT 4 QUEUE9 215 0
 28 41 42 ;
 1 G_A8 G_A9 G_A10 G_A11 G_A12 G_A7 G_CAPE G_AA G_AB G_A6 G_A5
   G_A4 G_A3 G_A2 G_A1 G_B1 G_B2 G_B3 G_B4 G_B6 G_B8 G_B10 G_B12
   G_B13 G_B11 G_B9 G_B7 G_B5 G_B14 G_B15 G_B16 G_B17 1 ;
 1 G_B28 G_B27 G_B26 G_B23 G_B42 G_B43 G_C41 G_C40 G_C25 G_C27 G_C33
   G_C31 G_C29 G_C30 G_C32 G_C34 G_C36 G_C28 G_C26 G_C12 G_C14 G_C21
   G_C20 G_C19 G_C18 G_C17 G_C16 G_C15 G_C11 G_D1E G_E1B G_E1A G_E2A
   G_E2B G_E3A G_E3B G_E4 G_E5 G_E6 G_E7A G_E7B G_E8A G_E8B 2 ;
 1 G_B17A G_B18 3 ;
 1 G_B18A G_B19 G_B22 G_B21 G_B20 G_B24 G_B25 G_B29 4 ; ;
 ; ;
2 0 0 0 0 MIT 5 QUEUE4R 96 0
 23 37 38 39 ;
 ; ;
 ; ;
3 0 0 0 0 MIT 3 QUEUE4L 432 0
 22 34 35 36 ;
 1 G_A8 G_A9 G_A10 G_A11 G_A12 G_A7 G_CAPE G_AA G_AB G_A6 G_A5
   G_A4 G_A3 G_A2 G_A1 G_B1 G_B2 G_B3 G_B4 G_B6 G_B8 G_B10 G_B12
   G_B13 G_B11 G_B9 G_B7 G_B5 G_B14 G_B15 G_B16 G_B17 1 ;
 1 G_B28 G_B27 G_B26 G_B23 G_B42 G_B43 G_C41 G_C40 G_C25 G_C27 G_C33
   G_C31 G_C29 G_C30 G_C32 G_C34 G_C36 G_C28 G_C26 G_C12 G_C14 G_C21
   G_C20 G_C19 G_C18 G_C17 G_C16 G_C15 G_C11 G_D1E G_E1B G_E1A G_E2A
   G_E2B G_E3A G_E3B G_E4 G_E5 G_E6 G_E7A G_E7B G_E8A G_E8B 2 ;
 1 G_B17A G_B18 3 ;
 1 G_B18A G_B19 G_B22 G_B21 G_B20 G_B24 G_B25 G_B29 4 ; ;
 ; ;
4 0 0 0 0 MIT 5 QUEUE15R 29 0
 32 ;
5 0 0 0 0 MIT 5 QUEUE22R 129 0
 25 ;
6 0 0 0 0 MIT 5 QUEUE22L 139 0
 26 ;
7 0 0 0 0 MIT 5 QUEUE27 350 0
```

27 44 45 46 ;
8 0 0 0 0 MIT 5 QUEUE33L 80 0
29 47 48 49 ;
9 0 0 0 0 MIT 5 QUEUE33L2 352 0
33 ;
10 0 0 0 0 MIT 2 QUEUE92 430 0
43 ;

We do not define thresholds for dynamic rerouting or spacing arrivals.

Runway	Departure queue	Node	Route	Taxipath to runway	Length
9	QUEUE9	215	28	497	251
9	QUEUE92	430	43	827 387	462
4R	QUEUE4R	96	23	491	384
4L	QUEUE4L	101	22	762 479	413
15R	QUEUE15R	29	32	707	286
22R	QUEUE22R	129	25	466	348
22L	QUEUE22L	139	26	708	333
27	QUEUE27	350	27	705	346
33L	QUEUE33L	80	29	711	344
33L	QUEUE33L2	352	33	726	722

The fifth column in this chart lists the links that define the taxipaths between each departure queue and its runway. They must be included in the TAXIPATHS record (p. 49).

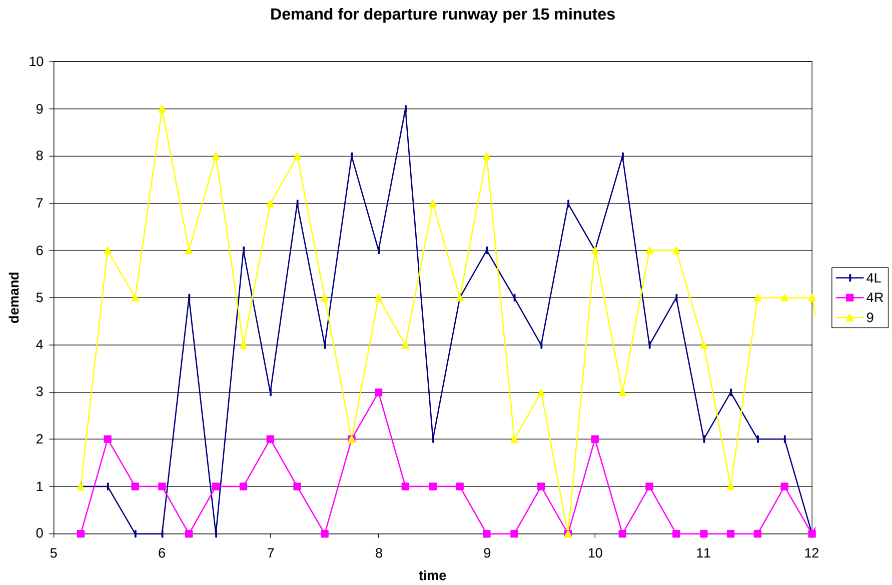
For the first configuration, the airport machine model considers 3 departure queues for runway 9[3], but none for runways 4L and 4R. We consider 2 departure queues since dynamic selection of departure queue is not possible with SIMMOD.

Finally, departure staging areas are defined on Kilo to keep aircraft from blocking the whole area around the departure queue for 4L. These departure staging areas are defined in the DSTAGING record, p. 55.

9.3 A problem: the dynamic traffic dispatching between QUEUE4L (if more than 5 aircraft) and 9

As we have commented in the report on the South West *corner*, even the simplest dynamic balancing between departing runways can not be achieved with SIMMOD. When we use the simple rules to choose which runway to use, we come up with the following chart (configuration 2):

[3] 2 on Sierra and 1 on Victor.



This chart simply shows an absence of coordination between these departures. This simply leads to large queues for one runway while the other is idle. At one point in the development of the model, this was blocking all operations on 9 because arrivals on 4L were limiting departures on this runway.

We have had to modify manually the *events* file to achieve a better balance. In order to do that, we have transferred 7 operations from 4L to 9 between 7:25 and 8:30. Besides, we have used systematic gate hold to alleviate much of the congestion that would happen because of this poor control of the traffic. Typically, there are still aircraft travelling towards runway 4R that roll over aircraft staging on Kilo in order to go to 4L or 9. This problem can not be solved convincingly. With the current choice, as we noticed in the report on the “South West corner” case study, the simulation model is more efficient than the controllers to balance aircraft between runways and it has thus no problem to handle a taxiway closure (and do just as well without it).

10. TAXIPATHS record

10.1 Logic

This record is used to define taxipaths on the airfield. If a flight usually follows a specific path between gate and runway, this path can be defined. By assigning this path name to the flight in the Event file, the program will schedule this flight to follow that specific path. This record must always be included in the input for airfields, but if the user chooses to have the program select the most economical/optimal path for each flight, only the first line is required.

Beside the taxipath between departure queues and beginning of each runway, we have built the taxipaths used in the GATERWY record to link the terminals with the runways (See p. 51).

10.2 Features

We have considered 53 taxipaths for the departure queues and the 2 configurations:

Configuration	Taxipaths	Route
All	1-9	Departure queues to runways
All	10-12	Old routes (not used)
1	13-23	Terminals to 27
1	24-30	33L to terminals
1	31-35	33R to terminals
2	36-41	4R/4L to terminals
2	42-51	Terminals to 4R/4L/9

To enjoy more flexibility in the assignment of aircraft to taxiways, we have not considered fixed taxipaths between gates and runways but partial taxipaths between terminals (so-called "concourses" in the SIMMOD terminology, See next paragraph) and runways. We have:

TAXIPATHS There are 53 paths, 32 max links per path, 100 alternate paths,
and 150 nodes per route.
1 PATH1 497 ;
2 PATH2 491 ;
3 PATH3 762 479 ;
4 PATH4 707 ;
5 PATH5 466 ;
6 PATH6 708 ;
7 PATH7 705 ;
8 PATH8 711 ;
9 PATH9 726 ;

10 DEP 433 434 115 136 744 138 751 ;
11 SOUTH 26 25 24 51 52 43 44 179 826 819
181 199 820 200 201 202 203 204 205 206
207 113 391 223 389 234 233 232 240 243
246 250 ;
12 NORTH 217 433 434 115 136 744 138 751 821
181 66 64 62 60 58 56 815 816 55
733 54 75 53 339 342 344 347 ;
13 E227 745 796 26 25 24 51 52 43 44
179 ;
14 E127 346 25 24 51 52 43 44 179 826 819 ;
15 CDE27 743 24 51 52 43 44 179 826 819 ;
16 C327 72 51 52 43 44 179 826 819 ;
17 C227 78 44 179 826 819 ;
18 C127 84 179 826 819 ;
19 shoe27 181 ;
20 B227 112 138 751 821 ;
21 B127 236 433 434 115 136 744 138 751 821 ;
22 AB27 218 824 217 433 434 115 136 744 138
751 821 ;
23 A127 382 381 824 217 433 434 115 136 744
138 751 821 ;
24 33LE1 55 733 54 75 53 ;
25 33LCDE 55 733 54 ;
26 33LC3 179 826 819 181 66 ;
27 33Lshoe 179 826 819 181 ;
28 33LB2 179 826 819 181 199 ;
29 33LB1 179 826 819 181 199 ;
30 33LAB 391 223 389 234 233 ;
31 33RE2 72 75 53 ;
32 33RCDE 72 75 ;
33 33RC3 72 ;
34 33RC2 23 803 51 52 43 ;
35 33RC1 23 803 51 52 43 44 179 826 819 181 ;
36 4B1 821 751 138 744 392 391 ;
37 4B2 821 751 138 112 ;
38 4C4 181 66 ;
39 4C5 55 ;
40 4CDE 66 64 62 60 58 56 815 816 55
733 54 75 ;
41 4E1 75 53 339 ;
42 A14R 380 382 381 824 217 433 434 115 ;
43 AB4R 825 218 824 217 433 434 115 ;
44 B14R 236 433 434 115 ;
45 B24R 181 821 751 138 ;
46 C14R 84 179 826 819 821 751 138 ;
47 C24R 78 44 179 826 819 821 751 138 ;
48 C34R 72 51 52 43 44 179 826 819 821 751 138 ;
49 CDE4R 743 24 51 52 43 44 179 826 819 821
751 138 ;
50 E14R 346 25 24 51 52 43 44 179 826 819
821 751 138 ;
51 E24R 745 796 26 25 24 51 52 43 44
179 826 819 821 751 138 ;
52 PATH10 827 387 ;
53 PATH11 830 ;

11. CONCOURSE record

11.1 Logic

This optional record is used to reference a group of gates, a "concourse", rather than a single gate. We use concourses in the GATERWY record (See p. 52) in order to impose specific taxipaths between runways and groups of gates.

11.2 Features

We have defined 13 concourses including up to 23 gates. These groups are defined according to the topology of the aprons. The record is the following:

CONCOURSE 13 concourses in this application with up to 23 gates
1 termA1 G_A8 G_A9 G_A10 G_A11 G_A12 ; ;
2 termAB G_A7 G_CAPE G_AA G_AB G_A6 G_A5 G_A4 G_A3 G_A2 G_A1 G_B1 G_B2 G_B3 G_B4 G_B6 G_B8 G_B10 G_B12 G_B13 G_B11 G_B9 G_B7 G_B5 ; ;
3 termB1 G_B14 G_B15 G_B16 G_B17 ; ;
4 termB2 G_B17A G_B18 G_B18A G_B19 G_B22 G_B21 G_B20 G_B24 G_B29 ; ;
5 shoe G_B28 G_B27 G_B26 G_B23 G_B42 G_B43 G_C41 G_C40 G_C25 G_C27 G_C33 ; ;
6 termC1 G_C31 G_C29 G_C30 G_C32 G_C34 ; ;
7 termC2 G_C36 G_C28 G_C26 G_C12 G_C14 ; ;
8 termC3 G_C21 G_C20 G_C19 ; ;
9 termCDE G_C18 G_C17 G_C16 G_C15 G_C11 G_D1E G_E1B G_E1A G_E2A ; ;
10 termE1 G_E2B G_E3A G_E3B G_E4 ; ;
11 termE2 G_E5 G_E6 G_E7A G_E7B G_E8A G_E8B ; ;
12 termC4 G_C31 G_C29 G_C30 G_C32 ; ;
13 termC5 G_C20 G_C21 ; ;

12. GATERWY record

12.1 Logic

This optional record supplements SIMMOD's taxipath optimization logic. Users may use this record to specify taxipaths between concourses (or gates) and runways. This record is used when the gate assignment is not known in advance; SIMMOD references a GATERWY record to find a taxipath or partial taxipath that is suitable for that gate.

12.2 Features

This record has required an important development so as to define the appropriate partial taxipaths that would guide aircraft to and from their gate. We have considered 92 records in the first configuration and 74 in the second one[4]:

Configuration	Routes	GATERWY records
1 (Northwest)	Departures on 27	1-11
	Departures on 33L	12-22
	Arrivals on 33L	23-32
	Arrivals on 33R	33-43
2 (Northeast)	Arrivals on 4R	44-52
	Arrivals on 4L	53-61
	Departures on 4R	62-72
	Departures on 4L	73-83
	Departures on 9	84-94

The record is quite easy to read: a concourse, a taxipath to follow, a runway, used either for departures (DEP) or arrivals (ARR). Here is an extract of the record:

GATERWY There are 74 records defined for this run
1 termA1 A127 27 DEP ;
2 termAB AB27 27 DEP ;
3 termB1 B127 27 DEP ;
4 termB2 B227 27 DEP ;
5 shoe shoe27 27 DEP ;
6 termC1 C127 27 DEP ;
7 termC2 C227 27 DEP ;
8 termC3 C327 27 DEP ;
9 termCDE CDE27 27 DEP ;
10 termE1 E127 27 DEP ;

[4] In the file for the second configuration, we have suppressed some records for runways 33L.

13. RWYCROSS record

13.1 Logic

This optional record is used to model runway crossings from hold line to hold line. This record is also used to assign specific times and characteristics to each runway crossing. To decide whether an aircraft can cross, it follows these rules:

Current time + transit t. + start-up t. + pre-empt t. < start of roll of next arrival

Current time + transit t. + start-up t. - RC fudge < start of roll of next departure

Where *transit time* is defined by the links involved in the crossing

Start-up time is defined in the probability distribution (PROBDIST record)

Pre-empt time is given in the record

RC fudge is a global variable defined in the GLOBAL record.

13.2 Features

The start-up distribution is (p. 33):

```
1 DELAY_DIST
  1 ; 0.0 10.0 1.0 10.0 ;
  2 3 ; 0.0 6.0 1.0 6.0 ;
  4 ; 0.0 2.0 1.0 2.0 ;
```

corresponding to 10 seconds for heavy aircraft, 6 seconds for jets and 2 seconds for small aircraft. These values are comparable to E&K's 3 seconds controller lag. We consider that priorities change from departing aircraft to crossing ones when the later have waited more than 5 minutes and or when they are more than 5 in line.

For pre-empt time, we pick 5 seconds, except for November on 33L (where there is actually plenty of time to cross). For RC fudge, defined in the GLOBAL record (p. 59), we know that the departure roll from 27 or 33L until the runway crossings takes about 25 seconds. We can thus allow a 10 seconds lateness in the crossing.

In the Airport Machine model, E&K blocks departures and crossings when an arrival is within 1 nm of the runway.

Under the two configurations, we have considered the following values:

Runway crossing	**Corresponding**	**Nodes involved**	**Transit time (seconds)**	**Pre-empt time**
1st configuration				
DBL33L	Crossing 33L on Delta	387 76 386	21	5
CBL27	Crossing 27 on Charlie	388 81 389	22	5
NBL33L	Crossing 33L on November	384 19 25	27	3
2nd configuration				
CBL4L	Crossing 4L on Charlie	390 39 377	21	5
FBL4L	Crossing 4L on Fox-Trot	376 38 375	20	5
QBL4L	Crossing 4L on Quebec	374 37 391	18	5
33RBL4L	Crossing 4L on 33R	392 6 394	22	5
NBL4L	Crossing 4L on November	135 340 129	26	5
SBL4L	Crossing 4L on Sierra	380 102 94	26	10
WBL4L	Crossing 4L on Whisky	101 382 103 94	28	10
BBL4L	Crossing 4L on Bravo	113 93 12 433	26	10

Aircraft travel at 15 knots on all these links. This makes the following record:

RWYCROSS 11 crossings
1 CBL4L 5.0 5 5 1 390 39 377 ;
2 FBL4L 5.0 5 5 1 376 38 375 ;
3 QBL4L 5.0 5 5 1 374 37 391 ;
4 33RBL4L 5.0 5 5 1 392 6 394 ;
5 NBL4L 5.0 5 5 1 135 340 129 ;
6 SBL4L 5.0 5 10 1 380 102 94 ;
7 WBL4L 5.0 5 10 1 101 382 103 94 ;
8 BBL4L 5.0 5 10 1 113 93 121 433 ;
9 DBL33L 5.0 5 5 1 387 76 386 ;
10 CBL27 5.0 5 5 1 388 81 389 ;
11 NBL33L 5.0 5 3 1 384 19 415 ;

14. DCONGESTION and DSTAGING record

14.1 Logic

These records model departure staging: the location of the staging pads (DSTAGING) and cases when aircraft are sent to these pads (DCONGESTION). Normally, departures are sent to the departure staging areas when the number of aircraft in a given departure queue plus the ones that travel to this departure queue reaches a threshold given in the DEPARTQ record. Beside this logic, it is also possible to send them to the staging pad if congestion reaches a given threshold in a defined area.

14.2 Features

In the first configuration, since departure queues are located in clearly distinct zones, we do not need to consider specific congestion areas. We thus focused on improving the modeling of the "tight" aprons between terminals A and B (map 6, page A-6) and B and C ("horseshoe", map 2, page A-2). This has lead to both CONGESTION and DCONGESTION areas with the same links involved.

Under configuration 2, we have considered 2 departure congestion areas to model congestion around the departure queues for 4L and 9. We had to consider 4 staging areas: two on kilos for aircraft coming from terminal A and B or C, D and E, plus two for the gates closer to the South West corner. Then, we added staging areas on each section of the taxiways leading to the South West corner.

This leads to the following record for configuration 1:

```
DCONGESTION We consider 2 congestion area with all these 28 links and 3 departure queues
1 1 ; 822 320 308 319 804 805 806 807 808
  809 810 317 312 316 315 309 306 304 811
  70 71 826 67 199 66 181 819 821 ; QUEUE27 QUEUE33L QUEUE33L2 ;
2 1 ; 266 253 812 265 264 263 262 261
  260 ; QUEUE27 QUEUE33L QUEUE33L2 ;
```

And for configuration 2:

```
DSTAGING We consider 15 departure staging areas
1 KILO1 176 433 434 4 2 ;
2 KILO2 373 751 138 4 2 ;
3 GATE17 98 198 112 2 1 ;
4 BGATES 98 207 112 2 1 ;
5 SP1 436 838 115 1 0 ;
6 SP2 176 433 434 3 1 ;
```

7 SP3 435 382 837 1 0 ;
8 SP4 437 112 839 1 0 ;
9 SP5 98 207 113 2 0 ;
10 SP51 98 207 112 2 0 ;
11 SP52 98 198 113 2 0 ;
12 SP53 98 198 112 2 0 ;
13 SP6 373 751 138 3 1 ;
14 SP7 382 762 479 1 0 ;
15 SP8 380 758 784 1 0 ;
DCONGESTION We consider 2 dcongestion areas with 3 links and 1 queue
1 2 ; 394 ; QUEUE4L ;
2 3 ; 841 119 785 ; QUEUE9 ;

15. DSDPATH record

15.1 Logic

The DSDPATH record is used to more realistically model cul-de-sacs and gate terminal traffic. DSDPATH (Dynamic Single Direction Path) allow users to define a group of links as a path that may have multiple entry and exit points. SIMMOD permits the user **to restrict aircraft to taxi in one direction at a time** on this group of links. The designated direction of the path depends on the direction of travel of any aircraft already on the links. Oncoming aircraft are held until the possibility of head-on encounters is eliminated. This level of control is optional.

The typical use of this record is to block taxiways while an aircraft pushes back. It is important to note that this will not change the taxipath an aircraft uses: the taxipath is still calculated as the fastest one based on the AFLINKS record.

15.2 Features

We have thus developed various DSDPATH for the gate/aprons areas around the terminals. Here they are, first for configuration 1:

```
DSDPATHS There are 10 paths, 37 max links per path
1 KA 377 250 246 243 240 228 232 233 234
  389 223 391 249 247 245 244 242 241 239
  238 237 231 230 229 227 226 235 219 225
  212 222 221 220 214 211 210 248 ; 5 ;
2 KA2 200 201 202 203 204 205 206 207 749
  183 187 186 185 184 189 188 191 190 193
  192 195 194 196 198 209 208 197 750 ; 5 ;
3 KA3 347 344 342 339 53 75 54 733 55
  345 343 340 341 337 338 335 336 328 334
  327 323 330 74 73 727 728 76 77 818
  816 815 ; 5 ;
4 SHOE 822 320 308 319 804 805 806 807 808
  809 810 317 312 316 315 309 306 304 811
  70 71 826 ; 1 ;
5 TAB1 259 260 261 267 269 262 273 274 ; 1 ;
6 TAB2 263 271 272 264 ; 1 ;
7 TAB3 265 813 277 812 ; 1 ;
8 TAB4 252 253 286 266 814 ; 2 ;
9 KILO 217 236 ; 2 ;
10 CROSS 67 199 66 181 819 821 ; 3 ;
```

← Circulation on Kilo and Alpha

← Circulation in the “horseshoe” between terminal

← Circulation between terminal A and B

and for configuration 2,

```
DSDPATHS There are 20 paths, 37 max links per path
1 KA 377 250 246 243 240 228 232 233 234
  389 223 391 249 247 245 244 242 241 239
```

← Records kept from the first configuration

238 237 231 230 229 227 226 235 219 225
212 222 221 220 214 211 210 248 ; 5 ;
4 SHOE 822 320 308 319 804 805 806 807 808
809 810 317 312 316 315 309 306 304 811
70 71 826 ; 1 ;
5 TAB1 259 260 261 267 269 262 273 274 ; 1 ;
6 TAB2 263 271 272 264 ; 1 ;
7 TAB4 265 813 277 812 ; 1 ;
8 KILO 217 236 ; 2 ;
9 CROSS 67 199 66 181 819 821 ; 3 ;
11 AROUND4L 136 744 394 ; 4 ;
12 PBB1 183 820 ; 2 ;
13 PBB2 187 200 ; 2 ;
14 PBB3 185 201 ; 2 ;
15 PBB4 189 202 ; 2 ;
16 PBB5 191 203 ; 2 ;
17 PBB6 193 204 ; 2 ;
18 PBB7 195 205 ; 2 ;
19 PBB8 196 206 ; 2 ;
20 PBB9 198 207 ; 2 ;
21 ALPHA1 835 56 ; 2 ;
22 ALPHA2 815 816 55 733 54 ; 2 ;
23 ALPHA3 75 53 ; 2 ;

← Circulation on Alpha in front of terminal B (map 2, gates B20, 24, 25)

← Circulation on Alpha in front of terminal C (map 1, gates C36, C21, etc.)

16. TOWING and GLOBAL records

This optional data record is used to define ground nodes as towing areas. The towing logic can be used by arrivals, departures, and arrival and departure turnarounds. Arrivals, after unloading at a gate, tow to a towing area to release the gate. Departures enter the simulation at a towing area and tow to a gate where they become normal departure events. Arrival turnarounds unload at a gate and then tow to a towing area where they wait until their turnaround departure time. Departure turnarounds start at a towing area, tow to a gate, and depart for the destination airport where they become arrivals that use towing logic. If towing is used in an Events record (ARRIVAL, EMPLANE, MULTARR, and MULTDEP) and the towing identification number is not specified, SIMMOD will look here for the appropriate towing area. Therefore, towing areas must be specified in this record if they are not specified in Events records.

Although this record appears useful in the framework of this modeling effort, the corresponding codes in the event file have generated errors. This means that we can not properly model towing operations performed for instance by America West or Virgin Atlantic. The former airline needs to send an aircraft to its RON around 9, bring another back and tow it away at night. For the moment, we have to consider that gate B17 has a capacity of 2 aircraft.

The GLOBAL record is used to define some variables. Most of them do not work. We just define the value of the RC_fudge_time for the runway crossings, at 10 seconds (p. 53).

4. The Airspace network description file "Airspace.xxx"

This file defines all operations in the airspace. This includes nodes, links and routes taken by aircraft in the terminal area, procedures followed for landing and take-off on the different runways, and relationship between operations in the air and on the ground. For the second configuration, it looks as follows.

```
COMMENT CENTER NM 0:00.0000 0:00.0000
NODES The default separation is 3.0 miles, Max nodes: 38
   NodeNo Name Altitude Strategy ArrStrat MIT Cap HoldStrat HoldStak ; x y
3    NODE_3     00100 1 0  0.0   1 1 1 ;    0.981268    3.696758
[…]
52   NODE_52    00000 1 0  3.0   1 1 1 ;   -2.844252    3.337308
LINKS Over = 1 , Wake = 1 , Cap = 15 , Del = 0 min, Mlnks = 40
   LinkNo Name From To Len Heading LkType Overtake WakeT Cap MaxDly (Mate MateFlag);
2    LINK_2              3    4   29 197 1 1 1   1 0 ;
[…]
67   LINK_67             25   52   37 316 1 1 1   2 0 ;
ROUTES Def sep dist = 3.0 nmiles, Max route = 37 , node/route = 3
2     RT_2 ; 7 3 4 ; ; ;
[…]
49  ROUTE_49 ; 25 52 ; ; ;
PROCEDURES Def time sep = 35 sec, dist sep = 1.00 miles, 69 procedures
1 ARR MIT 4L 103 ;
  1 ; 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 ;
0.0 0.0 0.0 0.0 2.1 2.1 2.4 2.4 2.8 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 ;
[…]
115 DEP MIT 15R 21 QUEUE15R ;
  1 2 3 4 5 ; 50 ; 2.0 ;
AIRCRAFT 5 aircraft groups according to FTA with void separation
1 SML Min ceiling = 200 feet, min rwy vis = 1800
 I 130.00 ;
 I 110.00 ;
 I 90.00 ;
 0. ;  0. ;  110 ;
 2.1 2.1 2.1 2.1 2.1 ;
 0.0 0.5 0.2 1.1 0.4 1.2 0.5 1.3 0.6 1.5 1.0 2.0 ;
 53 62 75 98 99 ;
2 LRGPROP Min ceiling = 100 feet, min rwy vis = 1200
 I 160.00 ;
 I 140.00 ;
 I 110.00 ;
 0. ;  0. ;  140 ;
 3.4 2.1 2.1 2.1 2.1 ;
 0.0 0.5 0.2 1.1 0.4 1.2 0.5 1.3 0.6 1.5 1.0 2.0 ;
 64 67 ;
3 LRGJETS Min ceiling = 100 feet, min rwy vis = 1200
 I 160.00 ;
 I 140.00 ;
 I 110.00 ;
 0. ;  0. ;  140 ;
 3.4 2.1 2.1 2.1 2.1 ;
 0.0 0.5 0.2 1.1 0.4 1.2 0.5 1.3 0.6 1.5 1.0 2.0 ;
 10 11 13 16 29 32 34 35 40 41 42 47 50 59 85 86 89 97 ;
4 757 Min ceiling = 100 feet, min rwy vis = 1200
```

```
 I 160.00 ;
 I 140.00 ;
 I 110.00 ;
 0. ;  0. ;  140 ;
 4.3 3.4 3.4 3.4 3.4 ;
 0.0 0.5 0.2 1.1 0.4 1.2 0.5 1.3 0.6 1.5 1.0 2.0 ;
 12 51 ;
5 HVY Min ceiling = 0 feet, min rwy vis = 700
 I 160.00 ;
 I 140.00 ;
 I 110.00 ;
 0. ;  0. ;  140 ;
 5.1 4.3 4.3 4.3 3.4 ;
 0.0 0.5 0.2 1.1 0.4 1.2 0.5 1.3 0.6 1.5 1.0 2.0 ;
 1 2 5 14 15 20 22 31 84 87 ;
LATENESS there are 3 lateness distributions
0.0 30.0 0.6 32.0 0.8 35.0 1.0 40.0 ; emplane
0.0 30.0 0.6 32.0 0.8 35.0 1.0 40.0 ; arrivals
0.0 30.0 0.6 32.0 0.8 35.0 1.0 40.0 ; reemplane (turnaround)
AIRPORTS Def ceiling = 5000 ft, def rwy vis range = 30000 ft
1 MIT   Elev = 0 ft, interface nodes are: 4 5 8 11 13 15 25 27 29 31  ;
  LOGAN AIRPORT REVIEWED FIRST MODEL UNDER PLAN TWO
 1 101 ; 6 7 8 9 10  ; ;
 1 61 62 63 64 65 ; 16 17 18 19 20 ; ;
 1 1 2 3 4 5 ; 76 77 78 79 80 ; ;
 1 11 12 13 14 15 ; 71 72 73 74 75 ; ;
 1 110 ; 51 52 53 54 55 ; ;
 1 66 67 68 69 70 ; 21 22 23 24 25  ; ;
 1 107 ; 46 47 48 49 50 56 ; ;
 1 ; ; ;
 1 ; ; ;
 1 41 42 43 44 45 ; 115 ; ;
GO
```

1. NODES and LINKS records

1.1 Logic

The NODES record is used to create airspace nodes and define their characteristics. Characteristics include control strategies, holding strategies, separation distances, and maximum aircraft per airspace node.

The LINKS record is used to create airspace links and define aircraft movement on them. User-defined attributes include passing, sequencing, and number of aircraft per link.

1.2 Features

Since the airspace is not the focus of this model, we use the standard values for all inputs and we consider straight links from the runways, of sufficient length to ensure proper separations. An extract of these records appears below.

```
NODES The default separation is 3.0 miles, Max nodes: 38
    NodeNo Name Altitude Strategy ArrStrat MIT Cap HoldStrat HoldStak ; x y
3    NODE_3     00100 1 0  0.0   1 1 1 ;    0.981268    3.696758
4    NODE_4     00050 1 0  0.0   1 1 1 ;    0.124343    0.905331
5    NODE_5     00050 1 0  0.0   1 1 1 ;    0.341073    0.761722
6    NODE_6     00100 1 0  0.0   1 1 1 ;    1.559991    3.582390
7    NODE_7     00300 1 0  0.0   1 1 1 ;    1.553319    5.598403
8    NODE_8     00050 1 0  0.0   1 1 1 ;   -0.261698   -0.184830
9    NODE_9     00100 1 1  2.1   5 1 1 ;   -1.609113   -3.610970
10   NODE_10    00300 1 0  0.0   5 1 1 ;   -2.297306   -5.260359
LINKS Over = 1 , Wake = 1 , Cap = 15 , Del = 0 min, Mlnks = 40
    LinkNo Name From To Len Heading LkType Overtake WakeT Cap MaxDly (Mate MateFlag);
2    LINK_2           3    4   29 197 1 1 1   1 0 ;
3    LINK_3           6    5   31 203 1 1 1   2 0 ;
4    LINK_4           7    3   20 196 1 1 1   1 0 ;
5    LINK_5           9    8   37  21 1 1 1   2 0 ;
6    LINK_6          10    9   18  22 1 1 1   1 0 ;
7    LINK_7          12   11   38  18 1 1 1   2 0 ;
8    LINK_8          14   13   41  75 1 1 1   2 0 ;
9    LINK_9          16   15   39 256 1 1 1   2 0 ;
```

The figure on the next page shows the location of these links and nodes:

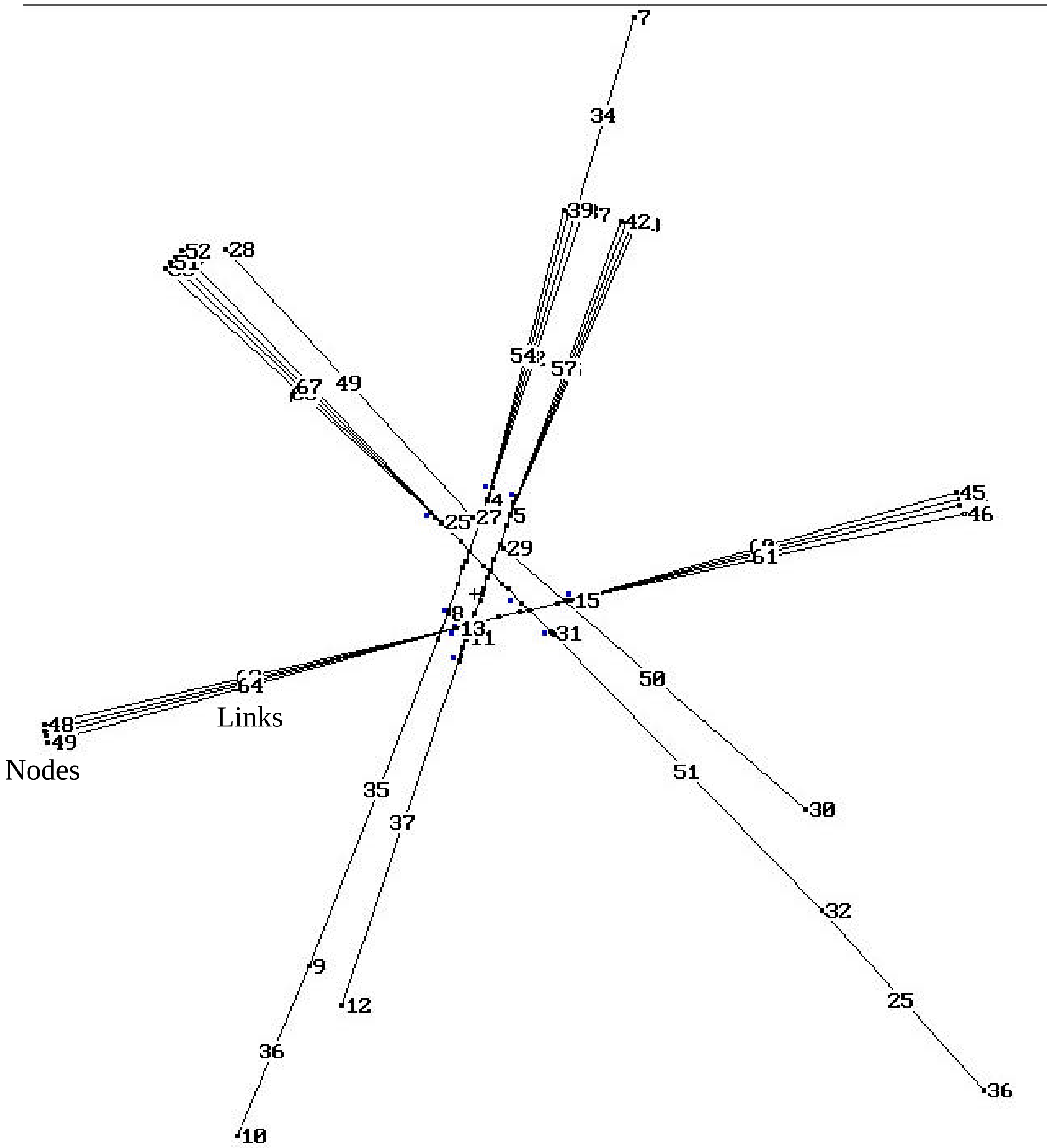
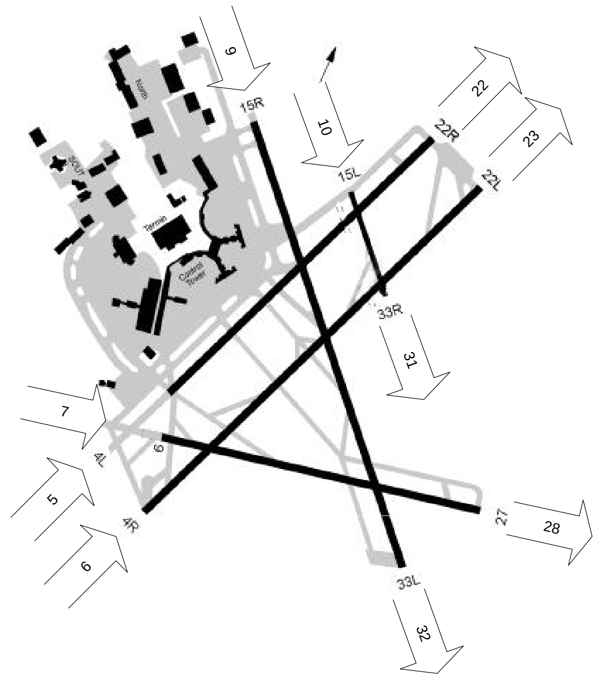


Figure 1: Location of the airspace nodes and links (2nd configuration file)

2. ROUTES record

2.1 Logic

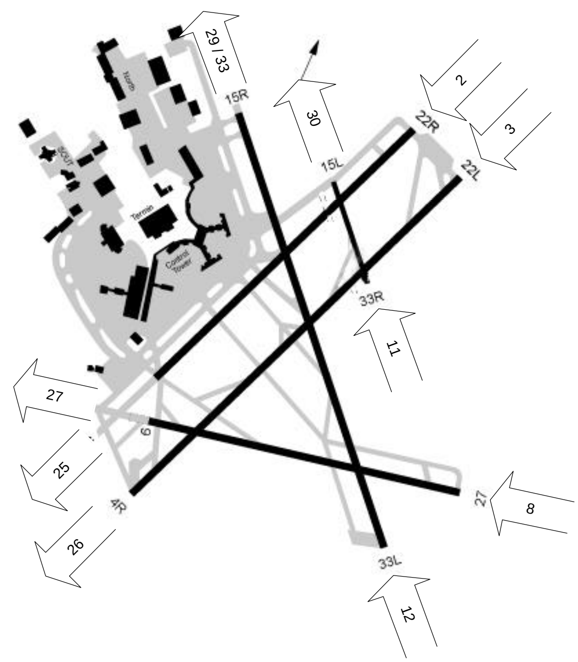
The ROUTES record is used to create routes, describe their attributes, and set the sequence of flight path nodes through which aircraft travel, including those required to recover from a missed approach.



2.2 Features

In order to build easily all possible configurations, we consider 20 routes in both directions for all runway-ends. Arrival routes are numbered 2 to 12 and departure routes 22 to 32:

Run way	Arrival route	Departure route
22R	2	25
4L	5	22
22L	3	26
4R	6	23
9	7	28
27	8	27
15R	9	32
33L	12	29
15L	10	31
33R	11	30



The charts on the right are clearer.

This means that the three plans we consider now use the following routes:

	Arrival routes	**Departure routes**
Northeast (plan 1)	5, 6	22, 23, 28
Northwest (plan 2)	11, 12	27, 29
Southwest (plan 3)	3, 8	25, 26

To take into account diverging routes for the various types of aircraft, we then have had to consider specific routes for each class:

RWY	**Small**	**Props**	**Jets**	**757 & Heavies**
Cfg No. 1				
4L	22	34	(35)	(36)
4R	(23)	(37)	38	39
9	(28)	41	42	43
Cfg No. 2				
27	27	44	45	46
33L	29		48	49
33L2		33		

3. PROCEDURES record

3.1 Logic

The PROCEDURES record defines steps a transitioning aircraft follows for approach/landing or takeoff/ascent, including runway occupancy times. Related procedures (using the same runway or closely spaced, parallel, or crossing runways) should be defined together for the simulation to resolve conflicts.

3.2 Features

In this first model, we consider the following values for arrival and departure procedures:

Arrivals on	Landing roll beginning at node
22R	1
4L	103
22L	381
4R	142
15R	20
33L	79
9	92
27	86
33R	142
15L	6

Departures on	Take-off roll beginning at node	Queue at
22R	340	QUEUE22R
4L	103	QUEUE4L
22L	339	QUEUE22L
4R	142	QUEUE4R
15R	21	QUEUE15R
33L	78	QUEUE33L
9	92	QUEUE9
27	86	QUEUE27
33L "33Golf"	33	QUEUE33L2

The following groups of procedures apply to the two configurations:

Configuration	Group of procedures	Procedures
1 (North West)	ARR on 33R	31[5]
	ARR and DEP on 33L	41-50
	DEP on 27	51-55
	DEP on 33L from Golf	56
2 (North East)	ARR and DEP on 4L	1-10
	ARR and DEP on 4R	11-20
	DEP on 9	21-25

Procedures 60 to 80 correspond to operations on 22L and 22R. They have not been thoroughly tested.

[5] Under the second configuration, it is necessary to suppress runway 33R to model the crossing of runway 4L. We thus suppress this procedure.

3.3 Motivation

Let us review the values we have used for the 4 groups of procedures involved in configuration No. 1: arrivals and departures on 33L and on 27.

Arrivals on 33L block departures on the same runway 0.6 to 0.9 nm before they actually touch down. Thus, in terms of procedure blocking, we have to add the travel time from the departure queue. Here are the links involved:

	Links	Travel time (sec.)	Length traveled at 110 knots	Length traveled at 140 knots
DQ → 4R	491	15.1	0.46	0.59
DQ → 4L	762 479	16.3	0.5	0.63
DQ1 → 9	497	10	0.3	0.38
DQ2 → 9	827 387	14.3	0.43	0.55
DQ → 33L	711	13.6	0.41	0.53
DQ → 33L intersect.	726	28.5	0.87	1.11

This applies both for time separation and distance separation. For instance, time separation between departures on intersecting runways must include both the time spent before an aircraft clears the intersection and the time it spent travelling from the departure queue to the runway.

The values used in the procedures are based on complex calculations to achieve the appropriate separations in the air with aircraft that get their clearances in departure queues away from the runways.

Time separation between procedures (2nd configuration):

Proc	**Op.**	**Runway**	**6**	**7**	**8**	**9**	**10**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
6	DEP	4L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	DEP	4L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	DEP	4L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	DEP	4L	0	0	0	0	0	105	105	105	105	105	0	0	0	0	0
10	DEP	4L	0	0	0	0	0	105	105	105	105	105	0	0	0	0	0
11	ARR	4R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	ARR	4R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	ARR	4R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	ARR	4R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	ARR	4R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	DEP	4R	112	112	112	112	112	0	0	0	0	0	45	45	45	45	45
17	DEP	4R	120	120	120	120	120	0	0	0	0	0	45	45	45	45	45
18	DEP	4R	120	120	120	120	120	0	0	0	0	0	40	40	40	40	40
19	DEP	4R	120	120	120	120	120	0	0	0	0	0	40	40	40	40	40
20	DEP	4R	120	120	120	120	120	0	0	0	0	0	40	40	40	40	40
21	DEP	9	0	0	0	0	0	30	30	30	30	30	0	0	0	0	0
22	DEP	9	0	0	0	0	0	30	30	30	30	30	0	0	0	0	0
23	DEP	9	0	0	0	0	0	25	25	25	25	25	0	0	0	0	0
24	DEP	9	0	0	0	0	0	30	30	30	30	30	0	0	0	0	0
25	DEP	9	0	0	0	0	0	30	30	30	30	30	0	0	0	0	0

This means that procedure 16 (departure on runway 4R) will block procedure 9 (departure on 4L) for 112 seconds. Other values are defined for distance separation:

Proc.	Op.	Runway	6	7	8	9	10	16	17	18	19	20	21	22	23	24	25
1	ARR	4L	2.1	2.1	2.4	2.4	2.8	0	0	0	0	0	0	0	0	0	0
2	ARR	4L	2.1	2.1	2.4	2.4	2.8	0	0	0	0	0	0	0	0	0	0
3	ARR	4L	2.2	2.2	2.5	2.5	3	0	0	0	0	0	0	0	0	0	0
4	ARR	4L	2.2	2.2	2.5	2.5	3	0	0	0	0	0	0	0	0	0	0
5	ARR	4L	2.2	2.2	2.5	2.5	3	0	0	0	0	0	0	0	0	0	0
6	DEP	4L	1.4	0.4	0.4	0.4	0.4	0	0	0	0	0	0	0	0	0	0
7	DEP	4L	0.4	1.5	0.4	0.4	0.4	0	0	0	0	0	0	0	0	0	0
8	DEP	4L	0.4	0.4	1.5	0.4	0.4	0	0	0	0	0	0	0	0	0	0
9	DEP	4L	4.4	3.4	3.4	3.4	3.4	0	0	0	0	0	0	0	0	0	0
10	DEP	4L	4.4	4.4	4.4	4.4	3.4	0	0	0	0	0	0	0	0	0	0
11	ARR	4R	0	0	0	0	0	1.6	1.6	1.9	1.9	2.4	2	2	2	2	2
12	ARR	4R	0	0	0	0	0	1.6	1.6	1.9	1.9	2.5	2	2	2	2	2
13	ARR	4R	0	0	0	0	0	1.7	1.7	2	2	2.5	2	2	2	2	2
14	ARR	4R	0	0	0	0	0	1.7	1.7	2	2	2.5	2	2	2	2	2
15	ARR	4R	0	0	0	0	0	1.7	1.7	2	2	2.5	2	2	2	2	2
16	DEP	4R	0	0	0	0	0	2.1	1	1	1	1	0	0	0	0	0
17	DEP	4R	0	0	0	0	0	1	2.1	1	1	1	0	0	0	0	0
18	DEP	4R	0	0	0	0	0	1	1	2.1	1	1	0	0	0	0	0
19	DEP	4R	0	0	0	0	0	5	4	4	4	4	0	0	0	0	0
20	DEP	4R	0	0	0	0	0	5	5	5	5	4	0	0	0	0	0
21	DEP	9	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
22	DEP	9	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
23	DEP	9	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
24	DEP	9	0	0	0	0	0	0	0	0	0	0	4	3	3	3	3
25	DEP	9	0	0	0	0	0	0	0	0	0	0	4	4	4	4	3

These values are adapted from the separations used in FTA’s FLAPS model. Various modifications are necessary to take into account the location of the points used to apply these separations (typically, the departure queue and not the beginning of the runway).

4. AIRCRAFT record:

4.1 Logic

The AIRCRAFT data record is used to define air traffic control characteristics by groups of aircraft models, weather parameters, link types by speed, holding stack types by times and speeds, and intrail separation distances between aircraft of different groups.

4.2 Features

In our case, separation distances are the most important. We can thus simply apply the new[6] FAA definition of the 4 classes of aircraft for intrail separation. Since specific separations apply when deciding how to allocate aircraft to runways, we add the distinction between large props and large jets. This makes 5 classes in the airspace:

(NM)	**Max TO weight**	**H (trail)**	**757**	**L**	**S**	**SIMMOD models**
Heavy (lead)	> 255,000 lbs.	4	5	5	6	1 2 5 20 22 31 84 87
757		2.5	2.5	4	5	51
Large Jets	> 41,000 lbs.	2.5	2.5	2.5	4	29 32 34 35 40 41 42 47 50 59 85 86 89 97
Large Props	> 41,000 lbs.	2.5	2.5	2.5	4	64 67
Small	< 41,000 lbs.	2.5	2.5	2.5	2.5	53 62 75 98 99

We thus have the following fleet mix:

Airspace cat.	**ARR**	**DEP**	**TOT OP.**	**%**	**%**
Heavy	30	29	59	4%	
757	59	59	118	9%	53%
Large Jets	274	275	549	40%	
Large Props	119	119	238	17%	47%
Small	200	201	401	29%	
Total	682	683	1365		

The record is written the following way (shortened for this edition):

```
AIRCRAFT 5 aircraft groups according to FTA with void separation
1 SML Min ceiling = 200 feet, min rwy vis = 1800
 I 130.00 ;  I 110.00 ;  I 90.00 ;  0. ;  0. ;  110 ;
 2.1 2.1 2.1 2.1 2.1 ;
```

[6] The old one was 12,500 and 300,000 lbs.

0.0 0.5 0.2 1.1 0.4 1.2 0.5 1.3 0.6 1.5 1.0 2.0 ;
53 62 75 98 99 ;
2 LRGPROP Min ceiling = 100 feet, min rwy vis = 1200
I 160.00 ; I 140.00 ; I 110.00 ; 0. ; 0. ; 140 ;
3.4 2.1 2.1 2.1 2.1 ;
0.0 0.5 0.2 1.1 0.4 1.2 0.5 1.3 0.6 1.5 1.0 2.0 ;
64 67 ;
3 LRGJETS Min ceiling = 100 feet, min rwy vis = 1200
I 160.00 ; I 140.00 ; I 110.00 ; 0. ; 0. ; 140 ;
3.4 2.1 2.1 2.1 2.1 ;
0.0 0.5 0.2 1.1 0.4 1.2 0.5 1.3 0.6 1.5 1.0 2.0 ;
10 11 13 16 29 32 34 35 40 41 42 47 50 59 85 86 89 97 ;
4 757 Min ceiling = 100 feet, min rwy vis = 1200
I 160.00 ; I 140.00 ; I 110.00 ; 0. ; 0. ; 140 ;
4.3 3.4 3.4 3.4 3.4 ;
0.0 0.5 0.2 1.1 0.4 1.2 0.5 1.3 0.6 1.5 1.0 2.0 ;
12 51 ;
5 HVY Min ceiling = 0 feet, min rwy vis = 700
I 160.00 ; I 140.00 ; I 110.00 ; 0. ; 0. ; 140 ;
5.1 4.3 4.3 4.3 3.4 ;
0.0 0.5 0.2 1.1 0.4 1.2 0.5 1.3 0.6 1.5 1.0 2.0 ;
1 2 5 14 15 20 22 31 84 87 ;

As far as airspeeds are concerned, we use average approach speeds for each of these classes: ~140 knots for Large and Heavy aircraft, ~110 knots for Small ones. In comparison, E&K considers

- a *mean approach speed* of 150 knots for jets (135 knots for small props);
- a *mean landing speed at touchdown* of 122 for Heavies, 117 for Large, 114 for Jets, 105 for Turboprops and 98 knots for Small;
- a *landing speed* of 100 knots for all groups.

5. LATENESS record

5.1 Logic

The lateness record defines probability distributions that are used in the events file to determine the individual lateness of each flight.

5.2 Features

We have considered 3 probability distributions for the 3 types of operations in our events file. These are cumulative probability distributions. By substracting 30 minutes to the original OAG schedule, we can then consider the following values:

LATENESS there are 3 lateness distributions
0.0 30.0 0.6 32.0 0.8 35.0 1.0 40.0 ; emplane
0.0 30.0 0.6 32.0 0.8 35.0 1.0 40.0 ; arrivals
0.0 30.0 0.6 32.0 0.8 35.0 1.0 40.0 ; reemplane (turnaround)

6. AIRPORTS record

6.1 Logic

This record is used to define airport characteristics from an airspace perspective. Data input includes ceiling, runway visual range and interface node characteristics including airport plans and arrival and departure procedures for each interface node.

6.2 Features

Default ceiling and runway visual range are set at 5,000 and 30,000 feet. We use 10 interface nodes with the ground.

In this first model, we consider 2 of the major configurations of the airport.

Plan	Landings	Take-off
Plan 1 (Northeast, VFR-1)	4R, 4L	4L, 4R, 9
Plan 2 (Northwest, VFR-1)	33L, 33R	33L, 27

In accordance with the procedures, we have the following record:

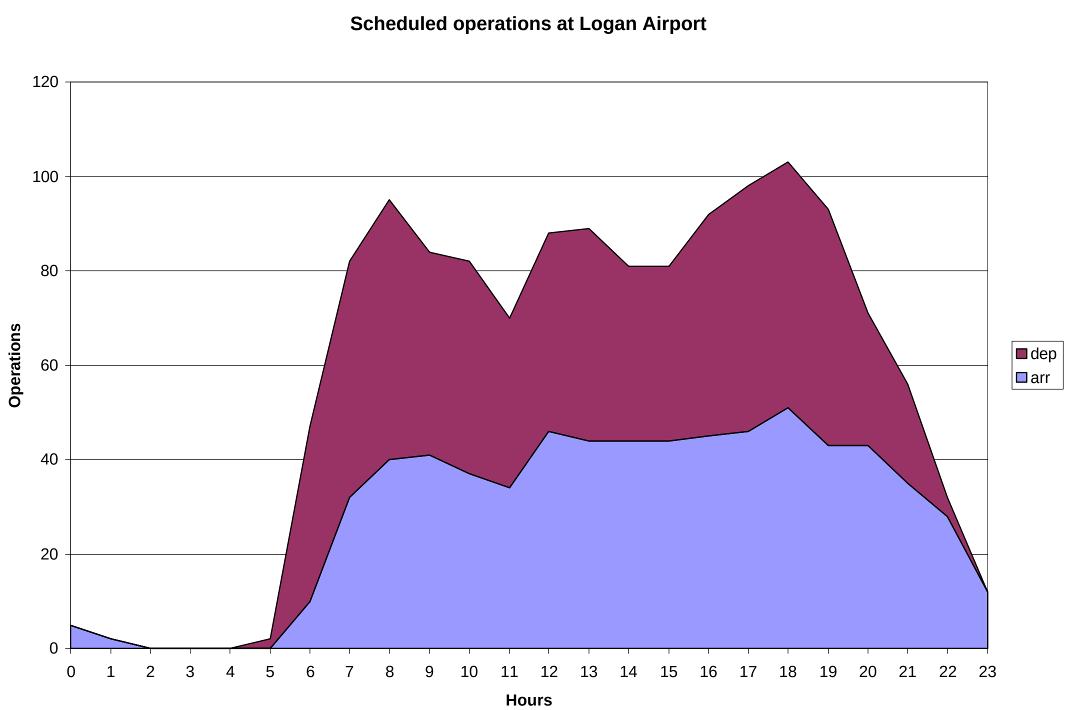
AIRPORTS Def ceiling = 5000 ft, def rwy vis range = 30000 ft
1 MIT   Elev = 0 ft, interface nodes are: 4 5 8 11 13 15 25 27 29 31 ;
LOGAN AIRPORT REVIEWED FIRST MODEL UNDER PLAN TWO
1 101 ; 6 7 8 9 10 ; ;
1 61 62 63 64 65 ; 16 17 18 19 20 ; ;
1 1 2 3 4 5 ; 76 77 78 79 80 ; ;
1 11 12 13 14 15 ; 71 72 73 74 75 ; ;
1 110 ; 51 52 53 54 55 ; ;
1 66 67 68 69 70 ; 21 22 23 24 25 ; ;
1 107 ; 46 47 48 49 50 56 ; ;
1 105 ; ; ;
1 31 ; ; ;
1 41 42 43 44 45 ; 115 ; ;

5. Events.xxx

Events are composed of arrivals and departures. We need the following data for each of these events:

- Arrival/departure times (correspond to the moment when the aircraft appears in the simulation, i.e. when an arrival appears on the route it is flying towards, or when an aircraft appears in its gate to be prepared for departure);
- Airline (for gate assignment);
- Flight number;
- Type of aircraft;
- Route of arrival or departure;
- Taxipath used (or ? for an optimal taxipath);
- Gate used (or ? for any available gate);

We use an OAG schedule for July 9, 1997 containing 683 departures and 682 arrivals. The types of aircraft and airlines used in this schedule are examined in the AIRLINE and AIRCRAFT records. (See p. 42 and 69)



We have had to make important modifications to the OAG schedule in order for it to fit our needs. We had to identify what was the probable outbound flight corresponding to an arriving aircraft, which is sometimes uncertain.

The current version of the EVENTS file thus consists of 884 events: 412 turnaround flights, 272 arrivals and 270 departures. All arrivals have not been assigned departures for commuter operations. Operations[7] are assigned to the following aircraft and the following companies:

SIM.	OAG	BE	USE	US	AA	DL	UA	9K	CO	UAE	DLS	NW	AC	USS	Total
64	SF3	220			4										224
62	BE1		168												188
50	M80			11	50	8			42						119
51	757			17	22	20	29					22			119
29	72S										44			34	78
47	73S			40		30									78
75	CNA							73							73
98	J41									44					70
99	DH8		36										16		54
35	733			23			18		10						53
40	D9S			22								3	2		47
97	32S						12					8	10		36
89	100			22	6										32
22	L10					4	11					3			26
59	CRJ	18											8		26
85	734			19											19
53	J31									18					18
86	735						8		8						16
87	763					14									14
67	ATR				14										14
31	AB3				8										12
32	767			4	2	4									12
20	D10				2							8			10
42	737								4						4
Total		238	204	158	108	80	78	73	64	62	44	44	36	34	1366

Aircraft	OAG	INT	TWE	9L	TW	HP	YX	CP	J7	JI	W9	NK	VS	SN	Total
62	BE1			20											188
50	M80				8										119
51	757	2				7									119

[7] A turnaround flight is counted as 2 operations, while simple arrivals and departure count for 1 each.

47	73S					2					6				78
98	J41		22					4							70
99	DH8							2							54
35	733					2									53
40	D9S						8		8			4			47
97	32S					2		2		2					36
89	100									4					32
22	L10				8										26
31	AB3	4													12
32	767	2													12
2	747, 743, 777	7											2		9
5	340	2												2	4
41	DC9						4								4
84	744	4													4
1	330	2													2
34	310	1													1
Total		24	22	20	16	13	12	8	8	6	6	4	2	2	1366

The main feature of the event file is the route assignment. As we have seen under the procedures (p. 62), routes are assigned by classes following specific percentages. The events file has the following records:

Class	**Total operations**	**Simple ARR**	**Simple EMPL**	**Turnaround**
1 (SML)	401	53	56	146
2 (LRGPR)	240	111	111	9
3 (JETS)	528	78	74	188
4 (757)	117	25	26	33
5 (HEAVY)	80	10	12	29

These operations must then be distributed randomly between the routes that are actually used by each class. We have to achieve the following repartitions:

CFG 1	**All arrivals**		**Simple EMPL**			**Turnaround**		
Route	**11**	**12**	**27**	**29**	**33**	**27**	**29**	**33**
	ARR 33R	*ARR 33L*	*DEP 27*	*DEP 33L*	*DEP 33G*	*DEP 27*	*DEP 33L*	*DEP 33G*
1	64	135	56			146		
2		120	5		106	1		8
3		266	69	5		175	13	
4		58	19	7		24	9	
5		39	7	5		16	13	
Props	*20%*	*80%*	*63%*		*37%*			
Jets	*0%*	*100%*	*82%*	*18%*				

Under configuration 2:

CFG 2	**All arrivals**		**Simple EMPL**			**Turnaround**		
Route	**5**	**6**	**22**	**23**	**28**	**22**	**23**	**28**

	ARR 4L	*ARR 4R*	*DEP 4L*	*DEP 4R*	*DEP 9*	*DEP 4L*	*DEP 4R*	*DEP 9*
1	199		56			146		
2	120		108		3	9		
3		266		5	69		14	174
4		58		7	19		10	23
5		39		5	7		12	17
Props	*100%*	*0%*	*99%*		*1%*[8]			
Jets	*0%*	*100%*		*15%*	*85%*			

To look at many iterations, as we did in our case studies, this entire day schedule has been reduced to a *morning push* schedule that was easier to manipulate. This schedule represents all the flights until 11:00am.

[8] These figures apply to both simple EMPLANE and turnaround operations.

6. Typical outputs

We comment here the results of typical runs of the model.

1. ECHO file: configuration 1, morning push schedule

The Echo file typically contains two warnings for all aircraft that are not assigned to ground and airspace groups. Other warnings must be corrected.

2. LOG file in the example of a morning push schedule on configuration 2

We list here all the notices that were reported in the log file for the 20 iterations of the second case (taxiway Kilo blocking) of our case study on the South West corner:

Notice in the Log file	First iteration	Total 20 iterations	Explanation
(AIR.101-ERR)	1	104	Delays in the air cancelled
(DSD.910-000)	10	162	Transfer between DSPPATHS
(END.100-000)	2	40	Logs at the end of the simulation
(END.SIM-000)	4	80	Logs at the end of the simulation
(GAT.100-ERR)	16	321	Gate changes
(LAN.200-000)	14	232	Missed approaches (2 lines per flight)
(LANDING+293)	7	116	Missed approaches (1 lines per flight)
(PTX.235-000)	12	184	Gridlock protection notices
(PTX.260-000)	0	1	Priority switching for runway crossing
(PTX.900-000)	18	40	Gridlock protection notices
(PTX.900-135)	9	10	Gridlock protection notices
(PTX.900-139)	9	10	Gridlock protection notices
(PTX.900-142)	0	4	Taxiing notifications?
(RWY.000-000)	13	208	Aircraft blocked on a runway (usually linked to the missed approaches)
(SET.PLN-000)	3	60	Logs at the beginning of the simulation
(TAK.100+293)	2	69	Runway blocking on take-off
(TRACE-000)	12	240	Logs of hours
(UTL.105-OOO)	16	303	Staging areas overflow
(UTL.820-197)	18	750	End of iteration notices
(UTL.860-000)	298	11192	Gate compatibility

A similar study on the 20 iterations when 4L is closed give the following list:

Notice in the Log file	First Iteration	Total 20 iterations	Explanation
(AIR.101-ERR)		1	Delays in the air cancelled
(DSD.910-000)	4	151	Transfer between DSPPATHS
(END.100-000)	2	40	Logs at the end of the simulation
(END.SIM-000)	4	80	Logs at the end of the simulation
(GAT.100-ERR)	19	334	Gate changes

(LAN.200-000)	14	400	Missed approaches (2 lines per flight)
(LANDING+293)	7	200	Missed approaches (1 lines per flight)
(PTX.235-000)	14	380	Gridlock protection notices
(PTX.900-000)		4	Gridlock protection notices
(PTX.900-142)		2	Taxiing notifications?
(RWY.000-000)	8	205	Aircraft blocked on a runway (usually linked to the missed approaches)
(SET.PLN-000)	3	60	Logs at the beginning of the simulation
(TRACE-000)	12	240	Logs of hours
(UTL.820-197)	4	1299	End of iteration notices
(UTL.860-000)	2388	48838	Gate compatibility

Three of these groups of notices deserve some comments.

1.1 Missed approaches

These missed approach notices correspond to situations when 2 aircraft are on the runway at the same time, which we often consider as possible. Among those 10 circumstances, 6 concerned aircraft taking off from 33L while others arrived on the same runway. 2 involved arrivals on 33L going to terminal E that were still on the runway. In the 2 last, aircraft took off on 33L from Golf while aircraft were arriving on the same runway.

These situations do not seem inappropriate.

1.2 "Gridlock protection" notices

These notices happen in very specific instances when the engine blocks aircraft because it has identified that a gridlock is bound to happen. This should never happen in a clear model. Yet, it has appeared impossible to model the exact behavior of aircraft on the aprons dead-ends of the airport. They simply confirm that the model is not perfect and that it will sometimes enter in a gridlock.

1.3 Incompatible gate assignments

These notices appear simply because regional carriers handle more aircraft on the ground than we estimated. The assignment problem is one of capacity.

7. Sources

Massport

The CAD layout is an Airport Layout Plan from 1996. We used a gate study issued in December 1996 entitled "1996 Logan International Airport Gate Utilization Study".

Flight Transportation Associates

This company provided input data for their FLAPS model of the runway operations. These inputs give aircraft classes used for runway assignment and in-trail separations between procedures under the various configurations that we studied.

A key output gave runway use percentages under the different configurations. This was used to assign randomly aircraft from the same class to two runways and to confirm that our overall assignment was not substantially wrong.

Besides, outputs of the two models were compared in order to identify serious discrepancies in the runway capacity estimates.

Edwards and Kelcey

We used the input files developed by these consultants for their *Airport Machine* model of Logan International Airport.

Station managers

We met with station managers from several airlines to collect data and identify aspects of the operations that required detailed modeling.

On-site data collection

To build various records and validate standard values, it has been necessary to collect data on-site. This has typically been the case for pushback times, speed on taxiways and actual direction of aircraft flows.

Chapter 3: Using a SIMMOD model to assign Gates, A Case Study

1. Content

In this chapter, we present a simple case study to show how the SIMMOD model we have developed for Logan Airport can be used to provide interesting results on the current gate assignment. It is not intended to suggest new policies but to demonstrate that Massport can gain valuable insights from such models to improve its short-term planning process.

2. The question

A simulation of the current operations at Logan Airport provides the following travel and total times on the ground averaged for each carrier:

Carrier (Hidden names)	Total Ground Time (min)	Ground Travel Time (min)
D	59.75	14.58
B	54.07	13.08
F	49.16	10.70
G	47.42	10.20
H	46.71	14.02
I	44.44	9.08
J	40.53	14.62
K	39.75	9.82
L	38.06	13.25
M	38.02	9.19
N	34.90	8.01
O	32.83	8.55
E	32.02	8.67
A	22.21	8.32

These figures come from 10 iterations of a simulation of the morning push (until noon) while in Northwest configuration. In this table, the *total ground time* represents the total time spent on the ground including landing and take-off roll. The *ground travel time* considers only the time spent traveling on the ground, thus excluding delays, landings/take-off and time spent in a departure queue.

What is noteworthy in this table is the large difference between these airlines for both variables. For instance, A has not only one of the lowest average travel time, but also the lowest delay (defined by the difference between the total ground time and the ground travel time). This is mainly due to the fact that all its aircraft can take-off from the Golf intersection. Against this, B and D face not only the highest overall waiting times, but also among the highest traveling times.

Since we note this relative unfairness in the gate allocation, we want to know what could be the impact of a limited reorganization of the gates. This could also suggest differential gate pricing.

3. Development of the models

To compare these two situations, we build two cases.

1. Baseline

In this example of study, the baseline has the following features:

— Current taxiway/runway/gates layout.

— OAG schedule for July 9th 1997, morning (until noon).

— Northwest configuration under VFR weather: landings on 33L and 33R, take-offs on 33L, 27 and 33G (33L from Golf). Assignments are based on weight classes and other models (FLAPS from FTA).

It is important to note that this configuration is not able to sustain the morning traffic that is planned in this schedule without building up significant delays.

Average runway flows, demands, and cumulative differences, based on 10 iterations[1]:

Arrivals	33L				33R				BOS			
	FLOW	DMND	DIFF	FLOW	FLOW	DMND	DIFF	FLOW	FLOW	DMND	DIFF	FLOW
TIME INTERVAL	ARR			ARR+ DEP	ARR			ARR+ DEP	ARR			ARR+ DEP
06:00-07:00	8.6	9	-0.4	18.2	0	0	0	0	8.6	9	-0.4	38.6
07:00-08:00	23.9	24	-0.5	33.4	7	7	0	7	30.9	31	-0.5	71.8
08:00-09:00	34	34.6	-1.1	47.4	3.9	3.9	0	3.9	37.9	38.5	-1.1	81.6
09:00-10:00	33.1	34.1	-2.1	43.5	5.7	5.7	0	5.7	38.8	39.8	-2.1	77.3
10:00-11:00	35.2	34.5	-1.4	44.3	3.4	3.4	0	3.4	38.6	37.9	-1.4	77.6
11:00-12:00	19.9	18.5	0	29.4	3	3	0	3	22.9	21.5	0	64.5

[1] The runway flow is the actual number of aircraft that used the runway during an interval, while the demand shows the aircraft that required using the runway in the same interval. The difference accumulates until the flow can be higher than the demand. For example, 33L can achieve 35.2 arrivals between 10 and 11, 34.5 new demand and 0.7 from the previous period.

Departures	27				33L				BOS			
	FLOW	DMND	DIFF	FLOW	FLOW	DMND	DIFF	FLOW	FLOW	DMND	DIFF	FLOW
TIME INTERVAL	DEP			ARR+ DEP	DEP			ARR+ DEP	DEP			ARR+ DEP
06:00-07:00	20.4	20.7	-0.3	20.4	9.6	9.9	-0.3	18.2	30	30.6	-0.6	38.6
07:00-08:00	31.4	39.7	-8.6	31.4	9.5	9.7	-0.5	33.4	40.9	49.4	-9.1	71.8
08:00-09:00	30.3	43.2	-21.5	30.3	13.4	13.4	-0.5	47.4	43.7	56.6	-22	81.6
09:00-10:00	28.1	32.9	-26.3	28.1	10.4	13.2	-3.3	43.5	38.5	46.1	-29.6	77.3
10:00-11:00	29.9	34.4	-30.8	29.9	9.1	9	-3.2	44.3	39	43.4	-34	77.6
11:00-12:00	32.1	1.3	0	32.1	9.5	6.3	0	29.4	41.6	7.6	0	64.5

As we see in the table above, arrivals are almost entirely served while 27 can not meet the departure demand. These measures can be compared with other models:

Model	ARR 33L	ARR 33R	DEP 33L	DEP 27	TOT
EPS (FAA)[2]	31	10	15	35	91
FLAPS	36.3	2.4	11	27.9	77
Saturation FLAPS 93	38	3	17	24	82
SIMMOD 8:00-9:00	34	3.9	13.4	30.3	81.6

This means that the total ground times are not extremely relevant since this configuration would not be used during peak demand times.

Since we focus on the actual time spent on the ground by each aircraft, it is important to list here the sources of errors on these values that are inherent to our model. Here are the points to make:

1. Although the total ground times are not realistic, they give a meaningful ranking of the various airlines: confronted with a lower demand, the system shall react less, but in the same way, than with this high demand.
2. The total travel time is meaningful as long as we note that it is lengthy to evaluate precisely the actual pushback time probability distribution for each gate/aircraft type. Measures of the speed on the taxiways have shown that arriving aircraft do taxi faster than departing aircraft, which is impossible to model with SIMMOD.[3]
3. Since delays pile up during the simulation, airlines that do not operate continuously will have irrelevant average total ground times. If an airline operates only when delays are high (late in the morning), its average will be high; if it operates only when delays are

---

[2] These figures are given for “75% or more arrivals”. This is confusing, as the figures lead to 50 departures and 41 arrivals.

[3] We have measured average speeds on Kilo in front of terminal B: arrivals at 25 knots and departures at 15 knots. Our average value of 15 knots is thus reasonable as it applies to all segments of the network, including those where aircraft slow down.

low (early in the morning), its average will be low. Thus, the most interesting comparison will be based on airlines with large operations.

4. These results concern only one of many configurations of the airport. It is necessary to consider the other *most used* configurations to have a clear picture of the respective advantages of each gate. We did not go through the whole comparison in the framework of this demonstration.

2. New configuration

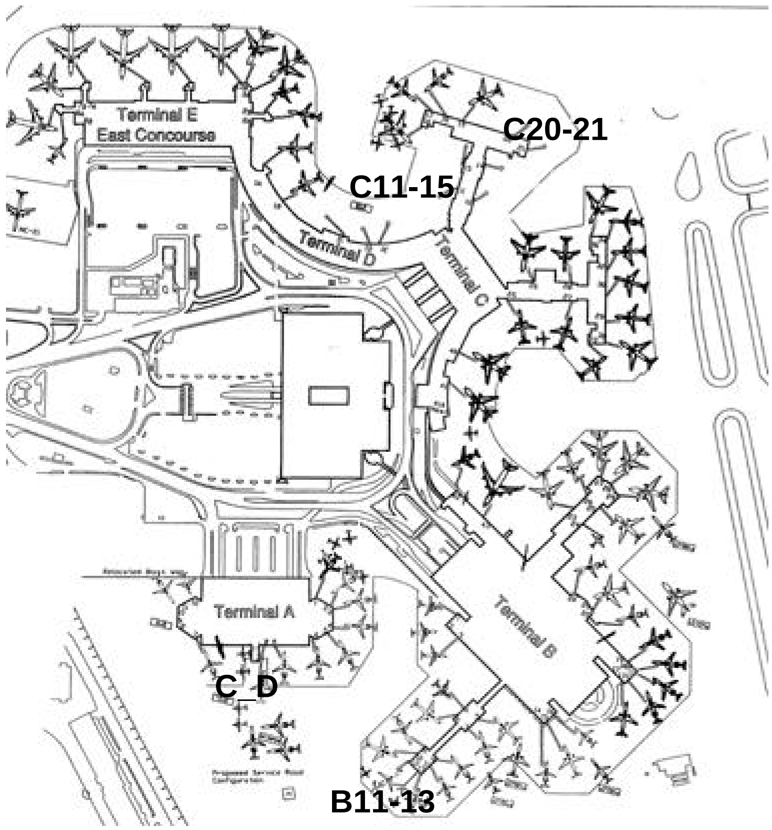
The new configuration is based on very small changes to the gate assignment. Considering that A takes profit from both the location of its gates and its use of smaller runways, its aircraft face substantially less delays than other airlines. To improve the *fairness*[4] of the whole system, we thus want to exchange A's gates with other comparable airlines.

This modification is just an exercise to show how we can get simple answers to these kinds of problems. To design this configuration, we simply notice that airlines A to D are all commuters and that they ranked among the best (A) and the worst (B, C, D) in terms of travel and total ground time (see table p. 82).

Their gates are located as shown on the map next page.

---

[4] We understand fairness in this context as the fact that different airlines receive the same "airside" treatment in terms of location of their gates.



Map of the terminals at Logan Airport

We thus come with the following modifications:

Gate	Capacity	Baseline	New configuration
B11	3	B	C, D
B12	1	B	A
B13	3	B	A
C15	2	A	B
C11	2	A	B
C20	2	A	B
C21	2	A	B
C_D	4	C, D	A

The gate we call "C_D" is the one located between gate B and gate 7 at terminal A.

The gate capacity does not play an important role in the simulation, but it is necessary to keep some kind of balance between the airlines. In this new configuration, A and B keep the same number of spots (8 for A, 8 to 7 for B), while D and C are moved to terminal B.

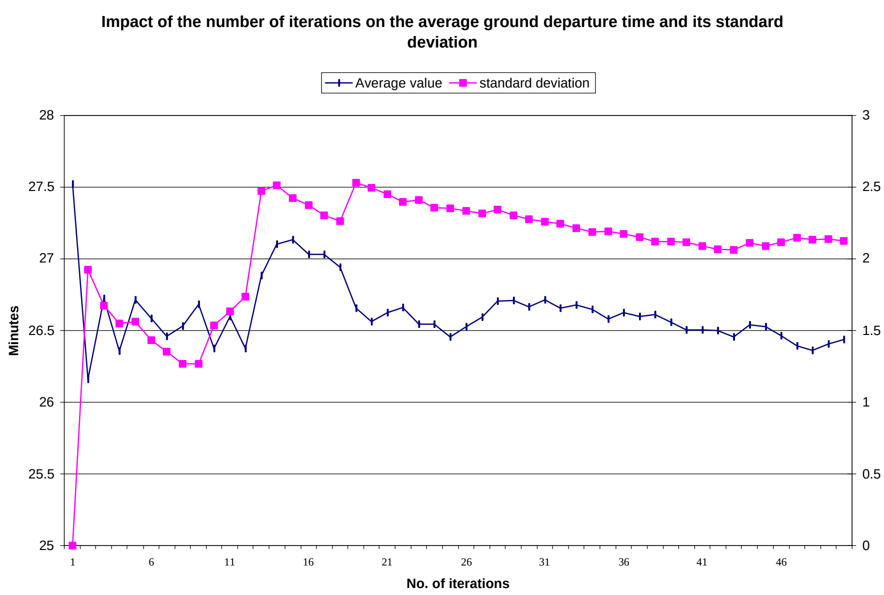
Since these commuter operations are already separated from the other regular operations, such reorganization would be feasible, aside from the fact that A would be split between two terminals.

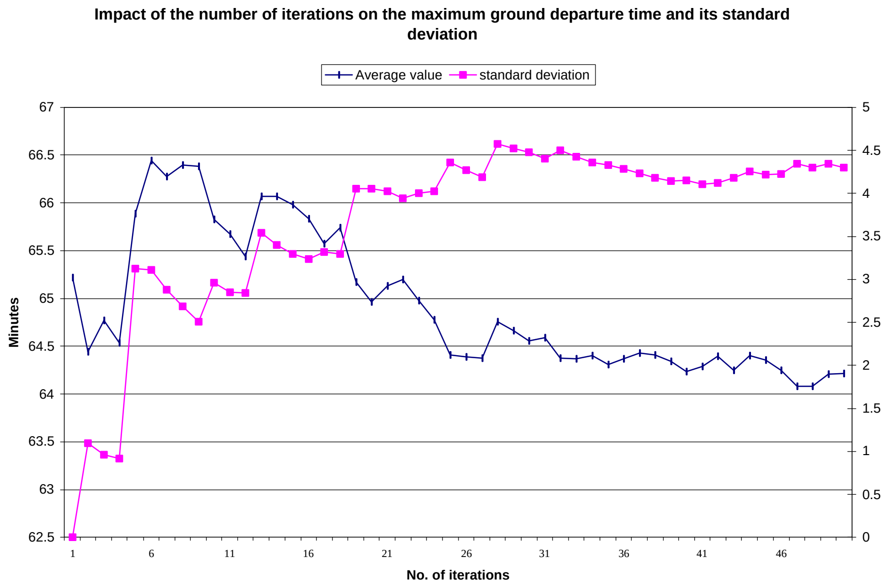
All other parameters are kept constant.

4. Results

1. Number of iterations needed

To determine this, we have run 50 iterations of the new configuration, and we have represented the impact of this number of iterations on the precision of the *average* and *maximum ground departure time for all aircraft*. This leads to the following charts:





From these charts, it appears that 25 iterations are sufficient to take into account most of the stochasticity of our inputs. We have thus performed 25 iterations of both models.

2. Reports generated

It is possible to obtain many reports to characterize the impact of our modifications. We have selected the following reports:

— Average runway flows, demands, and differences report

— Airport air and ground travel and delay report

— Iteration air and ground delay

— Taxi-in/taxi-out time, by airline report

These reports are listed in appendix to this study.

3. Comparison of runway flows

As expected there are no changes in the observed runway flows. If we consider for instance the *cumulative differences* between the actual flows and demands on each runway, we have the table below, with insignificant differences.

	ARRIVALS		DEPARTURES		DEPARTURES		DEPARTURES	
	MIT		33L		27		MIT	
INTERVAL	**Base**	**New Cfg**	**Base**	**New Cfg**	**Base**	**New Cfg**	**Base**	**New Cfg**
06:00-07:00	-0.5	-0.5	-0.2	-0.4	-0.5	-0.4	-0.7	-0.8
07:00-08:00	-0.6	-0.6	-0.7	-0.8	-9.2	-8.8	-9.8	-9.6
08:00-09:00	-1.2	-1.2	-0.5	-1.6	-21.2	-21.4	-21.7	-22.9
09:00-10:00	-1.9	-2	-3.3	-3.4	-25.9	-25.2	-29.2	-28.5
10:00-11:00	-1.4	-1.5	-2.8	-2.6	-29.8	-30.7	-32.6	-33.2

4. Iteration air and ground delay

These reports provide a quick check that our choice of 25 iterations is appropriate.

They also confirm that, in terms of efficiency, we can neglect the effect of the new configuration on arrival delays (increased from 0.2 to 0.3 minutes) and on the departure delays (for which we can not identify any clear trend). This is however further examined in the total delay report for all iterations (page 8 of the reports): the new configuration causes apparently larger average delays but lower maximums.

5. Airport air and ground travel and delay report

This report confirms what we have noted in the previous paragraph. The following table shows the *percentage changes* in the arrival times at the airport, between the baseline and the new configuration.

The total time spent by all arrivals on the ground appears in the "overall arr. Time" section; it is split between travel and delay, whose standard deviation (SDV) is given. This overall time is then divided by the arrival flow for each time period to give average values. The original values are given in the reports in appendix (p. 101 and 109).

		OVERALL ARR. TIME (MIN)				AVERAGE ARR. TIME (MIN)						
		TRAVEL		DELAY		TRAVEL			DELAY			
TIME INTERVAL	**ARRIVAL FLOW**	**TOT**	**SDV**	**TOT**	**SDV**	**AIR**	**GND**	**TOT**	**AIR**	**GND**	**GTE**	**TOT**
06:00-07:00	0%	+7%	-2%	-11%	0%	0%	+13%	+7%	0%	-14%		-9%
07:00-08:00	0%	0%	**-12%**	+1%	-4%	0%	+1%	0%	0%	0%		0%
08:00-09:00	0%	-2%	-8%	0%	0%	0%	-3%	-2%	0%	0%	+8%	+3%
09:00-10:00	+1%	+3%	-6%	+17%	**+28%**	0%	+2%	+1%	0%	**+42%**	-1%	+7%
10:00-11:00	+3%	+4%	**-13%**	+12%	**+23%**	0%	+3%	+2%	0%	**+85%**	-5%	+1%
11:00-12:00	+4%	+5%	-3%	+12%	**+13%**	0%	0%	0%	+3%	**+23%**	-2%	+2%
MIT TOTALS:	+1%	+2%	-9%	+8%	**+13%**	0%	+1%	+1%	+1%	**+29%**	0%	+4%
(baseline values)	*175.16*	*1232*	*1.49*	*203*	*1.61*	*2.7*	*4.36*	*7.03*	*0.95*	*0.21*	*0.9*	*2.06*

		OVERALL DEP. TIME (MIN)				AVERAGE DEP. TIME (MIN)						
		TRAVEL		DELAY		TRAVEL				DELAY		
TIME INTERVAL	DEPARTURE FLOW	TOT	SDV	TOT	SDV	AIR	GND	GTE	TOT	GND	QUE	TOT
06:00-07:00	-1%	+1%	**-8%**	+10%	+11%	0%	1%	N/A	+1%	**+21%**	+4%	+11%
07:00-08:00	0%	+1%	**-22%**	-5%	-4%	0%	1%	+8%	+2%	-6%	-1%	-5%
08:00-09:00	-2%	-1%	**-28%**	0%	-1%	0%	1%	+6%	+3%	+1%	+5%	+2%
09:00-10:00	+4%	+4%	**-21%**	+5%	-4%	-1%	0%	0%	0%	-1%	+10%	0%
10:00-11:00	0%	0%	**-27%**	-2%	0%	0%	0%	-1%	0%	-2%	+1%	-2%
11:00-12:00	+4%	+3%	**-18%**	+2%	+1%	0%	0%	+2%	+1%	-1%	-5%	-1%
MIT TOTALS:	+1%	+1%	**-20%**	+1%	-1%	0%	0%	+3%	+2%	-1%	+2%	0%
(baseline values)	*232.92*	*2301*	*1.52*	*6171*	*21.7*	*1.8*	*8.06*	*11.29*	*21.17*	*23.5*	*3.04*	*26.6*

The only visible impact is on the standard deviation of travel and delay times and on the arrival ground delays. These figures are very low in any case. We have already noted some vague impact on the standard deviation, which remains also low.

6. Taxi-in and taxi-out time

These discussions finally allow us to examine the impact of the new gate organization on the travel time of each carrier.

First, as we have noted before, we have to exclude airlines that do not operate continuously during the morning, as the build-up in delays would affect their performance. For this reason, some airlines do not appear in the reports below.

Second, we examine (1) the average arrival times spent by aircraft of each carrier of interest and (2) the average departure times. Extracted from the reports in appendix, these data appear in the following tables.

On the arrival side, we can consider all airlines and obtain valuable results. The overall impacts are the following:

Variation in total average arrival times, percentages from the baseline:

INTERVAL	A	B	C	D	E	F	G	H	I	J	K	L	N	M
06:00-07:00	**+83%**	**-33%**			-3%		+23%						-3%	
07:00-08:00	**+68%**	**-40%**	**-12%**	**-14%**			-10%	+1%		+1%	+1%	+1%		-2%
08:00-09:00	**+66%**	**-40%**	**-13%**	**-14%**		-6%	+3%	0%	+5%	+1%	+2%	0%	-1%	
09:00-10:00	**+81%**	**-37%**		**-8%**	+7%	-7%	0%	+12%	+5%	+5%	+9%	+1%	21%	-1%
10:00-11:00	**+67%**	**-34%**	**-14%**	**-10%**	-1%	-2%	-15%	-2%	+16%	0%	0%	+4%	+5%	-3%
11:00-12:00	**+73%**	**-29%**	**-95%**	**-6%**	-3%	+4%	+11%	-2%	-3%	+2%	+3%	0%	-3%	+1%
TOTALS:	**+71%**	**-37%**	**-8%**	**-11%**	0%	-3%	0%	2%	+7%	+2%	+3%	+1%	+4%	-1%

INTERVAL	O	P	Q	R	S
06:00-07:00	+1%				
07:00-08:00		+5%			
08:00-09:00	-5%				
09:00-10:00	-2%	+3%		-7%	
10:00-11:00	-6%		+4%		-3%
11:00-12:00	-11%		+2%		+2%
TOTALS:	-3%	+4%	+3%	-7%	0%

These tables show a clear impact on the arrival times of the 4 carriers involved, while other carrier do not face significant changes. In terms of absolute values, we have:

TIME INTERVAL	A			B			D			C		
NEW CFG	TRAV.	DLY	TOT[5]	TRAV.	DLY	TOT	TRAV.	DLY	TOT	TRAV.	DLY	TOT
06:00-07:00	5.04	0.05	5.71	2.97	0	3.68	0	0	0	0	0	0
07:00-08:00	4.99	0.04	5.67	2.66	0.16	3.4	4.94	0.27	5.76	5.44	0.4	6.21
08:00-09:00	4.95	0.05	5.63	2.6	0.31	3.53	4.52	0.01	5.25	4.53	0.07	5.32
09:00-10:00	4.99	0.35	5.97	2.6	0.69	3.87	4.91	0.76	6.23	0	0	0
10:00-11:00	4.94	0.03	5.61	2.7	0.34	3.7	4.73	0.66	6.04	4.58	0.04	5.31
11:00-12:00	4.97	0.01	5.61	2.52	2.23	5.27	5.44	3.33	9.14	5.44	4.76	10.6
TOTALS	4.97	0.1	5.7	2.64	0.43	3.69	4.85	0.66	6.1	5	1.32	6.85
BASELINE												
06:00-07:00	2.47	0	3.12	4.62	0.13	5.47	0	0	0	0	0	0
07:00-08:00	2.73	0.01	3.38	4.97	0.16	5.71	5.8	0.34	6.69	6.29	0.41	7.07
08:00-09:00	2.75	0.02	3.4	4.86	0.36	5.84	5.27	0.05	6.07	5.26	0.06	6.08
09:00-10:00	2.64	0.01	3.29	4.96	0.57	6.11	5.81	0.41	6.77	0	0	0
10:00-11:00	2.7	0	3.35	4.79	0.17	5.61	5.59	0.5	6.72	5.36	0.07	6.14
11:00-12:00	2.6	0	3.24	5.06	1.79	7.38	6.29	3.07	9.72	6.29	3.77	10.4
TOTALS	2.69	0.01	3.34	4.89	0.38	5.88	5.7	0.56	6.84	5.8	1.06	7.41

It is interesting to note that under the new configuration, arrival times are subject to various effects:

— B achieves substantially lower travel times and, conversely, A aircraft need much more time to access their gates.

— C and D profit from a slight reduction in travel time that is partly compensated by more delays to reach their gates. This is probably due to the overall traffic on Alpha along terminal B, while the space in front of terminal A is less congested.

On the departure side, after noticing negligible differences in take-off times, we have the following *variations of average total time spent on departure*:

	A	B	C	D	E	F	G	H	J	I
06:00-07:00	**17%**				2%	3%		-1%	3%	1%
07:00-08:00	**14%**	**-9%**		**1%**	-2%	1%	-3%	-5%	-5%	-1%
08:00-09:00	**15%**	**-3%**	**-8%**	**-4%**	0%		1%	1%	-1%	0%
09:00-10:00	**15%**	**-3%**	**-3%**	**-3%**	0%		2%	0%	-2%	1%
10:00-11:00	**6%**	**-4%**		**-3%**	-2%	-1%	0%	-1%	-1%	-2%

[5] The total includes taxi travel, taxi delay and landing time. Landing times are not included in this table as they are very stable.

11:00-12:00	**-4%**	**-1%**	**-1%**	**-2%**	0%	0%	-1%	0%	-1%	-1%
TOTALS:	**10%**	**-3%**	**-5%**	**-3%**	0%	0%	1%	-1%	-1%	-1%

	K	**L**	**M**	**N**	**O**	**P**	**R**	**T**	**U**
06:00-07:00	7%	1%	1%	1%	-1%				4%
07:00-08:00	2%	-3%		-4%	-4%		-6%	-2%	
08:00-09:00		-1%	1%	0%	-2%	19%		2%	
09:00-10:00	-1%	2%	1%	4%	-4%	-2%			-1%
10:00-11:00	-1%	-1%		2%	1%	-2%			
11:00-12:00	0%	0%	-2%	-1%	1%	-3%	-1%	-1%	
TOTALS:	0%	0%	1%	0%	0%	1%	-1%	-1%	0%

As expected, we observe no impact except for the 4 carriers concerned by the modifications, this effect being often low (-3% and –5% for B, C and D).

If we detail what happens to these airlines, we have[6]:

	A				**B**			
NEW CFG	**TRAV.**	**DLY**	**QUEUE**	**TOT**	**TRAV.**	**DLY**	**QUEUE**	**TOT**
06:00-07:00	6.64	0.01	0.52	7.86	0	0	0	0
07:00-08:00	6.63	0.05	1.46	8.81	7.14	9.43	1.53	18.98
08:00-09:00	7.02	3.98	6.28	17.96	7.17	23.12	1.77	32.94
09:00-10:00	6.74	6.13	10.1	23.65	7.14	39.84	1.96	49.82
10:00-11:00	6.82	7.79	13.65	28.94	7.1	53.51	2.03	63.53
11:00-12:00	6.96	11.44	9.86	28.95	7.2	52.29	1.73	62.12
TOTALS:	6.85	5.4	7.74	20.67	7.15	36.67	1.83	46.53
BASELINE								
06:00-07:00	5.46	0.03	0.54	6.72	0	0	0	0
07:00-08:00	5.45	0.06	1.5	7.7	8.2	10.15	1.57	20.81
08:00-09:00	5.83	3.35	5.7	15.57	8.19	23.1	1.77	33.95
09:00-10:00	5.69	5.94	8.3	20.61	8.22	40.34	2.16	51.6
10:00-11:00	5.58	6.68	14.27	27.22	8.19	54.91	2.06	66.03
11:00-12:00	5.78	12.33	11.26	30.06	8.17	52.18	1.66	62.9
TOTALS:	5.67	5.04	7.48	18.87	8.19	37.23	1.86	48.17

	C				**D**			
NEW CFG	**TRAV.**	**DLY**	**QUEUE**	**TOT**	**TRAV.**	**DLY**	**QUEUE**	**TOT**
06:00-07:00	0	0	0	0	0	0	0	0
07:00-08:00	0	0	0	0	8.12	10.65	1.21	20.87
08:00-09:00	8.11	24.25	2.14	35.37	8.11	22.69	1.94	33.63
09:00-10:00	8.12	43.48	1.8	54.29	8.12	40.59	1.94	51.52
10:00-11:00	0	0	0	0	8.12	53.89	1.97	64.87
11:00-12:00	8.1	43.73	2.09	54.81	8.12	51.47	1.66	62.13
TOTALS:	8.11	34.25	1.97	45.22	8.12	41.34	1.8	52.14
BASELINE								
06:00-07:00	0	0	0	0	0	0	0	0
07:00-08:00	0	0	0	0	8.88	9.55	1.28	20.59
08:00-09:00	8.88	26.82	1.88	38.46	8.88	23.39	1.78	34.94
09:00-10:00	8.89	44.36	1.76	55.89	8.88	41.46	1.99	53.21
10:00-11:00	8.9	49.17	2.68	61.63	8.88	55.57	1.8	67.14

[6] TRAV. being the time spent traveling on departure, DLY, the delay, and QUEUE, the time spent in queue.

11:00-12:00	8.87	44.57	1.09	55.41	8.88	51.96	1.59	63.32
TOTALS:	8.88	36.03	1.81	47.6	8.88	42.25	1.72	53.73

The apparently small improvements are due to the delays that do not change from one configuration to the other. If we only look at the travel times, we have the following changes in *average departure travel times*:

INTERVAL	A	B	C	D
06:00-07:00	22%			
07:00-08:00	22%	-13%		-9%
08:00-09:00	20%	-12%	-9%	-9%
09:00-10:00	18%	-13%	-9%	-9%
10:00-11:00	22%	-13%		-9%
11:00-12:00	20%	-12%	-9%	-9%
TOTALS:	21%	-13%	-9%	-9%

This becomes significant. If we finally come up with the overall variation in average total travel times, we have:

Airline	Baseline	New configuration	Variation (min)	Variation (%)
A	8.36	11.82	3.46	+41%
B	13.08	9.79	-3.29	-25%
C	14.68	13.11	-1.57	-11%
D	14.58	12.97	-1.61	-11%

Considering the cost of each minute of flight, these variations are substantial not only in relative but also in absolute terms.

5. Conclusions

As we have seen in the previous pages, this short study gives an example of the valuable data a SIMMOD simulation can provide to operational issues in gate management. Although the existence of differences in travel time between airlines is obvious, the level of detail we can reach with SIMMOD allows us to quantify these differences. On this simple example, we have seen that:

1. A enjoys a remarkable position on the terminals; its aircraft travel 40% less than B in the Northwest configuration. A quick examination of the other main configurations leads to the same conclusion, although we did not quantify it.
2. Exchanging gates between comparable airlines would increase the overall fairness of the system as far as ground time is concerned, since B and D have the highest average ground time while A has the lowest (See p. 82).
3. Such a simple exchange would not have side effects on delays, and would simply impact the involved airlines' travel times.

Again, in conclusion, this study shows that a SIMMOD model can be relevant for all discussions on gates between Massport and the airlines. Various types of studies can be performed, providing a valuable quantification of the effects of a decision. In any case, it is essential to (1) have a *clear question* to ask to the model, and (2) spend some time *tailoring the model* to realistically answer this question.

6. Appendix 1: baseline simulation reports

AVERAGE RUNWAY FLOWS, DEMANDS, AND DIFFERENCES REPORT
MIT AIRPORT -- AVERAGE RUNWAY A R R I V A L & D E P A R T U R E FLOWS, DEMANDS, AND CUMULATIVE DIFFERENCES
BASED ON 25 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#25 10/17/1997 AT 12:54:50 (0) mit/mit2113
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	A R R I V A L S			**27**	**A R R I V A L S**			**33L**
TIME INTERVAL	27 FLOW	27 DMND	27 DIFF	ARR+DEP FLOW	33L FLOW	33L DMND	33L DIFF	ARR+DEP FLOW
06:00-07:00	0	0	0	20.2	8.5	9.0	-.5	18.1
07:00-08:00	0	0	0	31.4	24.2	24.2	-.6	33.5
08:00-09:00	0	0	0	30.9	33.7	34.3	-1.2	47.3
09:00-10:00	0	0	0	28.0	33.0	33.7	-1.9	43.5
10:00-11:00	0	0	0	29.4	33.8	33.3	-1.4	42.8
11:00-12:00	0	0	0	30.8	19.3	17.9	0	28.4
MIT TOTALS:	0	0	0	171.7	152.4	152.4	0	213.6

TIME INTERVAL	33R FLOW	33R DMND	33R DIFF	ARR+DEP FLOW	MIT FLOW	MIT DMND	MIT DIFF	ARR+DEP FLOW
06:00-07:00	0	0	0	0	8.5	9.0	-.5	38.3
07:00-08:00	7.0	7.0	0	7.0	31.1	31.2	-.6	71.8
08:00-09:00	4.0	4.0	0	4.0	37.7	38.3	-1.2	82.2
09:00-10:00	5.6	5.6	0	5.6	38.6	39.4	-1.9	77.1
10:00-11:00	3.2	3.2	0	3.2	37.0	36.5	-1.4	75.5
11:00-12:00	2.9	2.9	0	2.9	22.2	20.8	0	62.1
MIT TOTALS:	22.7	22.7	0	22.7	175.2	175.2	0	408.1

	D E P A R T U R E S			**27**	**D E P A R T U R E S**			**33L**
TIME INTERVAL	27 FLOW	27 DMND	27 DIFF	ARR+DEP FLOW	33L FLOW	33L DMND	33L DIFF	ARR+DEP FLOW
06:00-07:00	20.2	20.7	-.5	20.2	9.6	9.8	-.2	18.1
07:00-08:00	31.4	40.0	-9.2	31.4	9.4	9.8	-.7	33.5
08:00-09:00	30.9	43.0	-21.2	30.9	13.6	13.4	-.5	47.3
09:00-10:00	28.0	32.7	-25.9	28.0	10.5	13.3	-3.3	43.5
10:00-11:00	29.4	33.3	-29.8	29.4	9.0	8.5	-2.8	42.8
11:00-12:00	30.8	1.0	0	30.8	9.2	6.4	0	28.4
MIT TOTALS:	171.7	171.7	0	171.7	61.2	61.2	0	213.6

TIME INTERVAL	33R FLOW	33R DMND	33R DIFF	ARR+DEP FLOW	MIT FLOW	MIT DMND	MIT DIFF	ARR+DEP FLOW
06:00-07:00	0	0	0	0	29.8	30.5	-.7	38.3
07:00-08:00	0	0	0	7.0	40.7	49.8	-9.8	71.8
08:00-09:00	0	0	0	4.0	44.5	56.4	-21.7	82.2
09:00-10:00	0	0	0	5.6	38.5	46.0	-29.2	77.1
10:00-11:00	0	0	0	3.2	38.5	41.8	-32.6	75.5
11:00-12:00	0	0	0	2.9	40.0	7.4	0	62.1
MIT TOTALS:	0	0	0	22.7	232.9	232.9	0	408.1

This SIMMOD REPORT MODULE version 2.0.2 run began 10/17/1997 at approximately 14:13:25
This page of the TIME.SECTION report was finished at 14:15:27

TAXI-IN/TAXI-OUT TIME, BY AIRLINE REPORT
TAXI ARR TIME, BY AIRLINE
BASED ON 25 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#25 10/17/1997 AT 12:54:50 (0) mit/mit2113
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	E AVG ARR TIMES (MIN)				A AVG ARR TIMES (MIN)				N AVG ARR TIMES (MIN)				M AVG ARR TIMES (MIN)			
TIME INTERVAL	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT
06:00-07:00	2.20	.18	.79	3.16	2.47	0	.65	3.12	1.74	.06	.78	2.58	0	0	0	0
07:00-08:00	0	0	0	0	2.73	.01	.64	3.38	0	0	0	0	1.45	.04	1.08	2.57
08:00-09:00	0	0	0	0	2.75	.02	.64	3.40	1.72	0	.78	2.50	0	0	0	0
09:00-10:00	2.83	.03	.62	3.48	2.64	.01	.64	3.29	1.88	.01	.75	2.63	1.30	.06	1.08	2.45
10:00-11:00	2.68	.03	.69	3.40	2.70	0	.64	3.35	2.02	.01	.68	2.71	1.60	0	1.09	2.70
11:00-12:00	2.78	.02	.61	3.41	2.60	0	.65	3.24	2.02	0	.70	2.72	1.43	.10	1.07	2.60
TOTALS:	2.68	.04	.67	3.39	2.69	.01	.64	3.34	1.92	.01	.72	2.66	1.43	.06	1.08	2.57

	J AVG ARR TIMES (MIN)				F AVG ARR TIMES (MIN)				L AVG ARR TIMES (MIN)				O AVG ARR TIMES (MIN)			
TIME INTERVAL	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT
06:00-07:00	0	0	0	0	0	0	0	0	0	0	0	0	2.51	.07	.70	3.28
07:00-08:00	5.55	.02	.65	6.22	0	0	0	0	4.97	.12	.65	5.73	0	0	0	0
08:00-09:00	5.65	.03	.66	6.35	3.01	.09	.72	3.82	4.67	.05	.67	5.39	2.60	.04	.70	3.33
09:00-10:00	5.44	.05	.64	6.13	2.84	1.08	.53	4.44	4.81	.05	.69	5.55	2.66	.10	.63	3.39
10:00-11:00	5.63	.01	.65	6.29	3.16	0	.70	3.86	4.66	.07	.68	5.41	2.51	.02	.71	3.24
11:00-12:00	5.42	.04	.68	6.14	3.01	0	.74	3.75	4.87	.02	.66	5.55	2.40	0	.77	3.16
TOTALS:	5.51	.04	.65	6.20	2.96	.51	.63	4.11	4.76	.06	.67	5.49	2.56	.05	.69	3.30

	U AVG ARR TIMES (MIN)				K AVG ARR TIMES (MIN)				H AVG ARR TIMES (MIN)				L AVG ARR TIMES (MIN)			
TIME INTERVAL	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT
06:00-07:00	0	0	0	0	0	0	0	0	0	0	0	0	4.62	.13	.72	5.47
07:00-08:00	0	0	0	0	3.19	.01	.66	3.86	5.10	.01	.67	5.77	4.97	.16	.58	5.71
08:00-09:00	0	0	0	0	3.10	.06	.67	3.83	5.25	.09	.64	5.98	4.86	.36	.62	5.84
09:00-10:00	0	0	0	0	3.06	.03	.68	3.76	5.10	.06	.69	5.85	4.96	.57	.58	6.11
10:00-11:00	0	0	0	0	3.31	.05	.65	4.01	5.20	.04	.64	5.88	4.79	.17	.65	5.61
11:00-12:00	0	0	0	0	3.09	0	.66	3.75	5.30	0	.64	5.94	5.06	1.79	.53	7.38
TOTALS:	0	0	0	0	3.15	.03	.66	3.84	5.19	.04	.66	5.88	4.89	.38	.61	5.88

This SIMMOD REPORT MODULE version 2.0.2 run began 10/17/1997 at approximately 14:13:25
This page of the GATE.SECTION report was finished at 14:16:29

TAXI-IN/TAXI-OUT TIME, BY AIRLINE REPORT
TAXI ARR TIME, BY AIRLINE (CONTINUED)
BASED ON 25 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#25 10/17/1997 AT 12:54:50 (0) mit/mit2113
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	I AVG ARR TIMES (MIN)				G AVG ARR TIMES (MIN)				S AVG ARR TIMES (MIN)				R AVG ARR TIMES (MIN)			
TIME INTERVAL	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT
06:00-07:00	0	0	0	0	1.88	0	.80	2.69	0	0	0	0	0	0	0	0
07:00-08:00	0	0	0	0	2.71	.44	.51	3.66	0	0	0	0	0	0	0	0
08:00-09:00	2.12	.09	.66	2.87	1.46	.04	1.09	2.59	0	0	0	0	0	0	0	0
09:00-10:00	2.06	.56	.59	3.21	2.82	0	.69	3.51	0	0	0	0	3.40	.02	.62	4.04
10:00-11:00	2.09	.74	.52	3.35	2.70	0	.70	3.39	4.54	0	.61	5.15	0	0	0	0
11:00-12:00	2.35	0	.71	3.06	2.48	0	.67	3.15	4.27	.02	.68	4.97	0	0	0	0
TOTALS:	2.14	.32	.62	3.08	2.44	.13	.71	3.28	4.39	.01	.65	5.05	3.40	.02	.62	4.04

	D AVG ARR TIMES (MIN)				P AVG ARR TIMES (MIN)				C AVG ARR TIMES (MIN)				Q AVG ARR TIMES (MIN)			
TIME INTERVAL	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT
06:00-07:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07:00-08:00	5.80	.34	.54	6.69	3.63	.01	.76	4.41	6.29	.41	.37	7.07	0	0	0	0
08:00-09:00	5.27	.05	.75	6.07	0	0	0	0	5.26	.06	.76	6.08	0	0	0	0
09:00-10:00	5.81	.41	.56	6.77	4.07	.05	.64	4.76	0	0	0	0	0	0	0	0
10:00-11:00	5.59	.50	.63	6.72	0	0	0	0	5.36	.07	.72	6.14	2.90	.08	.65	3.63
11:00-12:00	6.29	3.07	.37	9.72	0	0	0	0	6.29	3.77	.37	10.42	3.06	0	.62	3.68
TOTALS:	5.70	.56	.59	6.84	3.85	.03	.70	4.58	5.80	1.06	.55	7.41	2.96	.05	.64	3.65

This SIMMOD REPORT MODULE version 2.0.2 run began 10/17/1997 at approximately 14:13:25
This page of the GATE.SECTION report was finished at 14:16:29

TAXI-IN/TAXI-OUT TIME, BY AIRLINE REPORT
TAXI DEP TIME, BY AIRLINE
BASED ON 25 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#25 10/17/1997 AT 12:54:50 (0) mit/mit2113
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	E AVG DEP TIMES (MIN)					A AVG DEP TIMES (MIN)					N AVG DEP TIMES (MIN)				
TIME INTERVAL	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT
06:00-07:00	5.77	.40	.83	.65	7.65	5.46	.03	.68	.54	6.72	6.02	.53	.93	.50	7.98
07:00-08:00	6.40	3.84	.83	1.34	12.42	5.45	.06	.68	1.50	7.70	6.25	8.87	.81	1.76	17.68
08:00-09:00	6.41	13.69	.84	2.30	23.25	5.83	3.35	.69	5.70	15.57	6.07	13.07	.86	2.97	22.97
09:00-10:00	6.08	28.95	.87	3.28	39.17	5.69	5.94	.68	8.30	20.61	6.09	28.66	.88	4.27	39.89
10:00-11:00	6.29	43.78	.83	6.54	57.44	5.58	6.68	.68	14.27	27.22	6.20	55.03	.85	1.70	63.78
11:00-12:00	5.38	27.09	.73	4.69	37.87	5.78	12.33	.69	11.26	30.06	6.22	52.23	.81	1.59	60.86
TOTALS:	6.05	18.93	.82	2.88	28.69	5.67	5.04	.68	7.48	18.87	6.13	23.28	.86	2.12	32.40

	M AVG DEP TIMES (MIN)					J AVG DEP TIMES (MIN)					F AVG DEP TIMES (MIN)				
TIME INTERVAL	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT
06:00-07:00	7.46	.14	.96	.53	9.08	9.07	1.04	.78	1.14	12.02	7.72	.43	.88	.82	9.86
07:00-08:00	0	0	0	0	0	9.20	11.71	.78	1.79	23.48	7.73	12.40	.88	1.77	22.78
08:00-09:00	7.94	25.13	.88	1.45	35.40	8.97	21.32	.78	1.88	32.96	0	0	0	0	0
09:00-10:00	7.91	25.09	.95	5.81	39.75	9.19	45.09	.78	1.74	56.80	0	0	0	0	0
10:00-11:00	0	0	0	0	0	9.20	51.69	.78	1.64	63.31	7.74	55.33	.88	2.29	66.25
11:00-12:00	7.76	53.15	.87	1.39	63.17	9.04	53.30	.77	1.94	65.06	7.73	53.59	.88	1.54	63.74
TOTALS:	7.77	24.14	.92	2.44	35.26	9.09	22.71	.78	1.59	34.17	7.73	34.97	.88	1.75	45.33

	L AVG DEP TIMES (MIN)					O AVG DEP TIMES (MIN)					U AVG DEP TIMES (MIN)				
TIME INTERVAL	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT
06:00-07:00	8.50	1.04	.84	.94	11.31	6.06	.27	.87	.70	7.90	7.64	2.15	.78	1.60	12.17
07:00-08:00	8.43	8.63	.83	1.49	19.38	5.96	5.93	.86	1.61	14.36	0	0	0	0	0
08:00-09:00	8.66	17.42	.77	1.90	28.75	5.93	8.70	.90	2.58	18.10	0	0	0	0	0
09:00-10:00	8.38	30.72	.85	4.93	44.89	5.90	30.39	.94	3.37	40.60	7.69	44.78	.88	2.18	55.53
10:00-11:00	8.49	46.23	.85	2.57	58.14	6.00	43.08	.88	5.96	55.92	0	0	0	0	0
11:00-12:00	8.53	40.94	.88	3.30	53.65	5.97	32.27	.89	1.07	40.19	0	0	0	0	0
TOTALS:	8.49	20.71	.84	2.21	32.25	5.98	19.10	.88	2.75	28.71	7.67	23.47	.83	1.89	33.85

This SIMMOD REPORT MODULE version 2.0.2 run began 10/17/1997 at approximately 14:13:25
This page of the GATE.SECTION report was finished at 14:16:29

TAXI-IN/TAXI-OUT TIME, BY AIRLINE REPORT
TAXI DEP TIME, BY AIRLINE (CONTINUED)
BASED ON 25 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#25 10/17/1997 AT 12:54:50 (0) mit/mit2113
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME INTERVAL	K AVG DEP TIMES (MIN) TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	H AVG DEP TIMES (MIN) TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	L AVG DEP TIMES (MIN) TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT
06:00-07:00	6.74	.92	.77	1.40	9.83	8.38	.31	1.04	1.39	11.11	0	0	0	0	0
07:00-08:00	6.46	5.99	.91	1.27	14.62	8.89	11.73	.77	1.66	23.05	8.20	10.15	.88	1.57	20.81
08:00-09:00	6.69	15.60	.77	1.89	24.96	8.95	27.87	.77	1.78	39.38	8.19	23.10	.88	1.77	33.95
09:00-10:00	6.72	37.31	.77	2.01	46.82	8.89	43.73	.77	2.09	55.48	8.22	40.34	.88	2.16	51.60
10:00-11:00	6.77	58.29	.77	2.36	68.20	8.92	52.37	.77	1.83	63.89	8.19	54.91	.88	2.06	66.03
11:00-12:00	6.75	50.74	.77	1.52	59.78	8.94	51.83	.78	1.79	63.35	8.17	52.18	.88	1.66	62.90
TOTALS:	6.65	26.51	.82	1.65	35.62	8.82	28.88	.83	1.70	40.22	8.19	37.23	.88	1.86	48.17

TIME INTERVAL	I AVG DEP TIMES (MIN) TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	G AVG DEP TIMES (MIN) TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	S AVG DEP TIMES (MIN) TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT
06:00-07:00	6.98	.13	.88	.13	8.12	0	0	0	0	0	0	0	0	0	0
07:00-08:00	6.99	7.90	.88	1.40	17.18	7.49	12.28	.88	1.58	22.22	8.13	4.91	.78	1.31	15.14
08:00-09:00	7.00	23.77	.88	1.68	33.33	7.80	24.65	.88	2.08	35.42	0	0	0	0	0
09:00-10:00	7.00	37.22	.88	1.99	47.09	7.68	30.13	.88	2.19	40.88	0	0	0	0	0
10:00-11:00	7.00	51.08	.88	1.74	60.71	7.67	51.93	.88	1.94	62.42	0	0	0	0	0
11:00-12:00	7.00	51.05	.88	1.92	60.85	7.58	53.03	.77	1.82	63.20	0	0	0	0	0
TOTALS:	7.00	31.72	.88	1.63	41.24	7.60	33.57	.86	1.83	43.87	8.13	4.91	.78	1.31	15.14

TIME INTERVAL	R AVG DEP TIMES (MIN) TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	D AVG DEP TIMES (MIN) TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	P AVG DEP TIMES (MIN) TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT
06:00-07:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07:00-08:00	7.97	6.16	.77	1.65	16.55	8.88	9.55	.88	1.28	20.59	0	0	0	0	0
08:00-09:00	0	0	0	0	0	8.88	23.39	.88	1.78	34.94	7.93	.62	1.04	5.80	15.40
09:00-10:00	0	0	0	0	0	8.88	41.46	.88	1.99	53.21	8.49	35.27	.87	2.08	46.71
10:00-11:00	7.97	34.02	.77	1.50	44.25	8.88	55.57	.88	1.80	67.14	8.51	60.94	.87	1.77	72.09
11:00-12:00	8.02	53.74	.78	1.84	64.38	8.88	51.96	.88	1.59	63.32	8.50	51.22	.77	1.73	62.23
TOTALS:	7.99	29.56	.77	1.74	40.06	8.88	42.25	.88	1.72	53.73	8.36	36.87	.89	2.86	48.97

This SIMMOD REPORT MODULE version 2.0.2 run began 10/17/1997 at approximately 14:13:25
This page of the GATE.SECTION report was finished at 14:16:29

TAXI-IN/TAXI-OUT TIME, BY AIRLINE REPORT
TAXI DEP TIME, BY AIRLINE (CONTINUED)
BASED ON 25 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#25 10/17/1997 AT 12:54:50 (0) mit/mit2113
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	C AVG DEP TIMES (MIN)					Q AVG DEP TIMES (MIN)					T AVG DEP TIMES (MIN)				
TIME INTERVAL	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT
06:00-07:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07:00-08:00	0	0	0	0	0	7.19	12.82	.78	1.90	22.68	9.14	12.13	.77	1.70	23.75
08:00-09:00	8.88	26.82	.88	1.88	38.46	0	0	0	0	0	9.18	16.39	.77	1.77	28.11
09:00-10:00	8.89	44.36	.88	1.76	55.89	0	0	0	0	0	0	0	0	0	0
10:00-11:00	8.90	49.17	.88	2.68	61.63	0	0	0	0	0	0	0	0	0	0
11:00-12:00	8.87	44.57	.88	1.09	55.41	0	0	0	0	0	9.18	54.07	.78	1.68	65.71
TOTALS:	8.88	36.03	.88	1.81	47.60	7.19	12.82	.78	1.90	22.68	9.16	32.94	.77	1.70	44.57

This SIMMOD REPORT MODULE version 2.0.2 run began 10/17/1997 at approximately 14:13:25
This page of the GATE.SECTION report was finished at 14:16:29

AIRPORT AIR AND GROUND TRAVEL AND DELAY REPORT

MIT AIRPORT -- ALL RUNWAY A R R I V A L GROUND AND AIR TRAVEL AND DELAY TIMES
BASED ON 25 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#25 10/17/1997 AT 12:54:50 (0) mit/mit2113
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME INTERVAL	MIT ARRIVAL FLOW	OVERALL ARRIVAL TIMES (MIN) TRAVEL TOT	TRAVEL SDV	DELAY TOT	DELAY SDV	AVERAGE ARRIVAL TIMES (MIN) TRAVEL AIR	TRAVEL GND	TRAVEL GTE	TRAVEL TOT	DELAY AIR	DELAY GND	DELAY GTE	DELAY TOT
06:00-07:00	8.52	52.6	1.30	1.9	.42	2.72	3.45	0	6.17	.15	.07	0	.22
07:00-08:00	31.12	227.8	1.47	14.5	.73	2.63	4.69	0	7.32	.34	.13	0	.47
08:00-09:00	37.72	271.5	1.48	56.2	1.58	2.75	4.44	0	7.20	1.36	.13	.73	2.22
09:00-10:00	38.60	269.0	1.48	33.3	1.40	2.62	4.35	0	6.97	.55	.31	.83	1.69
10:00-11:00	37.04	257.8	1.53	42.0	1.28	2.69	4.27	0	6.96	1.00	.13	1.10	2.24
11:00-12:00	22.16	152.9	1.36	54.6	2.48	2.60	4.30	0	6.90	2.02	.44	2.62	5.09
MIT TOTALS:	175.16	1231.6	1.49	202.6	1.61	2.67	4.36	0	7.03	.95	.21	.90	2.06

MIT AIRPORT -- ALL RUNWAY D E P A R T U R E GROUND AND AIR TRAVEL AND DELAY TIMES

TIME INTERVAL	MIT DEPARTURE FLOW	OVERALL DEPARTURE TIMES (MIN) TRAVEL TOT	TRAVEL SDV	DELAY TOT	DELAY SDV	AVERAGE DEPARTURE TIMES (MIN) TRAVEL AIR	TRAVEL GND	TRAVEL GTE	TRAVEL TOT	DELAY AIR	DELAY GND	DELAY GTE	DELAY QUE	DELAY TOT
06:00-07:00	29.76	290.7	1.45	43.1	1.78	1.72	8.05	0	9.77	0	.63	0	.82	1.45
07:00-08:00	40.72	403.2	1.44	365.1	5.92	1.80	8.10	2.77	12.67	0	7.42	.01	1.55	8.98
08:00-09:00	44.48	435.9	1.60	780.9	9.90	1.81	7.99	5.26	15.06	0	14.46	.04	3.10	17.60
09:00-10:00	38.52	378.9	1.45	1331.5	15.23	1.82	8.02	12.59	22.42	0	30.78	.24	3.78	34.81
10:00-11:00	38.48	384.1	1.55	1847.2	18.09	1.86	8.12	17.16	27.14	0	43.07	.03	4.94	48.03
11:00-12:00	39.96	398.8	1.62	1803.3	17.46	1.85	8.13	28.47	38.45	0	41.47	.02	3.66	45.15
MIT TOTALS:	232.92	2300.7	1.52	6171.2	21.65	1.81	8.06	11.29	21.17	0	23.46	.06	3.04	26.55

This SIMMOD REPORT MODULE version 2.0.2 run began 10/17/1997 at approximately 15:43:14
This page of the APT.PAGE report was finished at 15:44:55

ITERATION AIR AND GROUND DELAY
AVERAGE, MIN, AND MAX AIRCRAFT GROUND AND AIR DELAY TIME (MINS) VERSB ITERATION
BASED ON 25 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#25 10/17/1997 AT 12:54:50 (0) mit/mit2113
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	ARRIVALS						DEPARTURES					
	AIR			GND			AIR			GND		
ITERATIONS	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
TOTALS:	.85	0	5.52	.17	0	4.22	0	0	0	28.47	0	68.67
TOTALS:	1.08	0	7.17	.23	0	6.17	0	0	0	23.18	0	59.15
TOTALS:	.86	0	5.88	.22	0	8.17	0	0	0	28.29	0	68.17
TOTALS:	.92	0	5.97	.27	0	12.47	0	0	0	26.32	0	65.88
TOTALS:	.98	0	8.10	.29	0	10.85	0	0	0	24.52	0	64.03
TOTALS:	.90	0	5.65	.14	0	6.28	0	0	0	26.68	0	65.43
TOTALS:	1.18	0	6.60	.20	0	8.37	0	0	0	30.20	0	72.12
TOTALS:	1.14	0	8.72	.25	0	10.22	0	0	0	28.67	0	68.82
TOTALS:	.91	0	5.50	.20	0	9.77	0	0	0	26.38	0	62.35
TOTALS:	.87	0	6.05	.13	0	6.05	0	0	0	24.92	0	61.08
TOTALS:	.89	0	7.10	.33	0	11.48	0	0	0	24.62	0	58.77
TOTALS:	1.07	0	6.88	.21	0	12.15	0	0	0	26.39	0	65.18
TOTALS:	1.11	0	6.45	.17	0	4.72	0	0	0	29.92	0	68.32
TOTALS:	.92	0	5.90	.16	0	7.83	0	0	0	27.29	0	62.78
TOTALS:	.86	0	6.25	.25	0	7.88	0	0	0	27.30	0	66.12
TOTALS:	1.11	0	7.78	.25	0	11.27	0	0	0	26.83	0	68.33
TOTALS:	.73	0	4.63	.14	0	4.28	0	0	0	22.48	0	61.38
TOTALS:	.83	0	6.78	.27	0	17.97	0	0	0	26.81	0	68.60
TOTALS:	1.04	0	6.53	.23	0	5.60	0	0	0	23.94	0	61.62
TOTALS:	.95	0	6.83	.16	0	10.32	0	0	0	24.52	0	61.32
TOTALS:	1.00	0	6.45	.16	0	4.63	0	0	0	26.17	0	65.65
TOTALS:	.90	0	5.75	.22	0	7.28	0	0	0	27.47	0	70.00
TOTALS:	.92	0	6.00	.14	0	5.52	0	0	0	24.06	0	62.15
TOTALS:	.96	0	6.77	.20	0	11.72	0	0	0	28.91	0	66.92
TOTALS:	.66	0	4.30	.16	0	9.58	0	0	0	27.68	0	62.57

TOTAL DELAYS FOR ALL ITERATIONS

	ARRIVALS						DEPARTURES					
TIME	AIR			GND			AIR			GND		
INTERVAL	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
06:00-07:00	.15	0	2.15	.07	0	1.10	0	0	0	1.45	0	9.38
07:00-08:00	.34	0	3.38	.13	0	5.90	0	0	0	8.97	0	20.90
08:00-09:00	1.36	0	8.10	.13	0	7.83	0	0	0	17.56	0	41.73
09:00-10:00	.55	0	4.27	.31	0	17.97	0	0	0	34.57	0	56.80
10:00-11:00	1.00	0	6.08	.13	0	9.58	0	0	0	48.00	.30	72.12
11:00-12:00	2.02	0	8.72	.44	0	12.47	0	0	0	45.13	0	65.48
TOTALS:	.95	0	8.72	.21	0	17.97	0	0	0	26.49	0	72.12

This SIMMOD REPORT MODULE version 2.0.2 run began 10/17/1997 at approximately 15:43:14
This page of the ITER.SECTION report was finished at 15:45:20

7. Appendix 2: new configuration simulation reports

AVERAGE RUNWAY FLOWS, DEMANDS, AND DIFFERENCES REPORT
MIT AIRPORT -- AVERAGE RUNWAY ARRIVAL & DEPARTURE FLOWS, DEMANDS, AND CUMULATIVE DIFFERENCES
BASED ON 25 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#25 10/17/1997 AT 14:12:29 (0) mit/mit2114
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	A R R I V A L S			27	A R R I V A L S			33L
TIME	27	27	27	ARR+DEP	33L	33L	33L	ARR+DEP
INTERVAL	FLOW	DMND	DIFF	FLOW	FLOW	DMND	DIFF	FLOW
06:00-07:00	0	0	0	20.2	8.5	9.0	-.5	17.9
07:00-08:00	0	0	0	31.6	24.2	24.2	-.6	33.4
08:00-09:00	0	0	0	30.7	33.7	34.3	-1.2	46.5
09:00-10:00	0	0	0	28.8	33.4	34.2	-2.0	44.8
10:00-11:00	0	0	0	28.9	34.7	34.2	-1.5	44.1
11:00-12:00	0	0	0	32.0	20.1	18.6	0	29.5
MIT TOTALS:	0	0	0	173.4	154.6	154.6	0	216.3

	A R R I V A L S			33R	A R R I V A L S			MIT
TIME	33R	33R	33R	ARR+DEP	MIT	MIT	MIT	ARR+DEP
INTERVAL	FLOW	DMND	DIFF	FLOW	FLOW	DMND	DIFF	FLOW
06:00-07:00	0	0	0	0	8.5	9.0	-.5	38.1
07:00-08:00	7.0	7.0	0	7.0	31.1	31.2	-.6	72.0
08:00-09:00	4.0	4.0	0	4.0	37.7	38.3	-1.2	81.2
09:00-10:00	5.7	5.7	0	5.7	39.1	40.0	-2.0	79.4
10:00-11:00	3.3	3.3	0	3.3	38.0	37.5	-1.5	76.4
11:00-12:00	3.0	3.0	0	3.0	23.1	21.6	0	64.5
MIT TOTALS:	23.0	23.0	0	23.0	177.6	177.6	0	412.6

	D E P A R T U R E S			27	D E P A R T U R E S			33L
TIME	27	27	27	ARR+DEP	33L	33L	33L	ARR+DEP
INTERVAL	FLOW	DMND	DIFF	FLOW	FLOW	DMND	DIFF	FLOW
06:00-07:00	20.2	20.6	-.4	20.2	9.4	9.7	-.4	17.9
07:00-08:00	31.6	40.1	-8.8	31.6	9.3	9.7	-.8	33.4
08:00-09:00	30.7	43.2	-21.4	30.7	12.8	13.6	-1.6	46.5
09:00-10:00	28.8	32.6	-25.2	28.8	11.4	13.2	-3.4	44.8
10:00-11:00	28.9	34.4	-30.7	28.9	9.4	8.6	-2.6	44.1
11:00-12:00	32.0	1.4	0	32.0	9.4	6.8	0	29.5
MIT TOTALS:	173.4	173.4	0	173.4	61.7	61.7	0	216.3

	D E P A R T U R E S			33R	D E P A R T U R E S			MIT
TIME	33R	33R	33R	ARR+DEP	MIT	MIT	MIT	ARR+DEP
INTERVAL	FLOW	DMND	DIFF	FLOW	FLOW	DMND	DIFF	FLOW
06:00-07:00	0	0	0	0	29.6	30.4	-.8	38.1
07:00-08:00	0	0	0	7.0	40.9	49.8	-9.6	72.0
08:00-09:00	0	0	0	4.0	43.5	56.8	-22.9	81.2
09:00-10:00	0	0	0	5.7	40.2	45.8	-28.5	79.4
10:00-11:00	0	0	0	3.3	38.4	43.1	-33.2	76.4
11:00-12:00	0	0	0	3.0	41.4	8.2	0	64.5
MIT TOTALS:	0	0	0	23.0	235.0	235.0	0	412.6

This SIMMOD REPORT MODULE version 2.0.2 run began 10/17/1997 at approximately 16:41:20
This page of the TIME.SECTION report was finished at 16:43:09

TAXI-IN/TAXI-OUT TIME, BY AIRLINE REPORT
TAXI ARR TIME, BY AIRLINE
BASED ON 25 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#25 10/17/1997 AT 14:12:29 (0) mit/mit2114
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	E AVG ARR TIMES (MIN)				A AVG ARR TIMES (MIN)				N AVG ARR TIMES (MIN)				M AVG ARR TIMES (MIN)			
TIME INTERVAL	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT
06:00-07:00	2.13	.16	.76	3.05	5.04	.05	.62	5.71	1.71	.02	.77	2.50	0	0	0	0
07:00-08:00	0	0	0	0	4.99	.04	.63	5.67	0	0	0	0	1.42	.01	1.09	2.53
08:00-09:00	0	0	0	0	4.95	.05	.63	5.63	1.71	.01	.76	2.48	0	0	0	0
09:00-10:00	2.74	.32	.65	3.72	4.99	.35	.64	5.97	1.98	.48	.70	3.17	1.27	.05	1.10	2.42
10:00-11:00	2.64	.02	.70	3.35	4.94	.03	.64	5.61	2.16	.01	.68	2.85	1.52	0	1.11	2.63
11:00-12:00	2.62	.02	.67	3.31	4.97	.01	.63	5.61	1.94	0	.70	2.64	1.39	.15	1.09	2.63
TOTALS:	2.60	.12	.68	3.40	4.97	.10	.63	5.70	1.96	.09	.71	2.76	1.39	.06	1.10	2.55

	J AVG ARR TIMES (MIN)				F AVG ARR TIMES (MIN)				L AVG ARR TIMES (MIN)				O AVG ARR TIMES (MIN)			
TIME INTERVAL	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT
06:00-07:00	0	0	0	0	0	0	0	0	0	0	0	0	2.54	.07	.71	3.31
07:00-08:00	5.53	.10	.66	6.29	0	0	0	0	5.04	.12	.63	5.78	0	0	0	0
08:00-09:00	5.76	.06	.63	6.44	2.74	.03	.82	3.60	4.65	.05	.68	5.38	2.39	.05	.74	3.18
09:00-10:00	5.43	.35	.63	6.41	2.74	.86	.54	4.14	4.81	.15	.68	5.63	2.62	.05	.66	3.33
10:00-11:00	5.56	.03	.68	6.26	2.97	.09	.73	3.79	4.63	.28	.69	5.60	2.34	.01	.72	3.06
11:00-12:00	5.58	.02	.65	6.25	3.09	.09	.72	3.91	4.91	.02	.64	5.57	2.02	0	.80	2.82
TOTALS:	5.53	.18	.64	6.35	2.89	.45	.64	3.98	4.76	.13	.67	5.56	2.45	.04	.71	3.21

	U AVG ARR TIMES (MIN)				K AVG ARR TIMES (MIN)				H AVG ARR TIMES (MIN)				L AVG ARR TIMES (MIN)			
TIME INTERVAL	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT
06:00-07:00	0	0	0	0	0	0	0	0	0	0	0	0	2.97	0	.71	3.68
07:00-08:00	0	0	0	0	3.21	.02	.65	3.88	5.16	.01	.66	5.83	2.66	.16	.58	3.40
08:00-09:00	0	0	0	0	3.24	.03	.63	3.91	5.26	.09	.64	5.99	2.60	.31	.62	3.53
09:00-10:00	0	0	0	0	3.31	.18	.62	4.11	5.15	.73	.67	6.54	2.60	.69	.59	3.87
10:00-11:00	0	0	0	0	3.40	.02	.60	4.03	5.03	.02	.68	5.74	2.70	.34	.66	3.70
11:00-12:00	0	0	0	0	3.22	0	.64	3.86	5.15	.01	.67	5.82	2.52	2.23	.52	5.27
TOTALS:	0	0	0	0	3.28	.05	.63	3.96	5.15	.17	.66	5.98	2.64	.43	.61	3.69

This SIMMOD REPORT MODULE version 2.0.2 run began 10/17/1997 at approximately 16:41:20
This page of the GATE.SECTION report was finished at 16:43:32

TAXI-IN/TAXI-OUT TIME, BY AIRLINE REPORT
TAXI ARR TIME, BY AIRLINE (CONTINUED)
BASED ON 25 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#25 10/17/1997 AT 14:12:29 (0) mit/mit2114
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	I AVG ARR TIMES (MIN)				G AVG ARR TIMES (MIN)				S AVG ARR TIMES (MIN)				R AVG ARR TIMES (MIN)			
TIME INTERVAL	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT
06:00-07:00	0	0	0	0	2.55	.03	.73	3.32	0	0	0	0	0	0	0	0
07:00-08:00	0	0	0	0	2.44	.36	.51	3.31	0	0	0	0	0	0	0	0
08:00-09:00	2.18	.18	.65	3.02	1.57	.04	1.06	2.67	0	0	0	0	0	0	0	0
09:00-10:00	2.10	.68	.58	3.36	2.76	.09	.67	3.52	0	0	0	0	3.07	.02	.67	3.75
10:00-11:00	2.00	1.37	.53	3.90	2.23	.04	.61	2.88	4.33	.01	.68	5.02	0	0	0	0
11:00-12:00	2.22	0	.75	2.97	2.86	0	.64	3.49	4.42	.01	.64	5.07	0	0	0	0
TOTALS:	2.13	.53	.63	3.29	2.45	.13	.69	3.27	4.38	.01	.66	5.05	3.07	.02	.67	3.75

	D AVG ARR TIMES (MIN)				P AVG ARR TIMES (MIN)				Q AVG ARR TIMES (MIN)				C AVG ARR TIMES (MIN)			
TIME INTERVAL	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT	TAXI TRAV	TAXI DLY	LAND ING	TOT
00:00-01:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01:00-02:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02:00-03:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03:00-04:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04:00-05:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05:00-06:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06:00-07:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07:00-08:00	4.94	.27	.55	5.76	3.86	.04	.72	4.63	0	0	0	0	5.44	.40	.37	6.21
08:00-09:00	4.52	.01	.72	5.25	0	0	0	0	0	0	0	0	4.53	.07	.72	5.32
09:00-10:00	4.91	.76	.56	6.23	4.05	.19	.64	4.88	0	0	0	0	0	0	0	0
10:00-11:00	4.73	.66	.65	6.04	0	0	0	0	3.04	.11	.63	3.77	4.58	.04	.69	5.31
11:00-12:00	5.44	3.33	.37	9.14	0	0	0	0	3.14	.03	.60	3.77	5.44	4.76	.37	10.56
TOTALS:	4.85	.66	.59	6.10	3.96	.12	.68	4.76	3.07	.08	.62	3.77	5.00	1.32	.54	6.85

This SIMMOD REPORT MODULE version 2.0.2 run began 10/17/1997 at approximately 16:41:20
This page of the GATE.SECTION report was finished at 16:43:32

TAXI-IN/TAXI-OUT TIME, BY AIRLINE REPORT
TAXI DEP TIME, BY AIRLINE
BASED ON 25 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#25 10/17/1997 AT 14:12:29 (0) mit/mit2114
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	E AVG DEP TIMES (MIN)					A AVG DEP TIMES (MIN)					N AVG DEP TIMES (MIN)				
TIME INTERVAL	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT
06:00-07:00	5.76	.58	.83	.62	7.79	6.64	.01	.68	.52	7.86	6.04	.57	.93	.55	8.09
07:00-08:00	6.34	3.61	.84	1.37	12.16	6.63	.05	.68	1.46	8.81	6.15	8.24	.81	1.74	16.95
08:00-09:00	6.34	13.83	.84	2.15	23.16	7.02	3.98	.69	6.28	17.96	6.11	12.78	.86	3.31	23.05
09:00-10:00	6.05	28.46	.88	3.62	39.01	6.74	6.13	.68	10.10	23.65	6.07	30.01	.87	4.50	41.46
10:00-11:00	6.45	42.95	.83	5.80	56.03	6.82	7.79	.68	13.65	28.94	6.27	56.24	.86	1.68	65.05
11:00-12:00	5.16	27.34	.73	4.48	37.71	6.96	11.44	.69	9.86	28.95	6.27	51.64	.81	1.59	60.30
TOTALS:	5.98	18.91	.82	2.85	28.56	6.85	5.40	.68	7.74	20.67	6.14	23.08	.86	2.26	32.34

	M AVG DEP TIMES (MIN)					J AVG DEP TIMES (MIN)					F AVG DEP TIMES (MIN)				
TIME INTERVAL	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT
06:00-07:00	7.46	.16	.96	.58	9.17	9.07	1.34	.77	1.20	12.37	7.72	.68	.88	.85	10.14
07:00-08:00	0	0	0	0	0	9.20	10.49	.77	1.78	22.25	7.73	12.50	.88	1.86	22.98
08:00-09:00	7.93	25.49	.88	1.41	35.71	8.99	20.88	.77	1.93	32.57	0	0	0	0	0
09:00-10:00	7.91	25.64	.95	5.74	40.24	9.19	43.85	.77	1.69	55.51	0	0	0	0	0
10:00-11:00	0	0	0	0	0	9.21	50.96	.77	1.72	62.67	7.74	54.50	.88	2.28	65.40
11:00-12:00	7.74	51.93	.88	1.31	61.86	9.06	52.48	.77	2.03	64.35	7.73	53.52	.88	1.36	63.50
TOTALS:	7.76	24.29	.92	2.50	35.47	9.10	22.44	.77	1.64	33.95	7.73	34.99	.88	1.73	45.34

	L AVG DEP TIMES (MIN)					O AVG DEP TIMES (MIN)					U AVG DEP TIMES (MIN)				
TIME INTERVAL	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT
06:00-07:00	8.50	1.12	.84	1.00	11.46	6.04	.21	.87	.69	7.81	7.66	2.74	.77	1.50	12.67
07:00-08:00	8.48	8.01	.83	1.42	18.74	6.00	5.41	.85	1.46	13.72	0	0	0	0	0
08:00-09:00	8.69	17.09	.78	1.85	28.42	5.92	8.53	.90	2.44	17.78	0	0	0	0	0
09:00-10:00	8.41	31.70	.85	4.66	45.62	6.09	28.17	.95	3.93	39.14	7.68	44.19	.89	2.16	54.91
10:00-11:00	8.55	45.82	.85	2.49	57.71	6.00	43.80	.87	5.81	56.49	0	0	0	0	0
11:00-12:00	8.49	40.11	.88	4.14	53.61	6.09	32.71	.88	1.02	40.70	0	0	0	0	0
TOTALS:	8.52	20.59	.84	2.29	32.23	6.01	19.07	.88	2.68	28.65	7.67	23.46	.83	1.83	33.79

This SIMMOD REPORT MODULE version 2.0.2 run began 10/17/1997 at approximately 16:41:20
This page of the GATE.SECTION report was finished at 16:43:32

TAXI-IN/TAXI-OUT TIME, BY AIRLINE REPORT
TAXI DEP TIME, BY AIRLINE (CONTINUED)
BASED ON 25 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#25 10/17/1997 AT 14:12:29 (0) mit/mit2114
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	K AVG DEP TIMES (MIN)					H AVG DEP TIMES (MIN)					L AVG DEP TIMES (MIN)				
TIME INTERVAL	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT
06:00-07:00	6.72	1.57	.78	1.48	10.54	8.36	.32	1.04	1.33	11.04	0	0	0	0	0
07:00-08:00	6.46	6.15	.90	1.38	14.90	8.88	10.41	.77	1.89	21.96	7.14	9.43	.88	1.53	18.98
08:00-09:00	0	0	0	0	0	8.92	28.33	.77	1.60	39.62	7.17	23.12	.88	1.77	32.94
09:00-10:00	6.74	36.81	.77	2.11	46.44	8.95	44.16	.77	1.59	55.47	7.14	39.84	.88	1.96	49.82
10:00-11:00	6.75	57.67	.77	2.35	67.54	8.92	51.99	.78	1.69	63.38	7.10	53.51	.88	2.03	63.53
11:00-12:00	6.75	50.67	.77	1.48	59.68	8.95	51.87	.77	1.92	63.51	7.20	52.29	.88	1.73	62.12
TOTALS:	6.65	26.50	.82	1.70	35.67	8.81	28.46	.82	1.68	39.77	7.15	36.67	.88	1.83	46.53

	I AVG DEP TIMES (MIN)					G AVG DEP TIMES (MIN)					S AVG DEP TIMES (MIN)				
TIME INTERVAL	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT
06:00-07:00	6.98	.10	.88	.27	8.24	0	0	0	0	0	0	0	0	0	0
07:00-08:00	6.99	7.53	.88	1.68	17.09	7.50	11.76	.88	1.52	21.66	8.12	4.10	.77	1.70	14.70
08:00-09:00	7.00	23.53	.88	1.82	33.22	7.23	25.64	.88	2.05	35.81	0	0	0	0	0
09:00-10:00	7.00	37.64	.88	1.97	47.49	7.65	30.95	.88	2.17	41.66	0	0	0	0	0
10:00-11:00	7.00	49.69	.88	1.83	59.41	7.71	51.59	.88	2.03	62.21	0	0	0	0	0
11:00-12:00	7.01	50.78	.88	1.86	60.53	7.44	52.45	.73	1.80	62.42	0	0	0	0	0
TOTALS:	7.00	31.40	.88	1.71	40.98	7.55	33.88	.86	1.83	44.12	8.12	4.10	.77	1.70	14.70

	R AVG DEP TIMES (MIN)					D AVG DEP TIMES (MIN)					P AVG DEP TIMES (MIN)				
TIME INTERVAL	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT
06:00-07:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07:00-08:00	7.97	5.19	.77	1.61	15.55	8.12	10.65	.88	1.21	20.87	0	0	0	0	0
08:00-09:00	0	0	0	0	0	8.11	22.69	.88	1.94	33.63	7.93	1.75	1.03	7.65	18.36
09:00-10:00	0	0	0	0	0	8.12	40.59	.88	1.94	51.52	8.45	33.05	.89	3.28	45.66
10:00-11:00	0	0	0	0	0	8.12	53.89	.88	1.97	64.87	8.52	59.57	.88	1.91	70.87
11:00-12:00	8.03	53.46	.77	1.76	64.02	8.12	51.47	.88	1.66	62.13	8.53	49.66	.77	1.67	60.64
TOTALS:	8.00	29.32	.77	1.69	39.78	8.12	41.34	.88	1.80	52.14	8.36	36.50	.89	3.56	49.32

This SIMMOD REPORT MODULE version 2.0.2 run began 10/17/1997 at approximately 16:41:20
This page of the GATE.SECTION report was finished at 16:43:32

TAXI-IN/TAXI-OUT TIME, BY AIRLINE REPORT
TAXI DEP TIME, BY AIRLINE (CONTINUED)
BASED ON 25 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#25 10/17/1997 AT 14:12:29 (0) mit/mit2114
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	Q AVG DEP TIMES (MIN)					C AVG DEP TIMES (MIN)					T AVG DEP TIMES (MIN)				
TIME INTERVAL	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT	TAXI TRAV	TAXI DLY	TAKE OFF	DEP QUE	TOT
06:00-07:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07:00-08:00	7.19	11.74	.77	1.72	21.42	0	0	0	0	0	9.15	11.67	.77	1.69	23.28
08:00-09:00	0	0	0	0	0	8.11	24.25	.88	2.14	35.37	9.12	17.01	.77	1.66	28.55
09:00-10:00	0	0	0	0	0	8.12	43.48	.88	1.80	54.29	0	0	0	0	0
10:00-11:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11:00-12:00	0	0	0	0	0	8.10	43.73	.88	2.09	54.81	9.18	53.30	.78	1.72	64.98
TOTALS:	7.19	11.74	.77	1.72	21.42	8.11	34.25	.88	1.97	45.22	9.16	32.70	.77	1.70	44.34

This SIMMOD REPORT MODULE version 2.0.2 run began 10/17/1997 at approximately 16:41:20
This page of the GATE.SECTION report was finished at 16:43:32

AIRPORT AIR AND GROUND TRAVEL AND DELAY REPORT

MIT AIRPORT -- ALL RUNWAY A R R I V A L GROUND AND AIR TRAVEL AND DELAY TIMES
BASED ON 25 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#25 10/17/1997 AT 14:12:29 (0) mit/mit2114
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	MIT	OVERALL ARRIVAL TIMES (MIN)				AVERAGE ARRIVAL TIMES (MIN)							
TIME	ARRIVAL	TRAVEL		DELAY		TRAVEL				DELAY			
INTERVAL	FLOW	TOT	SDV	TOT	SDV	AIR	GND	GTE	TOT	AIR	GND	GTE	TOT
06:00-07:00	8.52	56.5	1.28	1.7	.42	2.72	3.91	0	6.63	.15	.06	0	.20
07:00-08:00	31.12	228.6	1.29	14.6	.70	2.63	4.72	0	7.35	.34	.13	0	.47
08:00-09:00	37.72	266.5	1.36	56.3	1.58	2.75	4.31	0	7.07	1.36	.13	.79	2.29
09:00-10:00	39.12	275.8	1.39	38.8	1.79	2.62	4.43	0	7.05	.55	.44	.82	1.81
10:00-11:00	38.00	268.8	1.33	47.0	1.57	2.69	4.38	0	7.07	1.00	.24	1.04	2.27
11:00-12:00	23.12	160.1	1.32	61.0	2.79	2.60	4.32	0	6.92	2.09	.54	2.57	5.20
MIT TOTALS:	177.60	1256.3	1.35	219.3	1.82	2.67	4.41	0	7.07	.96	.27	.90	2.14

MIT AIRPORT -- ALL RUNWAY D E P A R T U R E GROUND AND AIR TRAVEL AND DELAY TIMES

	MIT	OVERALL DEPARTURE TIMES (MIN)				AVERAGE DEPARTURE TIMES (MIN)								
TIME	DEPARTURE	TRAVEL		DELAY		TRAVEL				DELAY				
INTERVAL	FLOW	TOT	SDV	TOT	SDV	AIR	GND	GTE	TOT	AIR	GND	GTE	QUE	TOT
06:00-07:00	29.60	292.4	1.34	47.4	1.98	1.72	8.16	0	9.88	0	.76	0	.85	1.61
07:00-08:00	40.92	408.2	1.13	348.2	5.67	1.80	8.17	3.00	12.97	0	6.97	.02	1.54	8.53
08:00-09:00	43.52	430.6	1.16	779.1	9.82	1.81	8.08	5.59	15.49	0	14.64	.08	3.27	17.98
09:00-10:00	40.24	394.7	1.14	1391.7	14.58	1.81	8.00	12.61	22.42	0	30.44	.21	4.15	34.79
10:00-11:00	38.36	382.6	1.13	1802.3	18.02	1.86	8.12	17.06	27.03	0	42.01	.08	4.97	47.06
11:00-12:00	41.40	412.6	1.33	1845.0	17.59	1.85	8.12	28.95	38.92	0	41.11	.02	3.46	44.59
MIT TOTALS:	235.04	2329.9	1.21	6213.7	21.36	1.81	8.10	11.60	21.51	0	23.33	.07	3.11	26.51

This SIMMOD REPORT MODULE version 2.0.2 run began 10/17/1997 at approximately 16:41:20
This page of the APT.PAGE report was finished at 16:43:56

ITERATION AIR AND GROUND DELAY
AVERAGE, MIN, AND MAX AIRCRAFT GROUND AND AIR DELAY TIME (MINS) VERSUS ITERATION
BASED ON 25 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#25 10/17/1997 AT 14:12:29 (0) mit/mit2114
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	ARRIVALS						DEPARTURES					
	AIR			GND			AIR			GND		
ITERATIONS	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
TOTALS:	.85	0	5.52	.22	0	11.10	0	0	0	27.52	0	65.22
TOTALS:	1.08	0	7.17	.18	0	10.47	0	0	0	24.80	0	63.67
TOTALS:	.86	0	5.88	1.14	0	17.92	0	0	0	27.85	0	65.43
TOTALS:	.92	0	5.97	.41	0	14.98	0	0	0	25.26	0	63.82
TOTALS:	.98	0	8.10	.23	0	10.12	0	0	0	28.15	0	71.30
TOTALS:	.90	0	5.65	.24	0	9.52	0	0	0	25.94	0	69.23
TOTALS:	1.16	0	6.60	.24	0	6.03	0	0	0	25.69	0	65.27
TOTALS:	1.14	0	8.72	.15	0	4.10	0	0	0	27.03	0	67.23
TOTALS:	.91	0	5.50	.10	0	3.07	0	0	0	27.89	0	66.30
TOTALS:	.87	0	6.05	.15	0	6.20	0	0	0	23.64	0	60.78
TOTALS:	.89	0	7.10	.47	0	14.38	0	0	0	28.82	0	64.17
TOTALS:	1.07	0	6.88	.36	0	13.77	0	0	0	23.92	0	62.82
TOTALS:	1.11	0	6.45	.40	0	12.83	0	0	0	32.96	0	73.62
TOTALS:	.92	0	5.90	.07	0	1.50	0	0	0	29.98	0	66.07
TOTALS:	.86	0	6.25	.22	0	9.25	0	0	0	27.53	0	64.80
TOTALS:	1.11	0	7.78	.24	0	6.77	0	0	0	25.54	0	63.63
TOTALS:	1.18	0	9.90	.18	0	4.13	0	0	0	26.99	0	61.38
TOTALS:	.83	0	6.78	.24	0	17.97	0	0	0	25.45	0	68.60
TOTALS:	1.04	0	6.53	.21	0	6.08	0	0	0	21.49	0	54.88
TOTALS:	.95	0	6.83	.10	0	2.68	0	0	0	24.82	0	61.08
TOTALS:	1.00	0	6.45	.40	0	15.42	0	0	0	27.83	0	68.47
TOTALS:	.90	0	5.75	.23	0	8.78	0	0	0	27.45	0	66.65
TOTALS:	.92	0	6.00	.18	0	5.30	0	0	0	23.95	0	60.02
TOTALS:	.96	0	6.77	.20	0	5.97	0	0	0	26.60	0	60.27
TOTALS:	.66	0	4.30	.19	0	4.62	0	0	0	24.26	0	55.50

TOTAL DELAYS FOR ALL ITERATIONS

	ARRIVALS						DEPARTURES					
TIME	AIR			GND			AIR			GND		
INTERVAL	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
06:00-07:00	.15	0	2.15	.06	0	1.07	0	0	0	1.60	0	10.97
07:00-08:00	.34	0	3.38	.13	0	4.48	0	0	0	8.51	0	20.97
08:00-09:00	1.36	0	8.10	.13	0	5.88	0	0	0	17.90	0	45.10
09:00-10:00	.55	0	4.27	.44	0	17.97	0	0	0	34.58	.13	56.75
10:00-11:00	1.00	0	6.08	.24	0	17.92	0	0	0	46.98	0	73.62
11:00-12:00	2.09	0	9.90	.54	0	15.42	0	0	0	44.57	0	69.65
TOTALS:	.96	0	9.90	.27	0	17.97	0	0	0	26.44	0	73.62

This SIMMOD REPORT MODULE version 2.0.2 run began 10/17/1997 at approximately 16:41:20
This page of the ITER.SECTION report was finished at 16:44:21

Chapter 4:
Measuring the impact of Construction in the South-West Corner, A Case Study

1. Content

In order to show what SIMMOD can (and can not) do for the *short-term planning* of an airport, we have examined a second question of practical use to the engineers in charge of the construction of new taxiways at Logan Airport: the impact of construction on the operations of the airport.

This work must not be considered as an in-depth study but simply as a demonstration project to explore the capabilities of SIMMOD.

2. The problem and its constraints

Construction is generally performed without impact on the operations, either:

- Outside of the so-called “runway safety areas”, under configurations that do not use the construction area.
- Or, at night, making sure that the construction area reopens at 6:00 am.

This means that a very limited number of taxiway alterations will impact the operations. Typically, it is always possible to work on very small chunks of the pavement to make sure everything can be used by 6:00 am. There is however a risk to be late. It would thus be interesting to simulate the impact on delays of various alternatives in order to use the slots in increasing order of disruption (filling nights first, then weekends, etc.).

We thus consider a specific phase of construction, Phase F of year 2 under the current project (See map in appendix, p. 128). Two sub-sections of this phase may generate disruption of the operations:

- Alterations within the 100 feet runway 4L safety area, during which 4L must be closed or limited to departures from Charlie (~6,000 feet).
- Alterations of taxiway Kilo.

A complete study may typically compare the following situations:

A	Normal VFR operations on 4L, 4R and 9
B-1	Closure from Friday 4pm to Sunday 2pm of runway 4L, under VFR conditions
B-2 B-3	Closure from 11pm to 6am of runway 4L, under VFR conditions, with some uncertainty on the actual end of the construction: B-2: end at 6am

	B-3: end at 8am because of problems
C-1	Closure from Friday 4pm to Sunday 2pm of taxiway Kilo in front of terminal B, under VFR conditions
C-2 C-3	Closure from 11pm to 6am of taxiway Kilo in front of terminal B, under VFR conditions, with some uncertainty on the actual end of the construction: C-2: end at 6am C-3: end at 8am because of problems
D-1	Closure from Friday 4pm to Sunday 2pm of taxiway Kilo in front of terminal B up to E, under VFR conditions
D-2 D-3	Closure from 11pm to 6am of taxiway Kilo in front of terminal B up to E, under VFR conditions, with some uncertainty on the actual end of the construction: D-2: end at 6am D-3: end at 8am because of problems
E-1	Closure from Friday 4pm to Sunday 2pm of taxiway Kilo in front of terminal B up to 4L threshold, under VFR conditions
E-2 E-3	Closure from 11pm to 6am of taxiway Kilo in front of terminal B up to 4L threshold, under VFR conditions, with some uncertainty on the actual end of the construction: E-2: end at 6am E-3: end at 8am because of problems

Weekends will of course be more disruptive than nights. They may however be needed to complete the work before the end of a given season. There is also a slight chance that the contractors can not finish for 6am. In that case, a good estimate of the impact would for instance be 5% (impact of X-3) + 95% (impact of X-2). This explains why we would consider the cases 2 and 3.

To have a first idea of the problems we may face when actually developing such a study, we have looked in details at two cases:

- Opening a portion of Kilo at 8am (a reasonable approximation of C-3).
- Keeping 4L closed for the whole morning (equivalent to the Saturday and Sunday morning of the B-1 case).

Developing the other cases from these two would not require large additional work.

3. Development of the models

In this second part, we give an idea of the assumptions of the baseline and the modifications that were made to develop the other cases. To simplify the comparison of the various cases, we have concentrated on the morning operations at Logan Airport until 12 noon, and how these operations would be affected by closure.

1. Baseline

We consider as a baseline what happens under the current Northeast configuration. This configuration has appeared more difficult to develop than expected because of major limitations in SIMMOD. As we have noticed in the report on the *general assumptions of the model*, SIMMOD is very poor when it comes to handling dynamic circulation and re-routing of aircraft. This is exactly what happens in this Northeast configuration.

This means that the simple rules that govern the affectation of aircraft to departure queues and runways can not be modeled in SIMMOD. The logic of this program considers that decisions are taken *before* an aircraft leaves its gate.

The baseline has the following features:

— Current taxiway/runway/gates layout.

— Official Airline Guide schedule for July 9th 1997, until noon (177 arrivals, 278 departures).

— Northeast configuration under VFR weather[1]: landings on 4L and 4R, take-offs on 4L, 4R and 9. Assignments are based on weight classes and FTA's FLAPS model.

It is important to mention from the start that at least three features of the animation of this model are not realistic at all:

(1) Aircraft lining up for take-off on runway 9 will wait in the middle of runway 4L if they can not move closer to runway 9, whatever landings and take-offs happen on 4L. However strange this may sound, this feature should not affect delays and throughput. This is equivalent to having them waiting 100 feet before the runway.

(2) Along Kilo, some aircraft may travel over some others that are staging before departure. We could avoid this by suppressing the entire staging pad, but this would probably be even less accurate. Similarly, it is impossible to control for aircraft that find their way on taxiways that are assigned in the opposite direction; SIMMOD simply models these aircraft as passing other aircraft at the nodes.

(3) SIMMOD does not allow us to model the complex runway balancing achieved by the tower in this configuration. Our capacity will likely be lower than in the real world.

---

[1] Corresponding to FTA's configuration 401DV/DB.

As far as runway procedures are concerned, the model attains the following runway flows:

Average runway flows, demands, and cumulative differences, based on 10 iterations[2]*:*

Arrivals	4L				4R				BOS			
	FLOW	DMND	DIFF	FLOW	FLOW	DMND	DIFF	FLOW	FLOW	DMND	DIFF	FLOW
TIME INTERVAL	ARR			ARR+ DEP	ARR			ARR+ DEP	ARR			ARR+ DEP
06:00-07:00	4.5	5	-0.5	10	4	4	0	8	8.5	9	-0.5	39
07:00-08:00	23.5	23.5	-0.5	35.8	7.8	7.8	0	11.5	31.3	31.3	-0.5	73.2
08:00-09:00	24.9	25.7	-1.4	38.7	12.4	12.4	0	18.7	37.2	38.1	-1.4	84.5
09:00-10:00	20.1	19.6	-0.9	37.2	19.4	19.6	-0.1	22.4	39.5	39.2	-1	83.3
10:00-11:00	19.7	19.1	-0.3	38.1	16.4	16.3	-0.1	19.3	36.1	35.4	-0.3	69
11:00-12:00	7.8	7.6	0	27.5	11.6	11.6	0	12.7	19.5	19.2	0	56.9

Departures	9				4L				4R			
	FLOW	DMND	DIFF	FLOW	FLOW	DMND	DIFF	FLOW	FLOW	DMND	DIFF	FLOW
TIME INTERVAL	DEP			ARR+ DEP	DEP			ARR+ DEP	DEP			ARR+ DEP
06:00-07:00	21.1	22.1	-1.1	21.1	5.5	6.5	-1	10	4	4	0	8
07:00-08:00	25.8	28.3	-3.5	25.8	12.3	12.7	-1.5	35.8	3.7	3.8	-0.1	11.5
08:00-09:00	27.1	24	-0.4	27.1	13.8	15.4	-3	38.7	6.3	6.2	0	18.7
09:00-10:00	23.6	23.6	-0.3	23.6	17.1	16.4	-2.3	37.2	3	3	0	22.4
10:00-11:00	11.5	11.7	-0.5	11.5	18.4	18.4	-2.3	38.1	2.9	3	-0.1	19.3
11:00-12:00	16.5	16	0	16.5	19.7	17.4	0	27.5	1.1	1	0	12.7

	BOS			
	FLOW	DMND	DIFF	FLOW
TIME INTERVAL	DEP			ARR+ DEP
06:00-07:00	30.6	32.7	-2	39
07:00-08:00	41.9	44.8	-5	73.2
08:00-09:00	47.2	45.6	-3.4	84.5
09:00-10:00	43.7	42.9	-2.6	83.3
10:00-11:00	32.9	33.2	-2.9	69
11:00-12:00	37.3	34.5	0	56.9

It is essential to note that these flows correspond to the morning operations. These operations are slightly skewed towards departures, leading to different apparent capacity than models based on a 50%/50% arrival/departure mix shown below.

[2] The runway flow is the actual number of aircraft that used the runway during an interval, while the demand shows the aircraft that required using the runway in the same interval. The difference accumulates until the flow can be higher than the demand.

Model	ARR 4L	ARR 4R	DEP 4L	DEP 4R	DEP 9	TOT
EPS (FAA)[3] (V)	31	31	10	10	32	114
FLAPS	28.0	38.1	23.5	5.3	37.3	132.3
FLAPS Saturation (93)	29	39	23	8	36	135
SIMMOD 38% arrivals	24.9	12.4	13.8	6.3	27.1	84.5
SIMMOD double arrivals on 4L (below)	34.8		11			
SIMMOD 4L closed (below)		34.5		5.7	28.6	68.8

If we double the number of arrivals on 4L, we get the following arrival and departure rates on this runway:

	Arrivals			Departures		
	Flow	Demand	Cumulative Difference	Flow	Demand	Cumulative Difference
06:00-07:00	4.4	5.2	-0.8	5.2	6.2	-1
07:00-08:00	31.2	31	-0.6	12.4	12.6	-1.2
08:00-09:00	34.8	35.2	-1	11	12.4	-2.6
09:00-10:00	24.6	24.6	-1	13.6	14.2	-3.2
10:00-11:00	23.6	22.8	-0.2	16.8	16.2	-2.6
11:00-12:00	9.4	9.2	0	18.6	16	0

When we close runway 4L, we also get a better estimate of the departure capacity of runway 9:

Departures	9				4R				BOS			
	FLOW	DMND	DIFF	FLOW	FLOW	DMND	DIFF	FLOW	FLOW	DMND	DIFF	FLOW
TIME INTERVAL	DEP			ARR+ DEP	DEP			ARR+ DEP	DEP			ARR+ DEP
06:00-07:00	24.3	27.9	-3.5	24.3	4	4	0	12.8	28.3	31.8	-3.5	37.2
07:00-08:00	28.2	28.4	-3.7	28.2	3.5	3.8	-0.4	34.6	31.6	32.2	-4.1	62.8
08:00-09:00	28.6	29.1	-4.2	28.6	5.7	6.2	-0.9	40.2	34.3	35.3	-5.1	68.8
09:00-10:00	29.1	32.1	-7.3	29.1	3.9	3	0	37.5	32.9	35.1	-7.3	66.6
10:00-11:00	29.3	28.6	-6.7	29.3	3	3	0	31	32.3	31.6	-6.7	60.4
11:00-12:00	28	21.4	0	28	1	1	0	16.5	29	22.4	0	44.5

This is to show that our model of runway operations is reasonably realistic, except that runway 9 does not achieve the very high rates suggested by FLAPS. The figures we get are more in the range of the EPS model. We should keep this is mind when examining the results.

Since our focus in this study lies in the impact on delay and travel time, it is important to list the sources of errors on these values that are inherent to our model. Here are a few points to make:

[3] These figures are given for "75% or more arrivals". This is confusing, as the figures lead to 50 departures and 41 arrivals.

(1) This model is weak on the pushback time probability distributions and on the actual speed on the taxiways. For instance, it is not possible to model the significant difference between the speed of arrivals and departures. We will hopefully reason by comparison.

(2) In terms of delays, since we are not able to model all the complex techniques used by the tower in this configuration, our baseline will not perform as well as in reality; however, the simpler configuration with runway 4L closed will perform closer to the reality. Similarly, we may not get the full impact of the closure of taxiway Kilo as our baseline does not use this taxiway the same way actual controllers do.

(3) In order to stay closer to the reality, we have chosen to model a systematic gate hold; this means that aircraft may not look as if they are waiting to take-off, but they will often be: they stay at gate until they are allowed to move to their departure queues.

2. Taxiway kilo blocking

In this second configuration, we model the impact of a closure of taxiway kilo between Charlie and Sierra. To achieve this, we define the two links involved (138 and 751) as going in the wrong way (South-North). Then, at 8, we reset both links to the correct direction.

Besides, we have to suppress the staging area that used to be on Kilo at this location (SP6, No. 13). This means that when the taxiway reopens, this case is not strictly equivalent to the baseline as aircraft do not use this staging area.
All other inputs are the same as in the baseline.

3. Closure of runway 4L

As we have discussed, it may be necessary to close entirely 4L. Thanks to this model, we can determine the impact of such a closure on delays and travel time. This configuration corresponds to the FLAPS configuration 403B2. Arrivals on 4L are transferred to 4R and departures are transferred to 9. From the point of view of the model, this concerns:

- 106 arrivals on route 5 transferred to route 6;
- 72 departures (23 simple and 49 turnaround) on 22 transferred to 28;

— 34 departures (31 simple and 3 turnaround) on route 34 transferred to route 41.

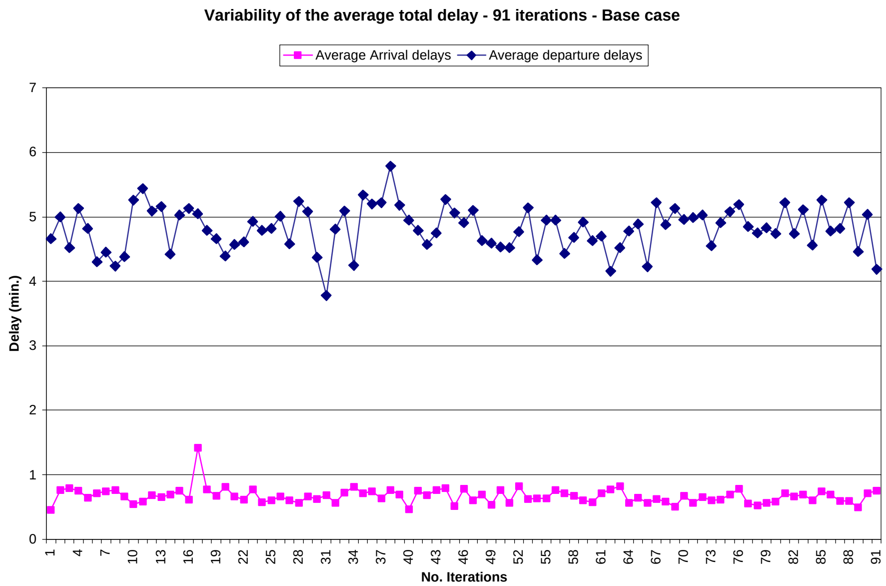
We have thus modified the event file to close the runway and transfer these operations to the other runways.

Finally, we made some slight modifications to handle small aircraft landings on 4R: speed on links 752 and 756 changed from 60 to 10 knots, speed on link 31 changed from 40 to 10 knots, link 130 restricted to departures, link 834 restricted to travel.

4. Results

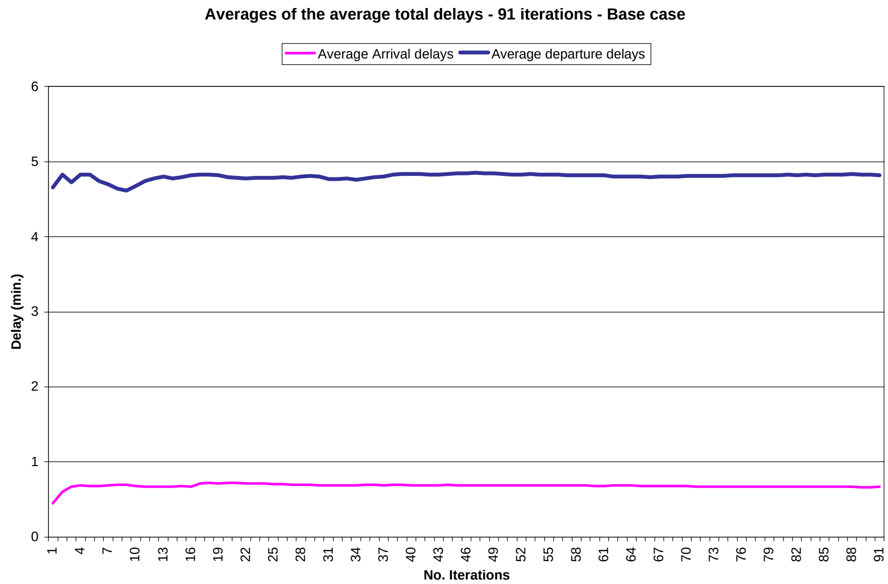
1. Number of iterations needed

To determine this, we have run 100 iterations[4] of the baseline, and charted the average total arrival and departure delays for each of these iterations. We also show the evolution of the average of all these values.



The average of these values shows a fast convergence:

[4] The program generating reports was actually not able to handle that many iterations, limiting the analysis to 91 configurations.



We can limit ourselves to 20 iterations to take into account most of the stochasticity of our inputs. This question may come back when we consider the more complex operations of the second case.

2. Reports generated

As explained earlier, we attempt to characterize the disruption caused by construction. It is clear that these events will affect (1) the ground travel time and (2) aircraft delays. We will thus consider both of these aspects. We will examine:

— Average runway flows, demands and difference report

— Airport air and ground travel delay report

— Runway air and ground travel and delay report

— Average arrival travel and delay report

— Average departure travel and delay report

— Departure queue length summary report

3. Average runway flows, demands and difference report

Since we compare configurations with different numbers of runways, the most interesting part of this report comes from the comparison of the total flows, and their cumulative differences with the demand. It is also important to underline that if the demand is low, these configurations should have comparable efficiencies.

Total arrival flows, demand and cumulative differences for Logan Airport under the 3 cases

Arrivals	BASELINE			KILO BLOCKED			4L CLOSED		
TIME INTERVAL	FLOW	DMND	DIFF	FLOW	DMND	DIFF	FLOW	DMND	DIFF
06:00-07:00	8.5	9	-0.5	8.5	9	-0.5	8.9	9.2	-0.4
07:00-08:00	31.3	31.3	-0.5	31.3	31.3	-0.5	31.1	31.3	-0.5
08:00-09:00	37.2	38.1	-1.4	37.2	38	-1.4	34.5	35.1	-1.1
09:00-10:00	39.5	39.2	-1	39.5	39.2	-1	33.7	34.8	-2.2
10:00-11:00	36.1	35.4	-0.3	36.3	35.6	-0.3	28.1	26.9	-1.1
11:00-12:00	19.5	19.2	0	19	18.7	0	15.6	14.4	0
BOS TOTALS	172.1	172.1	0	171.8	171.8	0	151.8	151.8	0

As expected, we notice a negligible variation in the arrival flow when we close Kilo, while we see a bigger impact when we close 4L. This suggests closing Kilo when arrivals are high, that is, at the end of the day.

On the departure side, we have:

Total departure flows, demand and cumulative differences for Logan Airport under the 3 cases

Departures	BASELINE			KILO BLOCKED			4L CLOSED		
TIME INTERVAL	FLOW	DMND	DIFF	FLOW	DMND	DIFF	FLOW	DMND	DIFF
06:00-07:00	30.6	32.7	-2	31	32.9	-1.9	28.3	31.8	-3.5
07:00-08:00	41.9	44.8	-5	41.9	44.6	-4.7	31.6	32.2	-4.1
08:00-09:00	47.2	45.6	-3.4	47.4	46.3	-3.6	34.3	35.3	-5.1
09:00-10:00	43.7	42.9	-2.6	43.4	43	-3.2	32.9	35.1	-7.3
10:00-11:00	32.9	33.2	-2.9	34.1	33.2	-2.3	32.3	31.6	-6.7
11:00-12:00	37.3	34.5	0	36.5	34.2	0	29	22.4	0
BOS TOTALS:	234.9	234.9	0	235.4	235.4	0	189.6	189.6	0

On this side, we are disappointed not to notice any impact when Kilo is blocked, while the closure of 4L is much clearer, with a cumulative difference between the demand and the flow that reaches 6.7 between 10 and 11. After 11, the demand is reduced and this third configuration does not cause additional delays.

According to these tables, at the peak hour (8:00-9:00), the closure of 4L has the following impact:

	Arrivals (8:00-9:00)	Departures (8:00-9:00)
Impact of 4L closure on runway flow	-7.3%	-27.6%

This first analysis leads us to consider the delays encountered by aircraft during the morning.

4. Airport and runway air and ground travel and delay report

Extracted from the reports in appendix, we have:

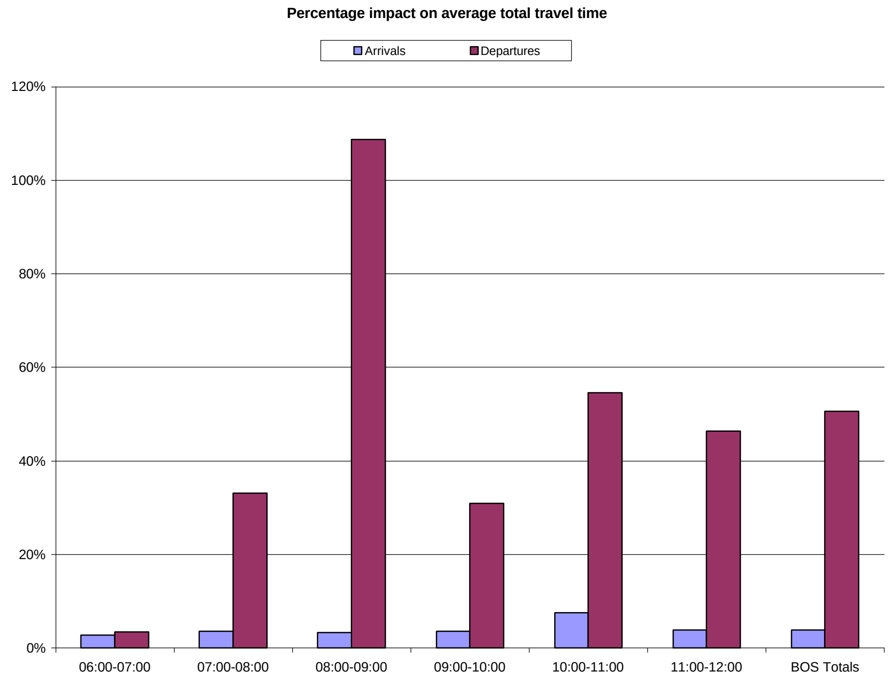
	Average Total Arrival Delays			Average Total Departure Delays		
Time Interval	**Baseline**	**Kilo closed**	**4L closed**	**Baseline**	**Kilo closed**	**4L closed**
06:00-07:00	0.14	0.14	0.18	2.44	2.43	3.28
07:00-08:00	0.52	0.55	3.69	5.23	5.02	6.74
08:00-09:00	11.92	11.1	32.49	6.46	6.18	7.77
09:00-10:00	5.57	5.4	21.73	6.34	6.77	9.34
10:00-11:00	7.53	7.45	13.69	5.18	5.37	12.78
11:00-12:00	4.99	4.48	8.99	5.39	5.14	15.85
BOS Totals	6.1	5.82	16.43	5.31	5.28	9.25

While travel times (including gate hold and air travel) reach:

	Average Total Arrival Travel Time			Average Total Departure Travel Time		
Time Interval	**Baseline**	**Kilo closed**	**4L closed**	**Baseline**	**Kilo closed**	**4L closed**
06:00-07:00	6.57	6.48	6.75	6.39	6.41	6.61
07:00-08:00	6.88	7	7.13	12.97	12.97	17.27
08:00-09:00	7.04	7.06	7.28	17.18	17.13	35.87
09:00-10:00	7.31	7.26	7.57	47.25	46.45	61.84
10:00-11:00	7.1	7.2	7.64	59.72	58.61	92.33
11:00-12:00	7.5	7.55	7.79	66.97	64.99	98.04
BOS Totals	7.12	7.15	7.4	34.43	33.76	51.86

Arrivals will wait an average of 9 minutes more if 4L is closed. This delay is mainly affected to the gate, apparently because aircraft have to wait for their gates. The major issue here is that blocking Kilo has no impact.

To qualify the impact of the closure of 4L, we can draw the following figure:



The average arrival time faces a small 3-4% increase as the flow is partially reduced. Departures are affected by the runway restriction and by the lateness of arrivals: with a 27% reduction of the flow, delays increase exponentially by up to 110% between 8 and 9. The average is a 51% increase.

This figure also shows a negligible impact of 4L closure between 6 and 7. This means that extending the construction period from 6 to 7 should not have negative impacts on the operations. Similarly, we expect that starting at night earlier than planned (when departures are low) would be interesting as construction has a much lower impact on arrivals.

The detail by runway provides basically the same conclusions.

5. Average arrival and departure travel and delay report, Departure queue length summary

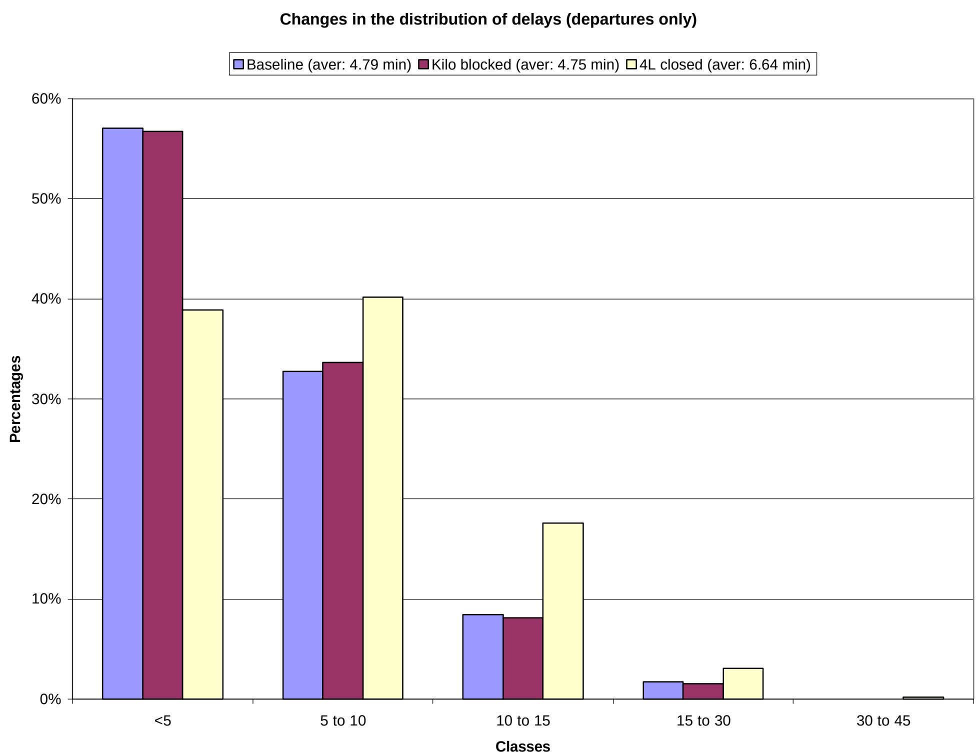
The first reports provide the number of flights with certain delays in each hour. This gives a clearer idea of the actual impact of reduced operations on the experience of each flight. The most interesting figures are the following:

Percentages	Arrivals				Departures				
	<5	5 to 10	10 to 15	15 to 30	<5	5 to 10	10 to 15	15 to 30	30 to 45
Baseline	99%	0%	0%	0%	57%	33%	8%	2%	0%
Kilo blocked	100%	0%	0%	0%	57%	34%	8%	2%	0%
4L closed	92%	7%	1%	0%	39%	40%	18%	3%	0%

As noticed earlier, blocking Kilo does not have an impact on the delays, while closing 4L has a clear impact. The low results of the baseline come from the low take-off rate on 9.

The number of flights per category is interesting as it shows in more details what happens to individual aircraft in either case. This representation has a drawback: it exaggerates impacts when the average time shifts from one class to another.

The delays used in these reports include only the ground and queue delays, excluding gate hold and gate delay (given for instance in the "airport air and ground travel and delay reports"). This is why we get quite different results (impact changing from 34, 33 and 52 minutes to 4 and 6 minutes[5]).



[5] According to the table at the top of this page.

As we see on this figure, approximately 18% of the departure aircraft shift from the “< 5 min.” class to the “5 to 10”. 11% shift from the “5 to 10” to the “10 to 15”. Finally, 2 or 3% get to the “15 to 30” class.[6]

To have a clear understanding of what these reports indicate, we can consider that the delay classes built above show the impact of the configurations on the ground network congestion by opposition to the entire travel time. Again, while we tried to model the probable conflict between the circulation of aircraft on taxiway alpha and the aircraft that may pushback from terminal B on this taxiway, the second case does not show such phenomenon.

The departure queue length summaries are not very interesting since we model a systematic gate hold.

[6] Assuming a simple model of transfer from one class to the next one as delays increase.

5. Conclusions

This short study does not give a clear picture of the potential impact of construction in the southwest corner. It only shows a 3-4% increase in total arrival times and a large increase (51% on average, up to 110% between 8 and 9) in total departure times when runway 4L is closed during the entire morning. Blocking Kilo does not give convincing results.

It has nevertheless allowed us to identify the problems that arise if we wish to conduct such an analysis. Among these problems, we will quote:

(1) **The ability to accurately model** what happens in the northeast configuration. Even if we admit that an unrealistic model can achieve realistic results, and that complex operations on the inputs can lead to a better model, SIMMOD does not allow us to see the impact of the closure of taxiway Kilo. Following our discussion with Mr. Bobby Sgroi from the tower, it appears that in the northeast configuration, the difficulty consists in achieving the appropriate balancing between runways: making sure that there are always aircraft ready to depart on each runway. This is actually very well achieved by SIMMOD; we define a threshold for each queue and SIMMOD holds aircraft at their gates. Simple flow constraints such as “no overtaking” can not be implemented.

(2) **The difficulty to build comparable cases**. By considering a given morning schedule, we have made it easy to compare the reports generated in the three cases. Considering the actual cases identified in the first part of this report would require to compare blocking the airport during a whole week-end vs. a single morning, i.e. modeling week-end operations during an entire day, and then, identifying appropriate performance measures of these alternatives.

(3) **The complexity of the reports** that are produced. There is no simple way to categorize the delays and travel times for each aircraft. The reports we examined in this study have appeared quite confusing. We believe that, if a study must be conducted in details, the best measures will come from a direct analysis of the *history* file that contains information for each aircraft gone through the system. Delay or travel distributions can be built easily from this file.

Overall, it seems that simulation is the best method only when we wish to capture dynamic systems effects that require meticulous modeling, such as the impact of blocking Kilo and the subsequent flow transfer onto Alpha. As a *rigid* and *limited* software, SIMMOD does not allow us to achieve this. More fundamental impacts, such as the runway closure in our third case, are faster and better modeled with conventional methods or simpler models.

6. Appendix 1: Map of the construction area

7. Appendix 2: baseline simulation reports

AVERAGE RUNWAY FLOWS, DEMANDS, AND DIFFERENCES REPORT
MIT AIRPORT--AVERAGE RUNWAY ARRIVAL and DEPARTURE FLOWS, DEMANDS, AND CUMULATIVE DIFFERENCES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 16:28:45 (0) mit/mit9000
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	ARRIVALS			9	ARRIVALS			4L
TIME INTERVAL	9 FLOW	9 DMND	9 DIFF	ARR+DEP FLOW	4L FLOW	4L DMND	4L DIFF	ARR+DEP FLOW
06:00-07:00	0	0	0	21.1	4.5	5.0	-.5	10.0
07:00-08:00	0	0	0	25.8	23.5	23.5	-.5	35.8
08:00-09:00	0	0	0	27.1	24.9	25.7	-1.4	38.7
09:00-10:00	0	0	0	23.6	20.1	19.6	-.9	37.2
10:00-11:00	0	0	0	11.5	19.7	19.1	-.3	38.1
11:00-12:00	0	0	0	16.5	7.8	7.6	0	27.5
MIT TOTALS:	0	0	0	126.8	100.4	100.4	0	187.6

	ARRIVALS			4R	ARRIVALS			MIT
TIME INTERVAL	4R FLOW	4R DMND	4R DIFF	ARR+DEP FLOW	MIT FLOW	MIT DMND	MIT DIFF	ARR+DEP FLOW
06:00-07:00	4.0	4.0	0	8.0	8.5	9.0	-.5	39.0
07:00-08:00	7.8	7.8	0	11.5	31.3	31.3	-.5	73.2
08:00-09:00	12.4	12.4	0	18.7	37.2	38.1	-1.4	84.5
09:00-10:00	19.4	19.6	-.1	22.4	39.5	39.2	-1.0	83.3
10:00-11:00	16.4	16.3	-.1	19.3	36.1	35.4	-.3	69.0
11:00-12:00	11.6	11.6	0	12.7	19.5	19.2	0	56.9
MIT TOTALS:	71.7	71.7	0	92.7	172.1	172.1	0	407.0

	DEPARTURES			9	DEPARTURES			4L
TIME INTERVAL	9 FLOW	9 DMND	9 DIFF	ARR+DEP FLOW	4L FLOW	4L DMND	4L DIFF	ARR+DEP FLOW
06:00-07:00	21.1	22.1	-1.1	21.1	5.5	6.5	-1.0	10.0
07:00-08:00	25.8	28.3	-3.5	25.8	12.3	12.7	-1.5	35.8
08:00-09:00	27.1	24.0	-.4	27.1	13.8	15.4	-3.0	38.7
09:00-10:00	23.6	23.6	-.3	23.6	17.1	16.4	-2.3	37.2
10:00-11:00	11.5	11.7	-.5	11.5	18.4	18.4	-2.3	38.1
11:00-12:00	16.5	16.0	0	16.5	19.7	17.4	0	27.5
MIT TOTALS:	126.8	126.8	0	126.8	87.1	87.1	0	187.6

	DEPARTURES			4R	DEPARTURES			MIT
TIME INTERVAL	4R FLOW	4R DMND	4R DIFF	ARR+DEP FLOW	MIT FLOW	MIT DMND	MIT DIFF	ARR+DEP FLOW
06:00-07:00	4.0	4.0	0	8.0	30.6	32.7	-2.0	39.0
07:00-08:00	3.7	3.8	-.1	11.5	41.9	44.8	-5.0	73.2
08:00-09:00	6.3	6.2	0	18.7	47.2	45.6	-3.4	84.5
09:00-10:00	3.0	3.0	0	22.4	43.7	42.9	-2.6	83.3
10:00-11:00	2.9	3.0	-.1	19.3	32.9	33.2	-2.9	69.0
11:00-12:00	1.1	1.0	0	12.7	37.3	34.5	0	56.9
MIT TOTALS:	21.0	21.0	0	92.7	234.9	234.9	0	407.0

This SIMMOD REPORT MODULE version 2.0.2 run began 10/25/1997 at approximately 17:06:25
This page of the TIME.SECTION report was finished at 17:07:45

AIRPORT AIR AND GROUND TRAVEL AND DELAY REPORT
MIT AIRPORT -- ALL RUNWAY A R R I V A L GROUND AND AIR TRAVEL AND DELAY TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 16:28:45 (0) mit/mit9000
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	MIT	OVERALL ARRIVAL TIMES (MIN)				AVERAGE ARRIVAL TIMES (MIN)							
TIME	ARRIVAL	TRAVEL		DELAY		TRAVEL				DELAY			
INTERVAL	FLOW	TOT	SDV	TOT	SDV	AIR	GND	GTE	TOT	AIR	GND	GTE	TOT
06:00-07:00	8.45	55.5	1.62	1.2	.31	2.16	4.40	0	6.57	.12	.03	0	.14
07:00-08:00	31.30	215.5	1.99	15.5	.99	2.47	4.42	0	6.88	.37	.12	.03	.52
08:00-09:00	37.25	262.2	2.04	34.0	1.32	2.41	4.63	0	7.04	.69	.22	11.01	11.92
09:00-10:00	39.55	289.2	2.10	23.5	.98	2.19	5.12	0	7.31	.31	.28	4.98	5.57
10:00-11:00	36.10	256.4	1.90	24.1	1.23	2.23	4.88	0	7.10	.37	.30	6.86	7.53
11:00-12:00	19.50	146.3	1.98	25.9	2.75	2.07	5.43	0	7.50	.57	.76	3.66	4.99
MIT TOTALS:	172.15	1225.1	2.01	124.2	1.43	2.28	4.84	0	7.12	.44	.28	5.38	6.10

MIT	OVERALL DEPARTURE TIMES (MIN)					AVERAGE DEPARTURE TIMES (MIN)								
TIME	DEPARTURE	TRAVEL		DELAY		TRAVEL				DELAY				
INTERVAL	FLOW	TOT	SDV	TOT	SDV	AIR	GND	GTE	TOT	AIR	GND	GTE	QUE	TOT
06:00-07:00	30.60	192.4	1.26	74.6	3.33	1.64	4.64	.10	6.39	0	1.19	0	1.25	2.44
07:00-08:00	41.85	253.9	.96	218.4	3.88	1.77	4.29	6.90	12.97	0	3.01	.01	2.21	5.23
08:00-09:00	47.25	302.5	1.19	293.2	4.06	1.78	4.62	10.78	17.18	0	2.72	.25	3.48	6.46
09:00-10:00	43.70	276.1	.97	234.3	3.74	1.91	4.41	40.93	47.25	0	1.57	.98	3.79	6.34
10:00-11:00	32.90	200.3	1.00	140.8	4.17	1.91	4.18	53.64	59.72	0	.76	.90	3.52	5.18
11:00-12:00	37.35	231.3	1.02	164.9	3.60	1.96	4.24	60.78	66.97	0	1.07	.98	3.34	5.39
MIT TOTALS:	234.90	1462.6	1.08	1126.2	3.99	1.83	4.40	28.20	34.43	0	1.81	.52	2.99	5.31

This SIMMOD REPORT MODULE version 2.0.2 run began 10/25/1997 at approximately 17:06:25
This page of the APT.PAGE report was finished at 17:08:05

RUNWAY AIR AND GROUND TRAVEL AND DELAY REPORT
MIT AIRPORT -- RUNWAY 4R 4L A R R I V A L GROUND AND AIR TRAVEL AND DELAY TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 16:28:45 (0) mit/mit9000
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	4R	OVERALL ARRIVAL TIMES (MIN)				AVERAGE ARRIVAL TIMES (MIN)							
TIME	ARRIVAL	TRAVEL		DELAY		TRAVEL				DELAY			
INTERVAL	FLOW	TOT	SDV	TOT	SDV	AIR	GND	GTE	TOT	AIR	GND	GTE	TOT
06:00-07:00	4.00	29.3	.93	0	.24	1.63	5.70	0	7.33	.07	.05	0	.11
07:00-08:00	7.80	66.4	1.81	4.2	1.52	1.63	6.89	0	8.52	.08	.46	0	.54
08:00-09:00	12.40	104.8	1.81	8.5	.84	1.63	6.82	0	8.45	.14	.55	.01	.70
09:00-10:00	19.45	167.6	1.70	14.6	1.20	1.63	6.98	0	8.62	.20	.55	.42	1.17
10:00-11:00	16.40	131.9	1.64	14.0	1.62	1.63	6.41	0	8.04	.21	.64	.71	1.56
11:00-12:00	11.65	97.4	1.67	15.9	2.76	1.63	6.73	0	8.36	.31	1.05	4.17	5.54
4R TOTALS:	71.70	597.5	1.71	57.7	1.64	1.63	6.70	0	8.33	.19	.62	.96	1.76

	4L	OVERALL ARRIVAL TIMES (MIN)				AVERAGE ARRIVAL TIMES (MIN)							
TIME	ARRIVAL	TRAVEL		DELAY		TRAVEL				DELAY			
INTERVAL	FLOW	TOT	SDV	TOT	SDV	AIR	GND	GTE	TOT	AIR	GND	GTE	TOT
06:00-07:00	4.45	26.2	1.79	.7	.36	2.64	3.24	0	5.88	.16	.01	0	.17
07:00-08:00	23.50	149.1	1.74	11.3	.74	2.74	3.60	0	6.34	.47	.01	.03	.52
08:00-09:00	24.85	157.4	1.77	25.5	1.49	2.79	3.54	0	6.34	.97	.05	16.49	17.52
09:00-10:00	20.10	121.6	1.63	8.9	.66	2.73	3.31	0	6.05	.42	.02	9.38	9.82
10:00-11:00	19.70	124.5	1.74	10.1	.74	2.72	3.60	0	6.32	.50	.02	11.99	12.50
11:00-12:00	7.85	48.9	1.68	10.0	2.74	2.72	3.51	0	6.23	.95	.33	2.90	4.18
4L TOTALS:	100.45	627.6	1.73	66.5	1.25	2.74	3.51	0	6.25	.61	.05	8.54	9.20

This SIMMOD REPORT MODULE version 2.0.2 run began 10/25/1997 at approximately 17:06:25
This page of the RWY.PAGE report was finished at 17:08:25

RUNWAY AIR AND GROUND TRAVEL AND DELAY REPORT
MIT AIRPORT -- RUNWAY 4R 4L 9 D E P A R T U R E GROUND AND AIR TRAVEL AND DELAY TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 16:28:45 (0) mit/mit9000
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME INTERVAL	4R DEPARTURE FLOW	OVERALL DEPARTURE TIMES (MIN) TRAVEL TOT	OVERALL TRAVEL SDV	OVERALL DELAY TOT	OVERALL DELAY SDV	AVERAGE DEPARTURE TIMES (MIN) TRAVEL AIR	TRAVEL GND	TRAVEL GTE	TRAVEL TOT	DELAY AIR	DELAY GND	DELAY GTE	DELAY QUE	DELAY TOT
06:00-07:00	4.00	30.3	.66	1.4	.69	1.33	6.23	0	7.56	0	.03	0	.32	.35
07:00-08:00	3.70	24.8	.60	5.1	3.84	1.33	5.38	16.37	23.08	0	1.13	0	.24	1.38
08:00-09:00	6.35	47.3	1.19	34.7	4.53	1.33	6.12	16.75	24.20	0	2.92	0	2.55	5.47
09:00-10:00	2.95	20.3	.31	6.7	2.96	1.33	5.55	20.77	27.66	0	1.53	0	.73	2.26
10:00-11:00	2.90	19.9	.36	8.2	4.95	1.33	5.53	71.05	77.91	0	2.15	0	.68	2.83
11:00-12:00	1.10	7.2	.43	6.0	7.47	1.33	5.26	6.92	13.51	0	4.69	.42	.77	5.88
4R TOTALS:	21.00	149.9	.87	62.1	4.53	1.33	5.80	21.04	28.18	0	1.85	.02	1.11	2.98

TIME INTERVAL	4L DEPARTURE FLOW	OVERALL DEPARTURE TIMES (MIN) TRAVEL TOT	OVERALL TRAVEL SDV	OVERALL DELAY TOT	OVERALL DELAY SDV	AVERAGE DEPARTURE TIMES (MIN) TRAVEL AIR	TRAVEL GND	TRAVEL GTE	TRAVEL TOT	DELAY AIR	DELAY GND	DELAY GTE	DELAY QUE	DELAY TOT
06:00-07:00	5.50	33.3	1.43	1.2	.43	1.78	4.27	0	6.05	0	0	0	.21	.22
07:00-08:00	12.30	78.9	.86	32.9	2.00	2.13	4.29	12.11	18.53	0	.09	.01	2.58	2.68
08:00-09:00	13.80	84.1	.64	103.8	3.98	2.22	3.88	19.27	25.36	0	.29	.45	7.24	7.97
09:00-10:00	17.10	105.7	.66	112.7	3.07	2.35	3.84	40.27	46.46	0	.19	2.14	6.40	8.73
10:00-11:00	18.45	112.4	.96	109.1	2.95	2.16	3.93	46.22	52.31	0	.28	1.59	5.64	7.50
11:00-12:00	19.70	123.1	.80	99.8	2.84	2.24	4.01	53.45	59.70	0	.13	1.82	4.94	6.88
4L TOTALS:	87.10	538.8	.86	459.4	3.53	2.19	3.99	34.55	40.73	0	.18	1.24	5.09	6.52

TIME INTERVAL	9 DEPARTURE FLOW	OVERALL DEPARTURE TIMES (MIN) TRAVEL TOT	OVERALL TRAVEL SDV	OVERALL DELAY TOT	OVERALL DELAY SDV	AVERAGE DEPARTURE TIMES (MIN) TRAVEL AIR	TRAVEL GND	TRAVEL GTE	TRAVEL TOT	DELAY AIR	DELAY GND	DELAY GTE	DELAY QUE	DELAY TOT
06:00-07:00	21.10	128.9	1.16	72.0	3.60	1.67	4.44	.15	6.25	0	1.72	0	1.70	3.41
07:00-08:00	25.85	150.1	.96	180.5	3.47	1.67	4.14	3.07	8.88	0	4.67	0	2.31	6.99
08:00-09:00	27.10	171.1	1.26	154.6	3.82	1.67	4.65	5.06	11.37	0	3.92	.21	1.79	5.92
09:00-10:00	23.65	150.1	1.17	115.0	3.92	1.67	4.68	43.92	50.26	0	2.58	.26	2.28	5.12
10:00-11:00	11.55	68.0	1.08	23.5	4.43	1.67	4.22	61.12	67.01	0	1.18	.03	.85	2.06
11:00-12:00	16.55	100.9	1.25	59.2	3.83	1.67	4.43	73.08	79.18	0	1.96	.02	1.61	3.59
9 TOTALS:	126.80	773.9	1.17	604.7	4.10	1.67	4.44	25.03	31.13	0	2.92	.10	1.85	4.87

This SIMMOD REPORT MODULE version 2.0.2 run began 10/25/1997 at approximately 17:06:25
This page of the RWY.PAGE report was finished at 17:08:25

ITERATION AIR AND GROUND DELAY
AVERAGE, MIN, AND MAX AIRCRAFT GROUND AND AIR DELAY TIME (MINS) VERSUS ITERATION
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 16:28:45 (0) mit/mit9000
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

ITERATION: 1 FILE: C:\Lti\data\mit\mit9000\inprep.mit

	ARRIVALS						DEPARTURES					
TIME	AIR			GND			AIR			GND		
INTERVAL	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
06:00-07:00	.06	0	.48	.00	0	.02	0	0	0	2.18	0	9.13
07:00-08:00	.20	0	1.53	.03	0	.37	0	0	0	6.13	0	18.05
08:00-09:00	.30	0	2.27	.11	0	.82	0	0	0	5.90	0	13.63
09:00-10:00	.09	0	.88	.23	0	1.50	0	0	0	4.20	0	11.73
10:00-11:00	.31	0	2.17	.24	0	2.32	0	0	0	4.36	0	28.60
11:00-12:00	.35	0	3.17	.83	0	3.32	0	0	0	4.44	0	10.30
TOTALS:	.23	0	3.17	.22	0	3.32	0	0	0	4.66	0	28.60

ITERATION: 2 FILE: C:\Lti\data\mit\mit9000\inprep.mit

06:00-07:00	.10	0	.93	.03	0	.23	0	0	0	2.62	0	13.02
07:00-08:00	.45	0	2.02	.12	0	1.95	0	0	0	4.62	0	13.23
08:00-09:00	1.01	0	5.93	.15	0	1.43	0	0	0	5.92	0	13.45
09:00-10:00	.32	0	1.67	.15	0	.92	0	0	0	5.79	0	19.40
10:00-11:00	.36	0	2.73	.69	0	18.02	0	0	0	4.57	0	18.80
11:00-12:00	.46	0	1.73	.26	0	1.60	0	0	0	5.94	0	25.23
TOTALS:	.50	0	5.93	.26	0	18.02	0	0	0	5.00	0	25.23

TOTAL DELAYS FOR ALL ITERATIONS

06:00-07:00	.12	0	1.97	.03	0	.58	0	0	0	2.44	0	18.00
07:00-08:00	.37	0	3.58	.12	0	18.08	0	0	0	5.22	0	21.30
08:00-09:00	.69	0	5.93	.22	0	18.07	0	0	0	6.21	0	26.73
09:00-10:00	.31	0	2.90	.28	0	17.98	0	0	0	5.36	0	22.63
10:00-11:00	.37	0	3.85	.30	0	18.78	0	0	0	4.28	0	33.78
11:00-12:00	.57	0	4.72	.76	0	19.82	0	0	0	4.42	0	25.23
TOTALS:	.44	0	5.93	.28	0	19.82	0	0	0	4.79	0	33.78

This SIMMOD REPORT MODULE version 2.0.2 run began 10/25/1997 at approximately 17:06:25
This page of the ITER.SECTION report was finished at 17:08:46

AVERAGE ARR TRAVEL AND DELAY REPORT
MIT AIRPORT -- AVERAGE A R R I V A L AIRCRAFT TRAVEL AND DELAY TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 16:28:45 (0) mit/mit9000
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME	ARRIVAL	TRAVEL TIMES (MIN)			DELAY TIMES (MIN)			# OF FLIGHTS WITH DELAY (MIN)						
INTERVAL	FLOW	TOT	SDV	AVE	TOT	SDV	AVE	< 5	5-10	10-15	15-30	30-45	45-60	> 60
06:00-07:00	8.45	55.5	1.62	6.57	1.2	.31	.14	8.5	0	0	0	0	0	0
07:00-08:00	31.30	215.5	1.99	6.88	15.5	.99	.49	31.2	0	0	.1	0	0	0
08:00-09:00	37.25	262.2	2.04	7.04	34.0	1.32	.91	36.8	.4	0	.1	0	0	0
09:00-10:00	39.55	289.2	2.10	7.31	23.5	.98	.59	39.5	.1	0	.1	0	0	0
10:00-11:00	36.10	256.4	1.90	7.10	24.1	1.23	.67	36.0	0	0	.1	0	0	0
11:00-12:00	19.50	146.3	1.98	7.50	25.9	2.75	1.33	19.1	0	.1	.3	0	0	0
00:00-12:00	172.15	1225.1	2.01	7.12	124.2	1.43	.72	171.1	.4	.1	.6	0	0	0

MIT AIRPORT -- A R R I V A L AIR/GND DELAY BIN TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 16:28:45 (0) mit/mit9000
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME	ARRIVAL	# OF FLIGHTS WITH AIR DELAY (MIN)							# OF FLIGHTS WITH GROUND DELAY (MIN)						
INTERVAL	FLOW	< 5	5-10	10-15	15-30	30-45	45-60	> 60	< 5	5-10	10-15	15-30	30-45	45-60	> 60
06:00-07:00	8.45	8.5	0	0	0	0	0	0	8.5	0	0	0	0	0	0
07:00-08:00	31.30	31.3	0	0	0	0	0	0	31.2	0	0	.1	0	0	0
08:00-09:00	37.25	37.0	.3	0	0	0	0	0	37.1	.1	0	.1	0	0	0
09:00-10:00	39.55	39.5	0	0	0	0	0	0	39.5	.1	0	.1	0	0	0
10:00-11:00	36.10	36.1	0	0	0	0	0	0	36.0	0	0	.1	0	0	0
11:00-12:00	19.50	19.5	0	0	0	0	0	0	19.1	0	.1	.3	0	0	0
00:00-12:00	172.15	171.8	.3	0	0	0	0	0	171.4	.1	.1	.6	0	0	0

This SIMMOD REPORT MODULE version 2.0.2 run began 10/25/1997 at approximately 17:06:25
This page of the ARRIVAL.DELAY.INTERVAL.REPORT report was finished at 17:09:26

AVERAGE DEP TRAVEL AND DELAY REPORT
MIT AIRPORT -- AVERAGE D E P A R T U R E AIRCRAFT TRAVEL AND DELAY TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 16:28:45 (0) mit/mit9000
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME	DEPARTURE	TRAVEL TIMES (MIN)			DELAY TIMES (MIN)			# OF FLIGHTS WITH DELAY (MIN)						
INTERVAL	FLOW	TOT	SDV	AVE	TOT	SDV	AVE	< 5	5-10	10-15	15-30	30-45	45-60	> 60
06:00-07:00	30.60	192.4	1.26	6.29	74.6	3.33	2.44	25.0	4.0	1.6	.1	0	0	0
07:00-08:00	41.85	253.9	.96	6.07	218.4	3.88	5.22	21.6	14.8	5.0	.5	0	0	0
08:00-09:00	47.25	302.5	1.19	6.40	293.2	4.06	6.21	19.1	20.3	6.4	1.4	0	0	0
09:00-10:00	43.70	276.1	.97	6.32	234.3	3.74	5.36	21.6	17.6	3.6	.8	0	0	0
10:00-11:00	32.90	200.3	1.00	6.09	140.8	4.17	4.28	21.1	9.1	2.0	.6	.1	0	0
11:00-12:00	37.35	231.3	1.02	6.19	164.9	3.60	4.42	24.2	11.0	1.3	.8	0	0	0
00:00-12:00	234.90	1462.6	1.08	6.23	1126.2	3.99	4.79	133.9	76.9	19.9	4.1	.1	0	0

MIT AIRPORT -- D E P A R T U R E AIR/GND DELAY BIN TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 16:28:45 (0) mit/mit9000
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME	DEPARTURE	# OF FLIGHTS WITH AIR DELAY (MIN)							# OF FLIGHTS WITH GROUND DELAY (MIN)						
INTERVAL	FLOW	< 5	5-10	10-15	15-30	30-45	45-60	> 60	< 5	5-10	10-15	15-30	30-45	45-60	> 60
06:00-07:00	30.60	30.6	0	0	0	0	0	0	25.0	4.0	1.6	.1	0	0	0
07:00-08:00	41.85	41.9	0	0	0	0	0	0	21.6	14.8	5.0	.5	0	0	0
08:00-09:00	47.25	47.2	0	0	0	0	0	0	19.1	20.3	6.4	1.4	0	0	0
09:00-10:00	43.70	43.7	0	0	0	0	0	0	21.6	17.6	3.6	.8	0	0	0
10:00-11:00	32.90	32.9	0	0	0	0	0	0	21.1	9.1	2.0	.6	.1	0	0
11:00-12:00	37.35	37.3	0	0	0	0	0	0	24.2	11.0	1.3	.8	0	0	0
00:00-12:00	234.90	234.9	0	0	0	0	0	0	133.9	76.9	19.9	4.1	.1	0	0

This SIMMOD REPORT MODULE version 2.0.2 run began 10/25/1997 at approximately 17:06:25
This page of the ARRIVAL.DELAY.INTERVAL.REPORT report was finished at 17:09:26

DEPARTURE QUEUE LENGTH SUMMARY REPORT
MIT AIRPORT -- DEPARTURE QUEUE LENGTH SUMMARY
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 16:28:45 (0) mit/mit9000
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME	MIT QUEUE QUEUE4L_MIT					MIT QUEUE QUEUE4R_MIT					MIT QUEUE QUEUE92_MIT				
INTERVAL	IN	OUT	AVE	STD	MAX	IN	OUT	AVE	STD	MAX	IN	OUT	AVE	STD	MAX
06:00-07:00	6.5	5.5	.03	.18	2	4.0	4.0	.02	.12	1	5.8	5.7	.16	.37	2
07:00-08:00	13.1	12.4	.59	.75	3	3.7	3.7	.01	.09	1	3.1	3.0	.13	.36	2
08:00-09:00	14.6	13.8	1.82	.81	4	6.3	6.3	.27	.57	3	4.2	4.2	.14	.36	2
09:00-10:00	17.0	17.1	1.74	.75	3	3.0	3.0	.04	.17	2	7.7	7.7	.27	.47	2
10:00-11:00	17.9	18.2	1.69	.83	3	3.0	2.9	.03	.17	2	2.0	2.0	.02	.11	1
11:00-12:00	17.7	19.6	1.52	.87	3	1.0	1.1	.01	.05	2	3.1	3.2	.08	.26	2
00:00-12:00	87.1	87.1			4	21.0	21.0			3	25.9	25.9			2

TIME	MIT QUEUE QUEUE9_MIT					MIT AIRPORT TOTALS				
INTERVAL	IN	OUT	AVE	STD	MAX	IN	OUT	AVE	STD	MAX
06:00-07:00	16.0	15.4	.46	.53	2	32.3	30.7	.67	.73	4
07:00-08:00	23.3	23.0	.87	.52	3	43.1	42.2	1.60	.94	5
08:00-09:00	21.8	22.6	.65	.57	3	47.0	47.0	2.87	1.25	8
09:00-10:00	15.8	15.9	.63	.49	2	43.5	43.7	2.68	1.04	7
10:00-11:00	9.7	9.6	.14	.34	1	32.5	32.7	1.89	.93	6
11:00-12:00	13.2	13.3	.37	.48	2	35.1	37.2	1.98	1.11	6
00:00-12:00	100.9	100.9			3	234.9	234.9			8

This SIMMOD REPORT MODULE version 2.0.2 run began 10/25/1997 at approximately 17:06:25
This page of the QUE.SECTION report was finished at 17:09:57

8. Appendix 3: Kilo blocked simulation reports

AVERAGE RUNWAY FLOWS, DEMANDS, AND DIFFERENCES REPORT
MIT AIRPORT -- AVERAGE RUNWAY A R R I V A L FLOWS, DEMANDS, AND CUMULATIVE DIFFERENCES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 18:56:37 (0) mit/mit9001
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	A R R I V A L S			9	A R R I V A L S			4L
TIME INTERVAL	9 FLOW	9 DMND	9 DIFF	ARR+DEP FLOW	4L FLOW	4L DMND	4L DIFF	ARR+DEP FLOW
06:00-07:00	0	0	0	21.2	4.5	5.0	-.5	10.3
07:00-08:00	0	0	0	25.9	23.5	23.5	-.5	35.8
08:00-09:00	0	0	0	26.9	24.8	25.6	-1.4	39.1
09:00-10:00	0	0	0	23.3	20.1	19.6	-.9	37.0
10:00-11:00	0	0	0	12.2	20.0	19.4	-.3	39.0
11:00-12:00	0	0	0	15.5	7.9	7.7	0	27.9
MIT TOTALS:	0	0	0	126.0	100.8	100.8	0	189.1

	A R R I V A L S			4R	A R R I V A L S			MIT
TIME INTERVAL	4R FLOW	4R DMND	4R DIFF	ARR+DEP FLOW	MIT FLOW	MIT DMND	MIT DIFF	ARR+DEP FLOW
06:00-07:00	4.0	4.0	0	8.0	8.5	9.0	-.5	39.5
07:00-08:00	7.8	7.8	0	11.4	31.3	31.3	-.5	73.2
08:00-09:00	12.4	12.4	0	18.5	37.2	38.0	-1.4	84.6
09:00-10:00	19.4	19.6	-.1	22.6	39.5	39.2	-1.0	83.0
10:00-11:00	16.3	16.2	-.1	19.2	36.3	35.6	-.3	70.4
11:00-12:00	11.1	11.1	0	12.2	19.0	18.7	0	55.5
MIT TOTALS:	71.1	71.1	0	92.1	171.8	171.8	0	407.3

This SIMMOD REPORT MODULE version 2.0.2 run began 10/26/1997 at approximately 15:13:16
This page of the TIME.SECTION report was finished at 15:14:32

AVERAGE RUNWAY FLOWS, DEMANDS, AND DIFFERENCES REPORT
MIT AIRPORT -- AVERAGE RUNWAY D E P A R T U R E FLOWS, DEMANDS, AND CUMULATIVE DIFFERENCES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 18:56:37 (0) mit/mit9001
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	D E P A R T U R E S			9	D E P A R T U R E S			4L
TIME INTERVAL	9 FLOW	9 DMND	9 DIFF	ARR+DEP FLOW	4L FLOW	4L DMND	4L DIFF	ARR+DEP FLOW
06:00-07:00	21.2	22.1	-1.0	21.2	5.8	6.7	-.9	10.3
07:00-08:00	25.9	28.1	-3.2	25.9	12.3	12.7	-1.3	35.8
08:00-09:00	26.9	24.1	-.4	26.9	14.3	16.0	-3.0	39.1
09:00-10:00	23.3	23.6	-.7	23.3	16.9	16.5	-2.5	37.0
10:00-11:00	12.2	11.7	-.1	12.2	19.0	18.5	-2.1	39.0
11:00-12:00	15.5	15.3	0	15.5	19.9	17.9	0	27.9
MIT TOTALS:	126.0	126.0	0	126.0	88.4	88.4	0	189.1

	D E P A R T U R E S			4R	D E P A R T U R E S			MIT
TIME INTERVAL	4R FLOW	4R DMND	4R DIFF	ARR+DEP FLOW	MIT FLOW	MIT DMND	MIT DIFF	ARR+DEP FLOW
06:00-07:00	4.0	4.0	0	8.0	31.0	32.9	-1.9	39.5
07:00-08:00	3.6	3.8	-.1	11.4	41.9	44.6	-4.7	73.2
08:00-09:00	6.2	6.2	-.3	18.5	47.4	46.3	-3.6	84.6
09:00-10:00	3.2	3.0	0	22.6	43.4	43.0	-3.2	83.0
10:00-11:00	3.0	3.0	-.1	19.2	34.1	33.2	-2.3	70.4
11:00-12:00	1.1	1.0	0	12.2	36.5	34.2	0	55.5
MIT TOTALS:	21.0	21.0	0	92.1	235.4	235.4	0	407.3

This SIMMOD REPORT MODULE version 2.0.2 run began 10/26/1997 at approximately 15:13:16
This page of the TIME.SECTION report was finished at 15:14:32

AIRPORT AIR AND GROUND TRAVEL AND DELAY REPORT
MIT AIRPORT -- ALL RUNWAY A R R I V A L A N D D E P A R T U R E GROUND AND AIR TRAVEL AND DELAY TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 18:56:37 (0) mit/mit9001
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	MIT	OVERALL ARRIVAL TIMES (MIN)				AVERAGE ARRIVAL TIMES (MIN)							
TIME	ARRIVAL	TRAVEL		DELAY		TRAVEL				DELAY			
INTERVAL	FLOW	TOT	SDV	TOT	SDV	AIR	GND	GTE	TOT	AIR	GND	GTE	TOT
06:00-07:00	8.45	54.7	1.46	1.2	.31	2.16	4.31	0	6.48	.12	.03	0	.14
07:00-08:00	31.30	219.0	2.06	14.7	.68	2.47	4.53	0	7.00	.37	.10	.08	.55
08:00-09:00	37.20	262.8	1.97	33.5	1.32	2.40	4.66	0	7.06	.70	.20	10.20	11.10
09:00-10:00	39.55	287.2	2.07	23.6	.99	2.19	5.07	0	7.26	.31	.28	4.80	5.40
10:00-11:00	36.30	261.4	1.98	22.6	.81	2.23	4.97	0	7.20	.37	.25	6.83	7.45
11:00-12:00	19.05	143.7	1.97	18.2	1.27	2.08	5.46	0	7.55	.59	.37	3.52	4.48
MIT TOTALS:	171.85	1228.8	2.00	113.7	1.03	2.28	4.87	0	7.15	.44	.22	5.16	5.82

	MIT	OVERALL DEPARTURE TIMES (MIN)				AVERAGE DEPARTURE TIMES (MIN)								
TIME	DEPARTURE	TRAVEL		DELAY		TRAVEL				DELAY				
INTERVAL	FLOW	TOT	SDV	TOT	SDV	AIR	GND	GTE	TOT	AIR	GND	GTE	QUE	TOT
06:00-07:00	31.05	195.8	1.25	75.4	3.29	1.64	4.67	.11	6.41	0	1.20	0	1.22	2.43
07:00-08:00	41.85	252.9	.97	209.9	3.75	1.78	4.27	6.92	12.97	0	2.88	.01	2.14	5.02
08:00-09:00	47.40	303.9	1.19	284.5	3.87	1.79	4.62	10.72	17.13	0	2.55	.18	3.45	6.18
09:00-10:00	43.40	273.9	.98	251.1	3.96	1.91	4.40	40.14	46.45	0	1.95	.98	3.84	6.77
10:00-11:00	34.15	208.8	1.02	142.8	3.90	1.91	4.21	52.50	58.61	0	.73	1.19	3.46	5.37
11:00-12:00	36.50	227.1	1.03	153.9	3.31	1.96	4.27	58.77	64.99	0	.94	.92	3.27	5.14
MIT TOTALS:	235.45	1467.9	1.08	1117.6	3.89	1.83	4.40	27.53	33.76	0	1.79	.53	2.95	5.28

This SIMMOD REPORT MODULE version 2.0.2 run began 10/26/1997 at approximately 15:13:16
This page of the APT.PAGE report was finished at 15:14:51

RUNWAY AIR AND GROUND TRAVEL AND DELAY REPORT
MIT AIRPORT -- RUNWAY 4R A R R I V A L GROUND AND AIR TRAVEL AND DELAY TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 18:56:37 (0) mit/mit9001
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME INTERVAL	4R ARRIVAL FLOW	OVERALL ARRIVAL TIMES (MIN) TRAVEL TOT	TRAVEL SDV	DELAY TOT	DELAY SDV	AVERAGE ARRIVAL TIMES (MIN) TRAVEL AIR	TRAVEL GND	TRAVEL GTE	TRAVEL TOT	DELAY AIR	DELAY GND	DELAY GTE	DELAY TOT
06:00-07:00	4.00	29.5	.88	0	.25	1.63	5.73	0	7.36	.07	.05	0	.11
07:00-08:00	7.80	67.7	1.77	3.3	.49	1.63	7.04	0	8.68	.08	.35	0	.43
08:00-09:00	12.40	104.8	1.77	8.9	1.38	1.63	6.82	0	8.45	.14	.59	.04	.76
09:00-10:00	19.45	165.4	1.68	14.7	1.22	1.63	6.87	0	8.50	.20	.55	.27	1.02
10:00-11:00	16.30	133.6	1.65	12.2	.87	1.63	6.57	0	8.20	.21	.54	1.04	1.79
11:00-12:00	11.15	93.6	1.61	10.4	1.28	1.63	6.76	0	8.39	.31	.61	3.90	4.83
4R TOTALS:	71.10	594.5	1.68	49.9	1.11	1.63	6.73	0	8.36	.19	.51	.93	1.63

TIME INTERVAL	4L ARRIVAL FLOW	OVERALL ARRIVAL TIMES (MIN) TRAVEL TOT	TRAVEL SDV	DELAY TOT	DELAY SDV	AVERAGE ARRIVAL TIMES (MIN) TRAVEL AIR	TRAVEL GND	TRAVEL GTE	TRAVEL TOT	DELAY AIR	DELAY GND	DELAY GTE	DELAY TOT
06:00-07:00	4.45	25.3	1.41	.7	.36	2.64	3.04	0	5.68	.16	.01	0	.17
07:00-08:00	23.50	151.4	1.84	11.4	.74	2.74	3.70	0	6.44	.47	.02	.11	.60
08:00-09:00	24.80	158.0	1.68	24.5	1.29	2.79	3.58	0	6.37	.98	.01	15.28	16.27
09:00-10:00	20.10	121.8	1.65	8.9	.66	2.73	3.32	0	6.06	.42	.02	9.19	9.63
10:00-11:00	20.00	127.7	1.86	10.4	.75	2.72	3.66	0	6.39	.50	.02	11.55	12.07
11:00-12:00	7.90	50.2	1.80	7.9	1.26	2.72	3.63	0	6.35	.97	.03	2.99	3.98
4L TOTALS:	100.75	634.3	1.76	63.8	.96	2.74	3.55	0	6.30	.62	.02	8.15	8.78

This SIMMOD REPORT MODULE version 2.0.2 run began 10/26/1997 at approximately 15:13:16
This page of the RWY.PAGE report was finished at 15:15:09

RUNWAY AIR AND GROUND TRAVEL AND DELAY REPORT
MIT AIRPORT -- RUNWAY 4R 4L 9 D E P A R T U R E GROUND AND AIR TRAVEL AND DELAY TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 18:56:37 (0) mit/mit9001
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	4R	OVERALL DEPARTURE TIMES (MIN)				AVERAGE DEPARTURE TIMES (MIN)								
TIME	DEPARTURE	T R A V E L		D E L A Y		T R A V E L				D E L A Y				
INTERVAL	FLOW	TOT	SDV	TOT	SDV	AIR	GND	GTE	TOT	AIR	GND	GTE	QUE	TOT
06:00-07:00	4.00	30.3	.68	2.9	2.29	1.33	6.23	0	7.57	0	.42	0	.31	.73
07:00-08:00	3.65	24.5	.58	6.3	4.65	1.33	5.38	16.58	23.30	0	1.43	.01	.30	1.73
08:00-09:00	6.15	46.1	1.25	25.4	3.57	1.33	6.17	16.80	24.31	0	1.87	0	2.26	4.13
09:00-10:00	3.20	22.2	.40	11.9	4.82	1.33	5.60	20.55	27.48	0	2.46	0	1.24	3.71
10:00-11:00	2.95	20.5	.36	6.0	3.78	1.33	5.61	71.25	78.19	0	1.25	0	.80	2.04
11:00-12:00	1.05	6.7	.41	3.9	6.01	1.33	5.05	4.14	10.52	0	2.99	0	.76	3.75
4R TOTALS:	21.00	150.3	.89	56.5	4.20	1.33	5.82	21.15	28.31	0	1.58	0	1.11	2.69

	4L	OVERALL DEPARTURE TIMES (MIN)				AVERAGE DEPARTURE TIMES (MIN)								
TIME	DEPARTURE	T R A V E L		D E L A Y		T R A V E L				D E L A Y				
INTERVAL	FLOW	TOT	SDV	TOT	SDV	AIR	GND	GTE	TOT	AIR	GND	GTE	QUE	TOT
06:00-07:00	5.85	35.6	1.41	1.4	.42	1.75	4.34	0	6.09	0	.03	0	.21	.24
07:00-08:00	12.30	78.3	.89	32.2	1.97	2.14	4.23	12.45	18.82	0	.15	.01	2.48	2.63
08:00-09:00	14.35	88.4	.61	110.2	3.72	2.23	3.93	19.00	25.16	0	.55	.38	7.13	8.06
09:00-10:00	16.90	105.1	.63	118.2	2.85	2.35	3.87	38.46	44.68	0	.52	2.03	6.48	9.02
10:00-11:00	18.95	116.0	.99	112.5	2.83	2.15	3.97	44.86	50.98	0	.42	2.14	5.52	8.07
11:00-12:00	19.95	125.2	.79	99.4	2.88	2.22	4.06	49.48	55.76	0	.27	1.69	4.71	6.67
4L TOTALS:	88.40	549.2	.86	473.9	3.50	2.19	4.03	32.95	39.17	0	.36	1.29	5.00	6.65

	9	OVERALL DEPARTURE TIMES (MIN)				AVERAGE DEPARTURE TIMES (MIN)								
TIME	DEPARTURE	T R A V E L		D E L A Y		T R A V E L				D E L A Y				
INTERVAL	FLOW	TOT	SDV	TOT	SDV	AIR	GND	GTE	TOT	AIR	GND	GTE	QUE	TOT
06:00-07:00	21.20	129.9	1.14	71.1	3.48	1.67	4.46	.16	6.28	0	1.68	0	1.68	3.36
07:00-08:00	25.90	150.1	.96	171.3	3.32	1.67	4.13	2.93	8.73	0	4.38	.01	2.24	6.62
08:00-09:00	26.90	169.4	1.27	148.9	3.68	1.67	4.63	4.92	11.21	0	3.77	.10	1.76	5.64
09:00-10:00	23.30	146.6	1.19	121.0	4.26	1.67	4.62	44.05	50.34	0	2.92	.36	2.28	5.56
10:00-11:00	12.25	72.3	1.06	24.3	3.98	1.67	4.24	59.81	65.71	0	1.08	0	.91	1.99
11:00-12:00	15.50	95.2	1.29	50.6	3.32	1.67	4.47	74.42	80.56	0	1.67	0	1.59	3.27
9 TOTALS:	126.05	768.4	1.17	587.2	3.98	1.67	4.43	24.79	30.88	0	2.84	.09	1.82	4.75

This SIMMOD REPORT MODULE version 2.0.2 run began 10/26/1997 at approximately 15:13:16
This page of the RWY.PAGE report was finished at 15:15:09

ITERATION AIR AND GROUND DELAY
AVERAGE, MIN, AND MAX AIRCRAFT GROUND AND AIR DELAY TIME (MINS) VERSUS ITERATION
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 18:56:37 (0) mit/mit9001
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

ITERATION: 1 FILE: C:\Lti\data\mit\mit9001\inprep.mit

	ARRIVALS						DEPARTURES					
TIME	AIR			GND			AIR			GND		
INTERVAL	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
06:00-07:00	.06	0	.48	.00	0	.02	0	0	0	2.07	0	9.15
07:00-08:00	.20	0	1.53	.17	0	1.30	0	0	0	5.01	0	18.82
08:00-09:00	.30	0	2.27	.16	0	2.30	0	0	0	6.08	0	13.58
09:00-10:00	.09	0	.88	.20	0	1.43	0	0	0	4.21	0	9.60
10:00-11:00	.31	0	2.17	.20	0	3.57	0	0	0	4.34	0	18.02
11:00-12:00	.84	0	4.20	0	0	0	0	0	0	4.06	0	13.75
TOTALS:	.26	0	4.20	.16	0	3.57	0	0	0	4.49	0	18.82

ITERATION: 2 FILE: C:\Lti\data\mit\mit9001\inprep.mit

06:00-07:00	.10	0	.93	0	0	0	0	0	0	2.72	0	13.17
07:00-08:00	.45	0	2.02	.07	0	1.10	0	0	0	5.02	0	12.03
08:00-09:00	1.01	0	5.93	.24	0	2.78	0	0	0	6.65	0	14.57
09:00-10:00	.32	0	1.67	.24	0	1.97	0	0	0	5.88	0	15.25
10:00-11:00	.40	0	2.73	.27	0	2.78	0	0	0	3.53	0	9.52
11:00-12:00	.46	0	1.73	.50	0	2.88	0	0	0	4.18	0	22.75
TOTALS:	.51	0	5.93	.23	0	2.88	0	0	0	4.82	0	22.75

TOTAL DELAYS FOR ALL ITERATIONS

06:00-07:00	.12	0	1.97	.03	0	.67	0	0	0	2.43	0	18.15
07:00-08:00	.37	0	3.58	.10	0	2.03	0	0	0	5.01	0	19.55
08:00-09:00	.70	0	5.93	.20	0	18.12	0	0	0	6.00	0	19.90
09:00-10:00	.31	0	2.90	.28	0	17.97	0	0	0	5.79	0	20.62
10:00-11:00	.37	0	3.85	.25	0	3.87	0	0	0	4.18	0	28.07
11:00-12:00	.59	0	4.72	.37	0	4.63	0	0	0	4.22	0	22.75
TOTALS:	.44	0	5.93	.22	0	18.12	0	0	0	4.75	0	28.07

This SIMMOD REPORT MODULE version 2.0.2 run began 10/26/1997 at approximately 15:13:16
This page of the ITER.SECTION report was finished at 15:15:30

AVERAGE ARR TRAVEL AND DELAY REPORT
MIT AIRPORT -- AVERAGE A R R I V A L AIRCRAFT TRAVEL AND DELAY TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 18:56:37 (0) mit/mit9001
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME	ARRIVAL	TRAVEL TIMES (MIN)			DELAY TIMES (MIN)			# OF FLIGHTS WITH DELAY (MIN)						
INTERVAL	FLOW	TOT	SDV	AVE	TOT	SDV	AVE	< 5	5-10	10-15	15-30	30-45	45-60	> 60
06:00-07:00	8.45	54.7	1.46	6.48	1.2	.31	.14	8.5	0	0	0	0	0	0
07:00-08:00	31.30	219.0	2.06	7.00	14.7	.68	.47	31.3	0	0	0	0	0	0
08:00-09:00	37.20	262.8	1.97	7.06	33.5	1.32	.90	36.8	.3	0	.1	0	0	0
09:00-10:00	39.55	287.2	2.07	7.26	23.6	.99	.60	39.5	0	0	.1	0	0	0
10:00-11:00	36.30	261.4	1.98	7.20	22.6	.81	.62	36.3	0	0	0	0	0	0
11:00-12:00	19.05	143.7	1.97	7.55	18.2	1.27	.96	18.6	.4	0	0	0	0	0
00:00-12:00	171.85	1228.8	2.00	7.15	113.7	1.03	.66	171.1	.7	0	.1	0	0	0

MIT AIRPORT -- A R R I V A L AIR/GND DELAY BIN TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 18:56:37 (0) mit/mit9001
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME	ARRIVAL	# OF FLIGHTS WITH AIR DELAY (MIN)							# OF FLIGHTS WITH GROUND DELAY (MIN)						
INTERVAL	FLOW	< 5	5-10	10-15	15-30	30-45	45-60	> 60	< 5	5-10	10-15	15-30	30-45	45-60	> 60
06:00-07:00	8.45	8.5	0	0	0	0	0	0	8.5	0	0	0	0	0	0
07:00-08:00	31.30	31.3	0	0	0	0	0	0	31.3	0	0	0	0	0	0
08:00-09:00	37.20	36.9	.3	0	0	0	0	0	37.1	0	0	.1	0	0	0
09:00-10:00	39.55	39.5	0	0	0	0	0	0	39.5	0	0	.1	0	0	0
10:00-11:00	36.30	36.3	0	0	0	0	0	0	36.3	0	0	0	0	0	0
11:00-12:00	19.05	19.0	0	0	0	0	0	0	19.0	0	0	0	0	0	0
00:00-12:00	171.85	171.6	.3	0	0	0	0	0	171.7	0	0	.1	0	0	0

This SIMMOD REPORT MODULE version 2.0.2 run began 10/26/1997 at approximately 15:13:16
This page of the ARRIVAL.AIR.GND.DELAY.INTERVAL.REPORT report was finished at 15:15:49

AVERAGE DEP TRAVEL AND DELAY REPORT
MIT AIRPORT -- AVERAGE D E P A R T U R E AIRCRAFT TRAVEL AND DELAY TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 18:56:37 (0) mit/mit9001
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME	DEPARTURE	TRAVEL TIMES (MIN)			DELAY TIMES (MIN)			# OF FLIGHTS WITH DELAY (MIN)						
INTERVAL	FLOW	TOT	SDV	AVE	TOT	SDV	AVE	< 5	5-10	10-15	15-30	30-45	45-60	> 60
06:00-07:00	31.05	195.8	1.25	6.31	75.4	3.29	2.43	25.2	4.3	1.4	.1	0	0	0
07:00-08:00	41.85	252.9	.97	6.04	209.9	3.75	5.01	22.2	15.8	3.3	.5	0	0	0
08:00-09:00	47.40	303.9	1.19	6.41	284.5	3.87	6.00	19.2	21.5	5.7	1.1	0	0	0
09:00-10:00	43.40	273.9	.98	6.31	251.1	3.96	5.79	19.4	17.9	5.2	1.0	0	0	0
10:00-11:00	34.15	208.8	1.02	6.12	142.8	3.90	4.18	22.0	9.7	1.9	.6	0	0	0
11:00-12:00	36.50	227.1	1.03	6.22	153.9	3.31	4.22	24.4	10.0	1.7	.4	0	0	0
00:00-12:00	235.45	1467.9	1.08	6.23	1117.6	3.89	4.75	133.6	79.2	19.1	3.6	0	0	0

MIT AIRPORT -- D E P A R T U R E AIR/GND DELAY BIN TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 18:56:37 (0) mit/mit9001
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME	DEPARTURE	# OF FLIGHTS WITH AIR DELAY (MIN)							# OF FLIGHTS WITH GROUND DELAY (MIN)						
INTERVAL	FLOW	< 5	5-10	10-15	15-30	30-45	45-60	> 60	< 5	5-10	10-15	15-30	30-45	45-60	> 60
06:00-07:00	31.05	31.0	0	0	0	0	0	0	25.2	4.3	1.4	.1	0	0	0
07:00-08:00	41.85	41.9	0	0	0	0	0	0	22.2	15.8	3.3	.5	0	0	0
08:00-09:00	47.40	47.4	0	0	0	0	0	0	19.2	21.5	5.7	1.1	0	0	0
09:00-10:00	43.40	43.4	0	0	0	0	0	0	19.4	17.9	5.2	1.0	0	0	0
10:00-11:00	34.15	34.1	0	0	0	0	0	0	22.0	9.7	1.9	.6	0	0	0
11:00-12:00	36.50	36.5	0	0	0	0	0	0	24.4	10.0	1.7	.4	0	0	0
00:00-12:00	235.45	235.4	0	0	0	0	0	0	133.6	79.2	19.1	3.6	0	0	0

This SIMMOD REPORT MODULE version 2.0.2 run began 10/26/1997 at approximately 15:13:16
This page of the DEPARTURE.AIR.GND.DELAY.INTERVAL.REPORT report was finished at 15:16:07

DEPARTURE QUEUE LENGTH SUMMARY REPORT
MIT AIRPORT -- DEPARTURE QUEUE LENGTH SUMMARY
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/25/1997 AT 18:56:37 (0) mit/mit9001
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME	MIT QUEUE QUEUE4L_MIT					MIT QUEUE QUEUE4R_MIT					MIT QUEUE QUEUE92_MIT				
INTERVAL	IN	OUT	AVE	STD	MAX	IN	OUT	AVE	STD	MAX	IN	OUT	AVE	STD	MAX
06:00-07:00	6.7	5.9	.03	.18	2	4.0	4.0	.02	.12	1	5.8	5.7	.15	.36	2
07:00-08:00	12.9	12.3	.55	.72	3	3.6	3.6	.02	.10	1	3.0	3.1	.12	.33	2
08:00-09:00	15.5	14.6	1.84	.74	3	6.2	6.2	.23	.51	3	4.1	4.2	.12	.33	2
09:00-10:00	16.5	16.8	1.76	.71	3	3.2	3.2	.07	.25	3	7.7	7.7	.27	.47	2
10:00-11:00	18.8	18.8	1.74	.71	3	3.0	3.0	.04	.17	2	2.1	2.2	.03	.13	2
11:00-12:00	17.9	19.9	1.44	.78	3	1.1	1.1	.01	.08	1	3.0	3.0	.06	.23	2
00:00-12:00	88.4	88.4			3	21.0	21.0			3	25.8	25.8			2

TIME	MIT QUEUE QUEUE9_MIT					MIT AIRPORT TOTALS				
INTERVAL	IN	OUT	AVE	STD	MAX	IN	OUT	AVE	STD	MAX
06:00-07:00	16.0	15.5	.45	.54	3	32.5	31.1	.66	.73	4
07:00-08:00	23.5	23.3	.87	.55	3	43.1	42.4	1.55	.95	6
08:00-09:00	21.7	22.2	.64	.59	3	47.5	47.1	2.83	1.20	8
09:00-10:00	15.6	15.8	.62	.50	2	43.1	43.5	2.72	1.06	8
10:00-11:00	9.9	9.9	.15	.34	1	33.7	33.8	1.95	.83	5
11:00-12:00	12.5	12.6	.35	.46	2	34.4	36.5	1.87	1.01	5
00:00-12:00	100.2	100.2			3	235.4	235.4			8

This SIMMOD REPORT MODULE version 2.0.2 run began 10/26/1997 at approximately 15:13:16
This page of the QUE.SECTION report was finished at 15:16:36

9. Appendix 4: 4L blocked simulation reports

AVERAGE RUNWAY FLOWS, DEMANDS, AND DIFFERENCES REPORT
MIT AIRPORT -- AVERAGE RUNWAY A R R I V A L FLOWS, DEMANDS, AND CUMULATIVE DIFFERENCES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/26/1997 AT 15:17:01 (0) mit/mit9002
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	A R R I V A L S			9	A R R I V A L S			4R	A R R I V A L S			MIT
TIME INTERVAL	9 FLOW	9 DMND	9 DIFF	ARR+DEP FLOW	4R FLOW	4R DMND	4R DIFF	ARR+DEP FLOW	MIT FLOW	MIT DMND	MIT DIFF	ARR+DEP FLOW
06:00-07:00	0	0	0	24.3	8.9	9.2	-.4	12.8	8.9	9.2	-.4	37.2
07:00-08:00	0	0	0	28.2	31.1	31.3	-.5	34.6	31.1	31.3	-.5	62.8
08:00-09:00	0	0	0	28.6	34.5	35.1	-1.1	40.2	34.5	35.1	-1.1	68.8
09:00-10:00	0	0	0	29.1	33.7	34.8	-2.2	37.5	33.7	34.8	-2.2	66.6
10:00-11:00	0	0	0	29.3	28.1	26.9	-1.1	31.0	28.1	26.9	-1.1	60.4
11:00-12:00	0	0	0	28.0	15.6	14.4	0	16.5	15.6	14.4	0	44.5
MIT TOTALS:	0	0	0	168.6	151.8	151.8	0	172.8	151.8	151.8	0	341.4

AVERAGE RUNWAY FLOWS, DEMANDS, AND DIFFERENCES REPORT
MIT AIRPORT -- AVERAGE RUNWAY D E P A R T U R E FLOWS, DEMANDS, AND CUMULATIVE DIFFERENCES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/26/1997 AT 15:17:01 (0) mit/mit9002
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	D E P A R T U R E S			9	D E P A R T U R E S			4R	D E P A R T U R E S			MIT
TIME INTERVAL	9 FLOW	9 DMND	9 DIFF	ARR+DEP FLOW	4R FLOW	4R DMND	4R DIFF	ARR+DEP FLOW	MIT FLOW	MIT DMND	MIT DIFF	ARR+DEP FLOW
06:00-07:00	24.3	27.9	-3.5	24.3	4.0	4.0	0	12.8	28.3	31.8	-3.5	37.2
07:00-08:00	28.2	28.4	-3.7	28.2	3.5	3.8	-.4	34.6	31.6	32.2	-4.1	62.8
08:00-09:00	28.6	29.1	-4.2	28.6	5.7	6.2	-.9	40.2	34.3	35.3	-5.1	68.8
09:00-10:00	29.1	32.1	-7.3	29.1	3.9	3.0	0	37.5	32.9	35.1	-7.3	66.6
10:00-11:00	29.3	28.6	-6.7	29.3	3.0	3.0	0	31.0	32.3	31.6	-6.7	60.4
11:00-12:00	28.0	21.4	0	28.0	1.0	1.0	0	16.5	29.0	22.4	0	44.5
MIT TOTALS:	168.6	168.6	0	168.6	21.0	21.0	0	172.8	189.6	189.6	0	341.4

This SIMMOD REPORT MODULE version 2.0.2 run began 10/26/1997 at approximately 15:45:10
This page of the TIME.SECTION report was finished at 15:46:12

AIRPORT AIR AND GROUND TRAVEL AND DELAY REPORT
MIT AIRPORT -- ALL RUNWAY A R R I V A L AND D E P A R T U R E GROUND AND AIR TRAVEL AND DELAY TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/26/1997 AT 15:17:01 (0) mit/mit9002
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	MIT	OVERALL ARRIVAL TIMES (MIN)				AVERAGE ARRIVAL TIMES (MIN)							
TIME	ARRIVAL	TRAVEL		DELAY		TRAVEL				DELAY			
INTERVAL	FLOW	TOT	SDV	TOT	SDV	AIR	GND	GTE	TOT	AIR	GND	GTE	TOT
06:00-07:00	8.85	59.7	1.30	1.6	.40	1.74	5.00	0	6.75	.18	.01	0	.18
07:00-08:00	31.15	222.2	1.84	24.5	1.68	1.83	5.31	0	7.13	.64	.15	2.90	3.69
08:00-09:00	34.50	251.2	1.80	76.0	2.16	1.82	5.46	0	7.28	2.14	.07	30.28	32.49
09:00-10:00	33.70	255.0	1.90	41.1	1.18	1.75	5.81	0	7.57	1.20	.02	20.51	21.73
10:00-11:00	28.05	214.3	1.68	46.2	1.57	1.77	5.87	0	7.64	1.62	.02	12.05	13.69
11:00-12:00	15.55	121.2	1.74	62.0	3.56	1.73	6.06	0	7.79	3.97	.02	5.00	8.99
MIT TOTALS:	151.80	1123.7	1.80	251.5	2.16	1.78	5.62	0	7.40	1.60	.06	14.77	16.43

	MIT	OVERALL DEPARTURE TIMES (MIN)				AVERAGE DEPARTURE TIMES (MIN)								
TIME	DEPARTURE	TRAVEL		DELAY		TRAVEL				DELAY				
INTERVAL	FLOW	TOT	SDV	TOT	SDV	AIR	GND	GTE	TOT	AIR	GND	GTE	QUE	TOT
06:00-07:00	28.35	182.0	1.19	92.7	3.52	1.64	4.77	.19	6.61	0	1.68	.01	1.59	3.28
07:00-08:00	31.65	197.2	1.02	213.2	3.86	1.69	4.54	11.04	17.27	0	4.66	0	2.08	6.74
08:00-09:00	34.30	221.9	1.32	262.6	4.23	1.69	4.78	29.40	35.87	0	4.52	.12	3.14	7.77
09:00-10:00	32.90	217.4	.98	269.9	5.65	1.77	4.84	55.23	61.84	0	4.68	1.14	3.52	9.34
10:00-11:00	32.30	199.5	.91	215.1	3.22	1.77	4.41	86.15	92.33	0	4.60	6.12	2.06	12.78
11:00-12:00	29.00	184.5	1.06	204.7	3.60	1.84	4.52	91.68	98.04	0	4.89	8.79	2.17	15.85
MIT TOTALS:	189.55	1207.5	1.10	1258.2	4.41	1.73	4.64	45.49	51.86	0	4.19	2.61	2.45	9.25

This SIMMOD REPORT MODULE version 2.0.2 run began 10/26/1997 at approximately 15:45:10
This page of the APT.PAGE report was finished at 15:46:27

RUNWAY AIR AND GROUND TRAVEL AND DELAY REPORT
MIT AIRPORT -- RUNWAY 4R A R R I V A L, 4R & 9 D E P A R T U R E GROUND AND AIR TRAVEL AND DELAY TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/26/1997 AT 15:17:01 (0) mit/mit9002
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

	4R	OVERALL ARRIVAL TIMES (MIN)				AVERAGE ARRIVAL TIMES (MIN)							
TIME	ARRIVAL	T R A V E L		D E L A Y		T R A V E L				D E L A Y			
INTERVAL	FLOW	TOT	SDV	TOT	SDV	AIR	GND	GTE	TOT	AIR	GND	GTE	TOT
06:00-07:00	8.85	59.7	1.30	1.6	.40	1.74	5.00	0	6.75	.18	.01	0	.18
07:00-08:00	31.15	222.2	1.84	24.5	1.68	1.83	5.31	0	7.13	.64	.15	2.90	3.69
08:00-09:00	34.50	251.2	1.80	76.0	2.16	1.82	5.46	0	7.28	2.14	.07	30.28	32.49
09:00-10:00	33.70	255.0	1.90	41.1	1.18	1.75	5.81	0	7.57	1.20	.02	20.51	21.73
10:00-11:00	28.05	214.3	1.68	46.2	1.57	1.77	5.87	0	7.64	1.62	.02	12.05	13.69
11:00-12:00	15.55	121.2	1.74	62.0	3.56	1.73	6.06	0	7.79	3.97	.02	5.00	8.99
4R TOTALS:	151.80	1123.7	1.80	251.5	2.16	1.78	5.62	0	7.40	1.60	.06	14.77	16.43

	4R	OVERALL DEPARTURE TIMES (MIN)				AVERAGE DEPARTURE TIMES (MIN)								
TIME	DEPARTURE	T R A V E L		D E L A Y		T R A V E L				D E L A Y				
INTERVAL	FLOW	TOT	SDV	TOT	SDV	AIR	GND	GTE	TOT	AIR	GND	GTE	QUE	TOT
06:00-07:00	4.00	30.1	.68	1.8	.74	1.33	6.19	0	7.52	0	.04	.01	.42	.47
07:00-08:00	3.45	23.3	.56	4.3	2.17	1.33	5.43	17.61	24.37	0	.02	0	1.21	1.23
08:00-09:00	5.70	42.4	1.23	45.2	5.54	1.33	6.10	15.47	22.90	0	.22	0	7.71	7.93
09:00-10:00	3.85	27.0	.67	42.9	10.46	1.33	5.69	20.50	27.53	0	1.01	0	10.14	11.14
10:00-11:00	3.00	21.1	.41	9.9	3.02	1.33	5.71	70.77	77.81	0	.01	0	3.30	3.31
11:00-12:00	1.00	6.3	.33	3.2	1.89	1.33	4.98	0	6.31	0	0	0	3.19	3.19
4R TOTALS:	21.00	150.3	.88	107.3	6.84	1.33	5.82	20.96	28.11	0	.26	0	4.85	5.11

	9	OVERALL DEPARTURE TIMES (MIN)				AVERAGE DEPARTURE TIMES (MIN)								
TIME	DEPARTURE	T R A V E L		D E L A Y		T R A V E L				D E L A Y				
INTERVAL	FLOW	TOT	SDV	TOT	SDV	AIR	GND	GTE	TOT	AIR	GND	GTE	QUE	TOT
06:00-07:00	24.35	151.9	1.16	90.9	3.58	1.70	4.54	.22	6.46	0	1.95	.01	1.78	3.74
07:00-08:00	28.20	173.9	1.05	208.9	3.46	1.74	4.43	10.23	16.40	0	5.22	0	2.19	7.41
08:00-09:00	28.60	179.6	1.25	217.4	3.91	1.77	4.51	32.18	38.46	0	5.37	.14	2.23	7.74
09:00-10:00	29.05	190.3	1.01	227.0	4.51	1.82	4.73	59.83	66.38	0	5.17	1.29	2.65	9.11
10:00-11:00	29.30	178.4	.90	205.2	3.04	1.81	4.28	87.73	93.82	0	5.07	6.75	1.93	13.75
11:00-12:00	28.00	178.2	1.08	201.5	3.57	1.86	4.50	94.96	101.32	0	5.06	9.10	2.14	16.30
9 TOTALS:	168.55	1057.2	1.09	1150.8	3.96	1.78	4.49	48.54	54.81	0	4.68	2.93	2.15	9.76

This SIMMOD REPORT MODULE version 2.0.2 run began 10/26/1997 at approximately 15:45:10
This page of the RWY.PAGE report was finished at 15:46:42

ITERATION AIR AND GROUND DELAY
AVERAGE, MIN, AND MAX AIRCRAFT GROUND AND AIR DELAY TIME (MINS) VERSUS ITERATION
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/26/1997 AT 15:17:01 (0) mit/mit9002
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

ITERATION: 1 FILE: C:\Lti\data\mit\mit9002\inprep.mit

TIME	A R R I V A L S						D E P A R T U R E S					
	A I R			G N D			A I R			G N D		
INTERVAL	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX	AVG	MIN	MAX
06:00-07:00	.04	0	.33	0	0	0	0	0	0	2.58	0	9.43
07:00-08:00	.44	0	1.78	.01	0	.15	0	0	0	7.37	0	17.40
08:00-09:00	1.11	0	3.83	.01	0	.20	0	0	0	6.59	0	14.00
09:00-10:00	1.19	0	3.65	.02	0	.12	0	0	0	7.58	.08	18.50
10:00-11:00	1.55	0	6.73	.03	0	.35	0	0	0	7.22	0	14.02
11:00-12:00	3.55	0	10.23	.00	0	.05	0	0	0	7.96	2.90	17.33
TOTALS:	1.23	0	10.23	.01	0	.35	0	0	0	6.55	0	18.50

ITERATION: 2 FILE: C:\Lti\data\mit\mit9002\inprep.mit

06:00-07:00	.11	0	.95	.00	0	.03	0	0	0	2.93	0	14.02
07:00-08:00	.82	0	2.58	.01	0	.33	0	0	0	7.12	0	18.22
08:00-09:00	2.49	0	7.10	.58	0	17.93	0	0	0	7.81	.30	21.92
09:00-10:00	1.15	0	3.22	.01	0	.22	0	0	0	7.93	.17	16.93
10:00-11:00	2.38	0	8.47	.04	0	.30	0	0	0	6.97	.27	15.47
11:00-12:00	3.99	0	9.62	0	0	0	0	0	0	7.04	2.15	14.95
TOTALS:	1.80	0	9.62	.14	0	17.93	0	0	0	6.65	0	21.92

TOTAL DELAYS FOR ALL ITERATIONS

06:00-07:00	.18	0	2.17	.01	0	.55	0	0	0	3.27	0	18.43
07:00-08:00	.64	0	4.23	.15	0	18.55	0	0	0	6.74	0	19.58
08:00-09:00	2.14	0	8.17	.07	0	17.93	0	0	0	7.66	0	29.07
09:00-10:00	1.20	0	6.87	.02	0	.57	0	0	0	8.20	0	36.25
10:00-11:00	1.62	0	8.47	.02	0	.70	0	0	0	6.66	0	15.88
11:00-12:00	3.97	0	13.27	.02	0	.57	0	0	0	7.06	0	19.98
TOTALS:	1.60	0	13.27	.06	0	18.55	0	0	0	6.64	0	36.25

This SIMMOD REPORT MODULE version 2.0.2 run began 10/26/1997 at approximately 15:45:10
This page of the ITER.SECTION report was finished at 15:46:59

AVERAGE ARR TRAVEL AND DELAY REPORT
MIT AIRPORT -- AVERAGE A R R I V A L AIRCRAFT TRAVEL AND DELAY TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/26/1997 AT 15:17:01 (0) mit/mit9002
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME	ARRIVAL	TRAVEL TIMES (MIN)			DELAY TIMES (MIN)			# OF FLIGHTS WITH DELAY (MIN)						
INTERVAL	FLOW	TOT	SDV	AVE	TOT	SDV	AVE	< 5	5-10	10-15	15-30	30-45	45-60	> 60
06:00-07:00	8.85	59.7	1.30	6.75	1.6	.40	.18	8.9	0	0	0	0	0	0
07:00-08:00	31.15	222.2	1.84	7.13	24.5	1.68	.79	30.8	.1	.1	.1	0	0	0
08:00-09:00	34.50	251.2	1.80	7.28	76.0	2.16	2.20	30.8	3.6	0	.1	0	0	0
09:00-10:00	33.70	255.0	1.90	7.57	41.1	1.18	1.22	33.4	.3	0	0	0	0	0
10:00-11:00	28.05	214.3	1.68	7.64	46.2	1.57	1.65	26.7	1.3	0	0	0	0	0
11:00-12:00	15.55	121.2	1.74	7.79	62.0	3.56	3.99	9.6	5.1	.9	0	0	0	0
00:00-12:00	151.80	1123.7	1.80	7.40	251.5	2.16	1.66	140.2	10.3	1.0	.3	0	0	0

MIT AIRPORT -- A R R I V A L AIR/GND DELAY BIN TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/26/1997 AT 15:17:01 (0) mit/mit9002
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME	ARRIVAL	# OF FLIGHTS WITH AIR DELAY (MIN)							# OF FLIGHTS WITH GROUND DELAY (MIN)						
INTERVAL	FLOW	< 5	5-10	10-15	15-30	30-45	45-60	> 60	< 5	5-10	10-15	15-30	30-45	45-60	> 60
06:00-07:00	8.85	8.9	0	0	0	0	0	0	8.9	0	0	0	0	0	0
07:00-08:00	31.15	31.1	0	0	0	0	0	0	30.8	.1	.1	.1	0	0	0
08:00-09:00	34.50	30.8	3.6	0	0	0	0	0	34.4	0	0	.1	0	0	0
09:00-10:00	33.70	33.4	.3	0	0	0	0	0	33.7	0	0	0	0	0	0
10:00-11:00	28.05	26.7	1.3	0	0	0	0	0	28.1	0	0	0	0	0	0
11:00-12:00	15.55	9.6	5.2	.8	0	0	0	0	15.6	0	0	0	0	0	0
00:00-12:00	151.80	140.6	10.4	.8	0	0	0	0	151.4	.1	.1	.3	0	0	0

This SIMMOD REPORT MODULE version 2.0.2 run began 10/26/1997 at approximately 15:45:10
This page of the ARRIVAL.AIR.GND.DELAY.INTERVAL.REPORT report was finished at 15:47:14

AVERAGE DEP TRAVEL AND DELAY REPORT
MIT AIRPORT -- AVERAGE D E P A R T U R E AIRCRAFT TRAVEL AND DELAY TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/26/1997 AT 15:17:01 (0) mit/mit9002
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME	DEPARTURE	TRAVEL TIMES (MIN)			DELAY TIMES (MIN)			# OF FLIGHTS WITH DELAY (MIN)						
INTERVAL	FLOW	TOT	SDV	AVE	TOT	SDV	AVE	< 5	5-10	10-15	15-30	30-45	45-60	> 60
06:00-07:00	28.35	182.0	1.19	6.42	92.7	3.52	3.27	21.2	5.1	2.0	.1	0	0	0
07:00-08:00	31.65	197.2	1.02	6.23	213.2	3.86	6.74	10.6	14.7	5.7	.7	0	0	0
08:00-09:00	34.30	221.9	1.32	6.47	262.6	4.23	7.66	10.0	14.6	8.2	1.6	0	0	0
09:00-10:00	32.90	217.4	.98	6.61	269.9	5.65	8.20	11.1	11.3	7.7	2.5	.4	0	0
10:00-11:00	32.30	199.5	.91	6.18	215.1	3.22	6.66	10.9	15.9	5.3	.2	0	0	0
11:00-12:00	29.00	184.5	1.06	6.36	204.7	3.60	7.06	8.9	14.5	4.7	.9	0	0	0
00:00-12:00	189.55	1207.5	1.10	6.37	1258.2	4.41	6.64	73.7	76.2	33.4	5.9	.4	0	0

MIT AIRPORT -- D E P A R T U R E AIR/GND DELAY BIN TIMES
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/26/1997 AT 15:17:01 (0) mit/mit9002
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME	DEPARTURE	# OF FLIGHTS WITH AIR DELAY (MIN)							# OF FLIGHTS WITH GROUND DELAY (MIN)						
INTERVAL	FLOW	< 5	5-10	10-15	15-30	30-45	45-60	> 60	< 5	5-10	10-15	15-30	30-45	45-60	> 60
06:00-07:00	28.35	28.3	0	0	0	0	0	0	21.2	5.1	2.0	.1	0	0	0
07:00-08:00	31.65	31.6	0	0	0	0	0	0	10.6	14.7	5.7	.7	0	0	0
08:00-09:00	34.30	34.3	0	0	0	0	0	0	10.0	14.6	8.2	1.6	0	0	0
09:00-10:00	32.90	32.9	0	0	0	0	0	0	11.1	11.3	7.7	2.5	.4	0	0
10:00-11:00	32.30	32.3	0	0	0	0	0	0	10.9	15.9	5.3	.2	0	0	0
11:00-12:00	29.00	29.0	0	0	0	0	0	0	8.9	14.5	4.7	.9	0	0	0
00:00-12:00	189.55	189.6	0	0	0	0	0	0	73.7	76.2	33.4	5.9	.4	0	0

This SIMMOD REPORT MODULE version 2.0.2 run began 10/26/1997 at approximately 15:45:10
This page of the DEPARTURE.AIR.GND.DELAY.INTERVAL.REPORT report was finished at 15:47:29

DEPARTURE QUEUE LENGTH SUMMARY REPORT
MIT AIRPORT -- DEPARTURE QUEUE LENGTH SUMMARY
BASED ON 20 ITERATIONS INCLUDED IN THE FOLLOWING SIMMOD RUN:
#1-#20 10/26/1997 AT 15:17:01 (0) mit/mit9002
ALL AIRLINES, AIRPORTS, AND ITERATIONS ARE INCLUDED IN THIS REPORT.

TIME	MIT QUEUE QUEUE4R_MIT					MIT QUEUE QUEUE92_MIT				
INTERVAL	IN	OUT	AVE	STD	MAX	IN	OUT	AVE	STD	MAX
06:00-07:00	4.0	4.0	.03	.15	1	5.9	5.7	.19	.40	2
07:00-08:00	3.8	3.5	.09	.25	1	3.1	3.1	.14	.35	2
08:00-09:00	6.2	5.7	.91	.96	3	4.0	4.2	.18	.40	2
09:00-10:00	3.0	3.9	.45	.66	3	8.0	7.9	.39	.53	2
10:00-11:00	3.0	3.0	.17	.37	2	1.7	1.8	.08	.26	1
11:00-12:00	1.0	1.0	.05	.21	1	3.2	3.2	.17	.40	2
00:00-12:00	21.0	21.0			3	25.9	25.9			2

TIME	MIT QUEUE QUEUE9_MIT					MIT AIRPORT TOTALS				
INTERVAL	IN	OUT	AVE	STD	MAX	IN	OUT	AVE	STD	MAX
06:00-07:00	19.7	18.9	.58	.55	3	29.6	28.6	.80	.75	4
07:00-08:00	25.3	25.2	.88	.50	3	32.2	31.8	1.11	.66	4
08:00-09:00	24.6	24.5	.88	.59	3	34.9	34.4	1.97	1.29	6
09:00-10:00	21.0	21.4	.89	.61	3	32.0	33.2	1.73	1.14	6
10:00-11:00	27.4	27.0	.85	.56	3	32.0	31.8	1.09	.73	4
11:00-12:00	23.6	24.5	.81	.59	3	27.9	28.7	1.03	.78	4
00:00-12:00	142.6	142.6			3	189.6	189.6			6

This SIMMOD REPORT MODULE version 2.0.2 run began 10/26/1997 at approximately 15:45:10
This page of the QUE.SECTION report was finished at 15:47:52

Chapter 5: Evaluation of the SIMMOD Airport Simulation Program, Propositions for its Future Development

1. Current status of SIMMOD

When assessing SIMMOD, it is necessary to consider its three components: (1) the simulation engine, coded in SIMSCRIPT, (2) the pre-processor, building the input files for the simulation engine and (3) the post-processor, helping to draw conclusions from the output files through animation and report building.

In the last 4 years, the **simulation engine** has been improved under funding of the FAA. Version 2.2beta was released early in 1996 and the official version 2.2 at the beginning of 1997. It includes valuable new features and is available for a very small fee on Solaris 1.# (Sun SPARCstation), HP UX (HP series 9000) and Windows or OS/2 (PC). The simulation engine is apparently not available on other platforms. It is important to mention that, under MIT's experience, version 2.2 of the simulation engine offers significant potential for improvement. This official version has numerous characteristics that make it challenging to simulate many ground operations. For instance, options for runway crossings and taxiing on runways appear not to be working. This has led the major users (Eurocontrol, ATAC, and Sabre) to correct the source code by themselves. A new user (such as MIT) has to rely on one of these major users to use a simulation engine.

The current **pre and post-processors** appear to be working correctly only for the initial versions of the simulation engine. The new simulation engine and the overall progress of computer graphics have outdated these pieces of software: they are not fully compatible with the new engine; animations look obsolete, especially in front of comparable software (The Airport Machine, TAAM, etc.). Recently, independent companies or institutions have thus developed their own pre- and post-processors to address these weaknesses.

The complex history of SIMMOD has led to five "current" versions available today:

PC Simmod 1.2 for DOS and OS/2 was released by SABRE in August 1995. This version contains the three pieces of software needed, based on the old simulation engine. This version is apparently working properly, but suffers from its "old-fashioned" appearance, although this issue is totally independent of SIMMOD's accuracy. Besides, it lacks many important features of large airports.

Simmod for workstation uses specific pre and post-processors that are not adapted to the new features of the 2.2 engine. It is less and less used.

PC Simmod for windows consists only of the version 2.2 of the simulation engine, compiled for Windows. Since the pre and post-processors are the old ones, running under DOS, developing a model with it supposes going back and forth between DOS and Windows. It is priced at $300.

Simmod PLUS! 1.0 for Windows 95, NT was released by ATAC in February 1997. Based on the latest simulation engine (version 2.2), it includes new pre and post-processors in Java.

Simmod turnkey system for Windows 95 & NT is the version in use at MIT. It competes with Simmod PLUS! to provide a convenient network editor and animation program. SIMMOD Turnkey System is priced $20,000 U.S. with a restricted licensing agreement (one airport, one user, training included, etc.) and $200 for academic use. It is still under development.

The following table compares the features of the current PC alternatives:

Product	**PC SIMMOD 1.2**	**PC SIMMOD 2.2**	**SIMMOD PLUS! 1.0**	**SIMMOD TURNKEY SYSTEM**
Company	SABRE	SABRE	ATAC	LeTech
Platform	DOS, OS/2	DOS, OS/2, Win 3.1, Win 95/NT	Win 95/NT, HPUX (?)	Win 95/NT
Release	1993, 1994?	January 97 for the engine, 94 for the pre and post	February 97	February 97
Functionalities				
(1) Network building	Uncertain, AutoCAD 9 layouts possible?	Same as 1.2	Mouse, AutoCAD (no layers)	Mouse, AutoCAD layers
(2) Event generator	None	None	None	Some interesting elements, under testing
(3) Simulation engine	1.2 limited features	2.2.23.11, valuable improvements, many bugs, lead users have developed their own corrected version		
(4) Animation	Triangles, names of a/c, limited number of a/c	layout?,	"True" planes, names, layouts	Curves, "True" planes, paths and names, layouts
(5) Reports	Existent	Existent	?	?
Price	$150?	$300	$2,950+ $150	$20,000

2. SIMMOD users

There are three distinct groups of users.

1. **Lead users: Eurocontrol, Sabre, ATAC, the FAA**

   These users have a substantial expertise in SIMMOD, have a SIMSCRIPT compiler and are thus able to correct the bugs when they are confronted with them in the course of some study.

   Eurocontrol, for example, has already developed 6 modified versions of the new simulation engine. It has now gathered probably the most competent team of SIMMOD experts. This team has developed a new report generator and other post-processors. It is now building a new interface for pre and post-processing. Its ESUG network works extremely well. Many European airports have been modeled with SIMMOD, relying heavily on Eurocontrol's expertise. Eurocontrol has achieved the critical mass to afford independent SIMMOD maintenance and development.

   SABRE has made its own corrections to the engine. Presumably, some of these improvements have addressed the same issues as Eurocontrol.

   This situation has probably led SIMMOD developers to costly, redundant development efforts. It is worth noting that these users are for-profit companies as well as non-profit institutions, whose strategies and sources of support may be totally different.

2. **Old SIMMOD users**

   These users, mainly consultants in the US and airport and aviation authorities in Europe, have had SIMMOD 1.2 knowledge for the last 5 years. In most cases, they have thus not transitioned to this new version. The reason for this is not necessarily for lack of information or funding sources, but rather because they have built confidence in the older engine and do not necessarily trust the newest developments. The Airspace Capacity Office, for example, typically needs a very reliable and tested tool for its studies. Some SIMMOD competitors, such as *the Airport Machine*, seem to adopt this standpoint: most enhancements to the latter model are concerned only with its pre- and post-processors.

   Finally, SIMMOD's low price has led most of its users to use it for a single study and then lose their know-how.

3. New users

Currently, new users do not know how to cope with SIMMOD, except by relying on the current power users. They may not know about the existing bugs, and may feel repelled from SIMMOD by its old-fashioned interface, or by the high price attached to the enhanced versions.

LeTech must be included in these new users. Tung Le, the person who has developed the first interface for SIMMOD, has created this company. He has built modern pre and post-processors that have proven difficult to sell. His problems can be attributed to (1) the problems with the simulation engine, (2) some approximations in his software, and (3) its relatively high price ($ 20,000). He is seriously considering building his own discrete event simulation engine.

SIMMOD still profits from its widespread diffusion, from its official endorsement by the FAA, and from its very low price.

3. SIMMOD's assets, other products

In this section, we outline the qualities and defaults that we found while extensively using this software and try and compare them with other available products.

(1) Simulation is **a good tool for airport and airspace planning**. It is not always necessary to develop total models of these systems to obtain appropriate answers. Typically, when system effects are not involved, simpler models focusing on the runways are more efficient.

(2) Simulation remains highly **time-consuming**. Collecting data and tailoring them to the structure of the inputs are the longest tasks. SIMMOD's lack of flexibility forces the analyst to use many tricks to correctly model a complex airport such as Logan Airport. Modern computer interfaces have remarkably speed up some tasks, such as the construction of the network. On the other hand, priorities between flows are difficult, if not impossible, to model.

(3) **Modern flow management techniques** can not be implemented in SIMMOD. What we call "runway balancing" or "smart logic" is not available in the latest version of the simulation engine. This means that we can not take advantage of SIMMOD's ability to model small details of any airport that require significant control. We typically faced this

issue when we tried to model the complex operations that happen in Logan Airport's southwest corner.

(4) **Discrete-event simulation software is becoming a commodity.** As we have seen in other projects[1], developing a simulation is a simple computer exercise. Although there are still few specific programs for airports, numerous companies propose simulation packages that can be tailored to airports. SIMMOD has been designed on good principles. These principles can however be easily imitated.

(5) **SIMMOD's market positioning** as a cheap, general purpose, FAA-endorsed software remains valuable; most airport authorities and consultants are probably not interested in investing in the heavy TAAM or more limited software. Its current weaknesses are threefold: the engine contains numerous bugs, the "modern" interfaces are not cheap (see ATAC or LeTech products) and many of its features are narrowly defined. Eurocontrol is likely to answer the first two weaknesses. The third one is deeply embedded in the design of the engine. Considering its complex history, such changes will require large investments that nobody seems to be willing to finance. Against this, whatever software the FAA uses for its own studies, making a general-purpose simulation program available to the public could be a simple way to promote more sound decision-making for airport capacity investments.

In this context, the large modifications and technical problems associated with version 2.2 of the engine must be acknowledged when it comes to managing the code.

4. A new management structure for SIMMOD

This section describes a SIMMOD management and control structure that may fit the needs of every partner while valuing SIMMOD's assets and preserving its integrity. The control mechanism is outlined in the figure on the next page.

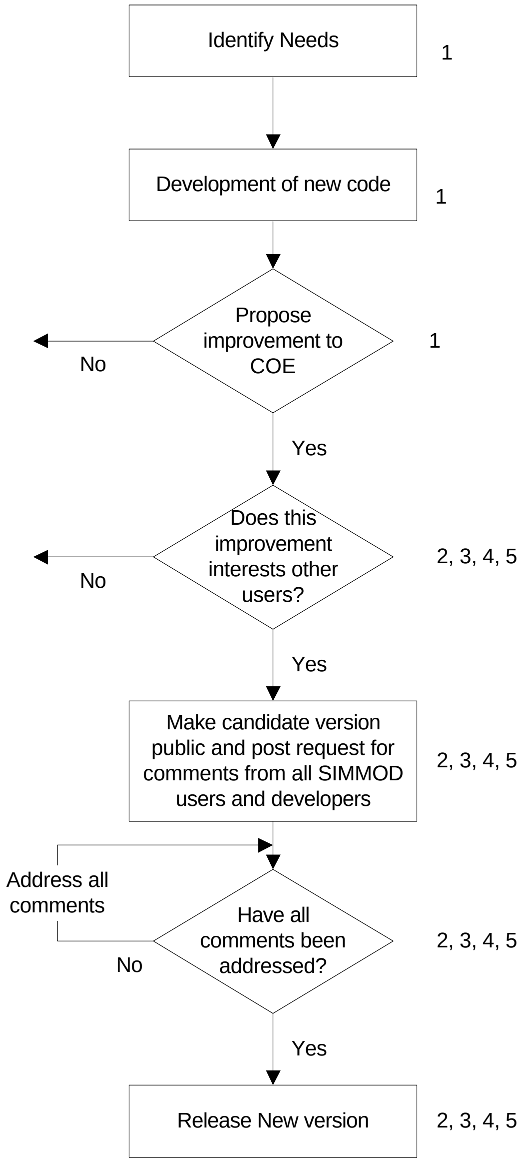
This structure intends to be inexpensive as the low-cost feature of SIMMOD must remain and fits more the aims of administrations and universities. It requires to:

[1] For instance, work at MIT on the modeling of the Airline Operating Center for a major airline.

(1) Establish a reasonably operational version of the simulation engine, certified by NEXTOR and the FAA (i.e., finish the development of version 2.2). This mainly means putting together the corrections that have been made by the various lead users.

Establish a web site/forum managed by NEXTOR that provides the official version of SIMMOD, corrected and clarified documentation and source code. On the “forum” side, independent organizations could inform others of pieces of code they have developed, offer technical support and discuss modeling questions and possible bugs. This web site would contain the official version of SIMMOD, along with a test version, if any. In order to ensure a sequential treatment of SIMMOD improvements, two test versions could never cohabit on the web site.

(2) Most management operations defined below could be performed electronically between users, thus at a very low cost.



Flow chart for SIMMOD management.

1: Any user or developer, 2: Sabre, 3: ATAC, 4: Universities (NEXTOR), 5: Eurocontrol

Under this plan, SIMMOD improvements and coding could originate from any user. Concerns about coding styles may arise if many users are to submit improvements. However, discrete-event system simulation technology is now a mature science and coding standards may be easily applied. For any improvement to be included in the "official" version of SIMMOD, it would have to be approved by NEXTOR and Eurocontrol and any significant user comment would have to be cleared.

The advantage of this plan is that it completely separates the issue of SIMMOD maintenance from its further development: any SIMMOD user could handle some development for specific purposes, but such development would have to be approved to be included in the "official" version. This plan would provide the basis for uniform and orderly SIMMOD development, and leave anyone free to pursue any independent development. It would require very limited funding; its operations could be done under NEXTOR's management budget as part of its core tasks.

Organizations would be free to develop their own pre and post-processors and market them the way they want. We can for instance expect Eurocontrol to provide soon, for a small fee, a new interface.

A fraction (probably not more than $30,000) of the existing funds could be used to:

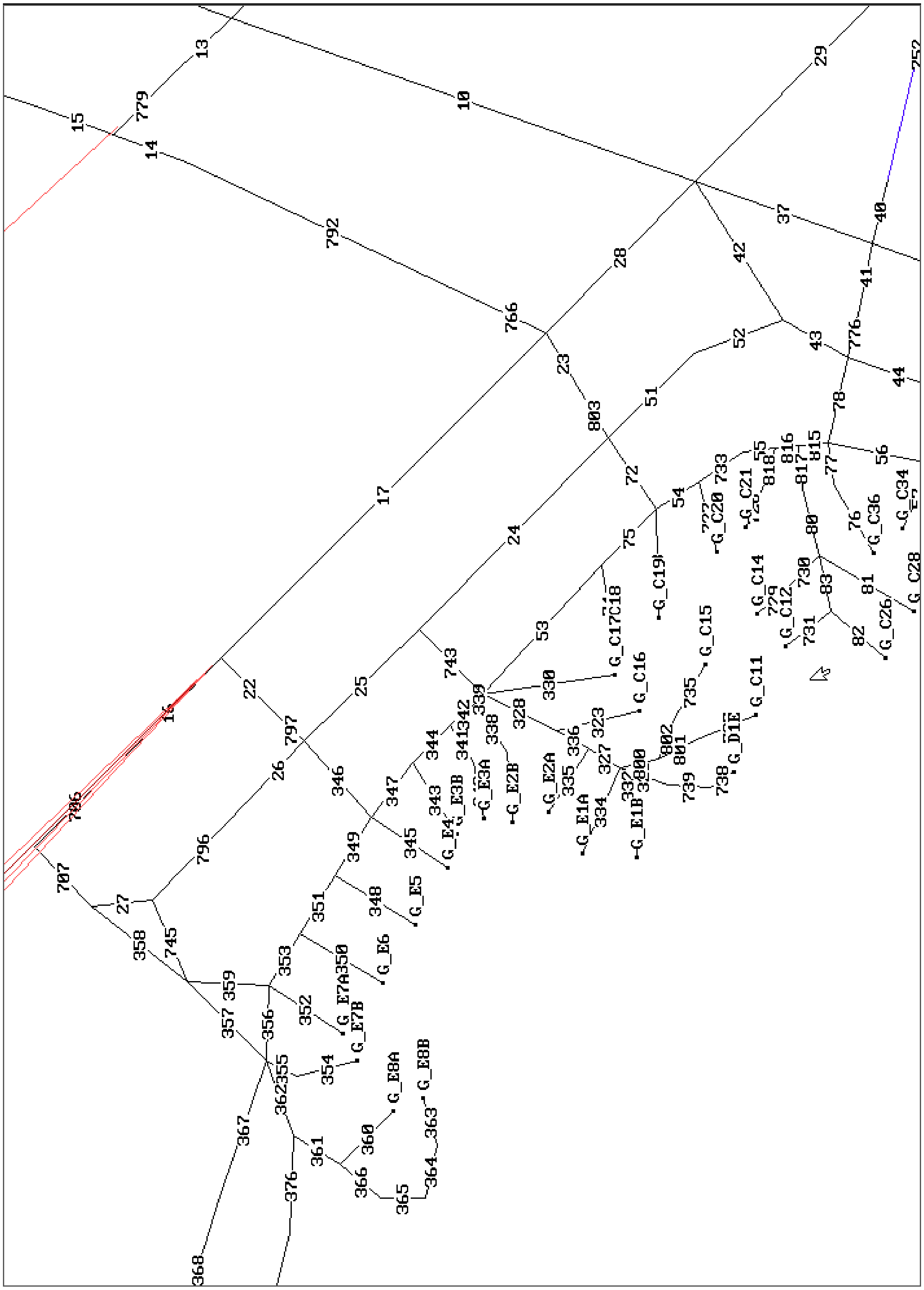
— Put together an initial corrected version of the simulation engine.

— Build a web site with all useful data.

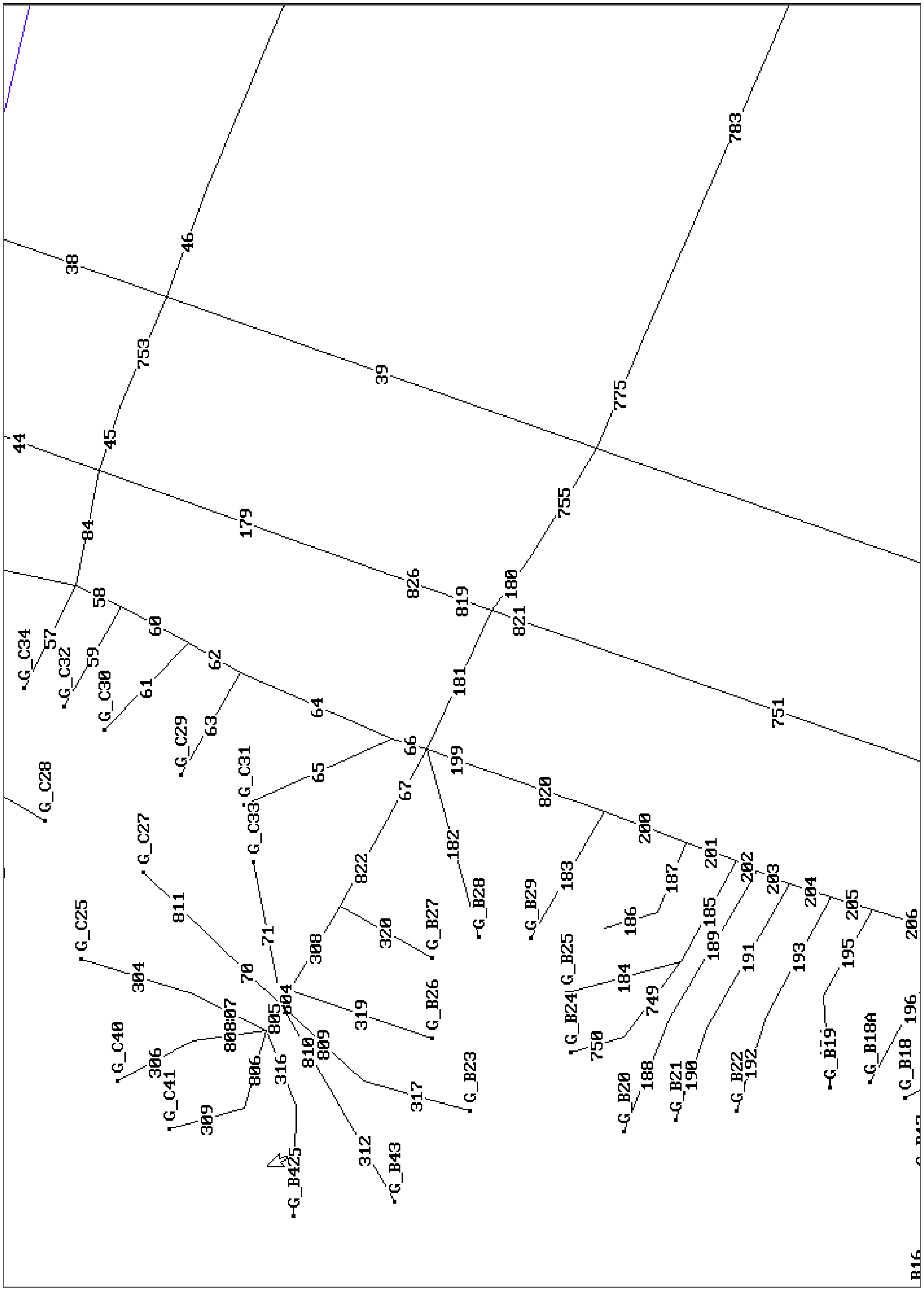
The remaining funds (about $70,000) would either be returned to FAA or used for new SIMMOD capability developments. In the latter case, these developments would have to go through the mechanism proposed above before approval for official release.

In conclusion, we have found that SIMMOD remains a valuable tool for airport planning. The current “official” version needs however to be corrected. Since some of the lead users have developed their own corrections, it is now more important to design a *control structure* to incorporate these modifications and later facilitate user-driven improvements. This would parallel FAA’s certification activity and requires very few funds.

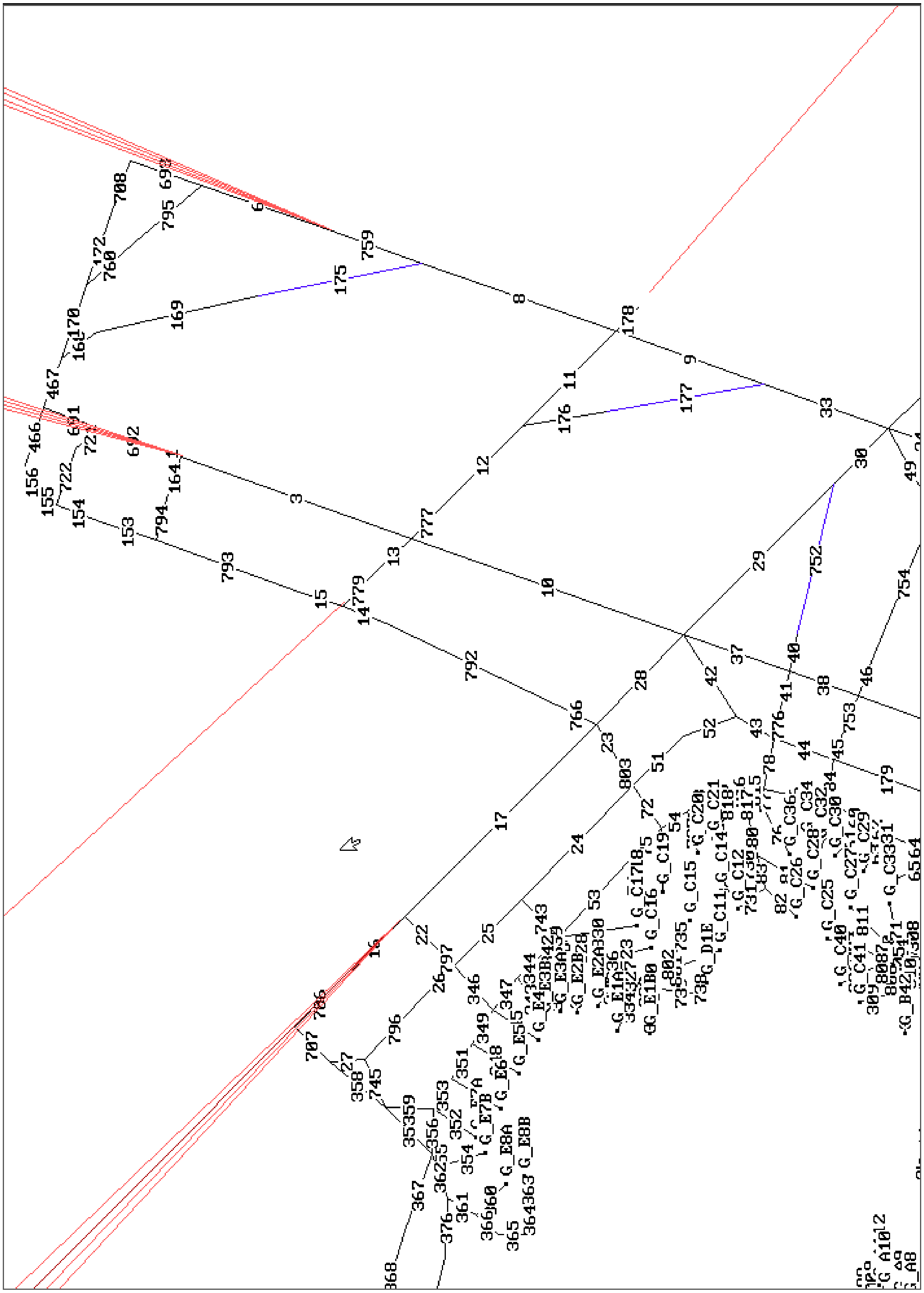
Appendix: Maps of the SIMMOD network



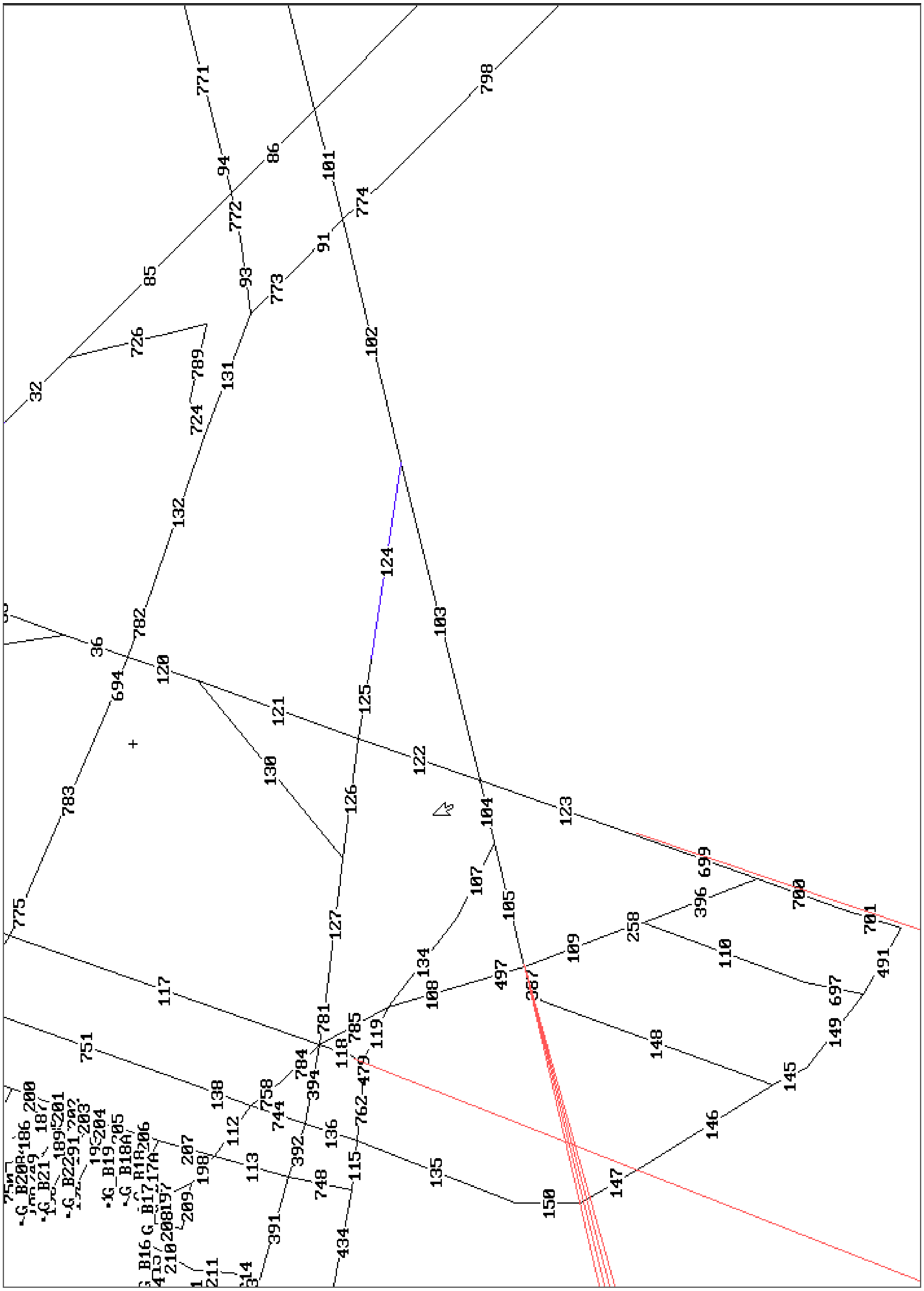
Map 1: map of the network in the north of the airport, Terminals C, D and E



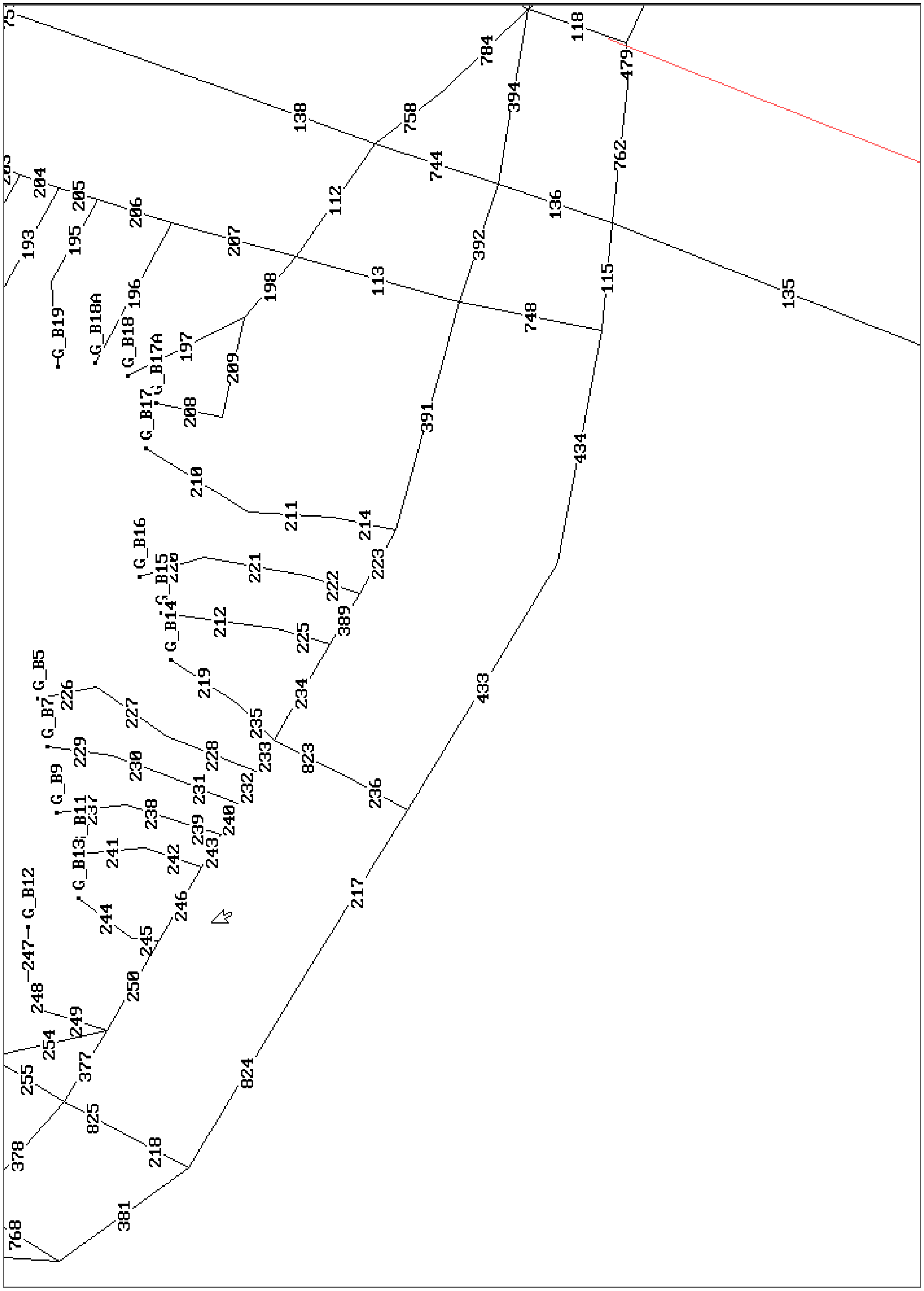
Map 2: Map of the network around the “horse-shoe” between terminal B and C.



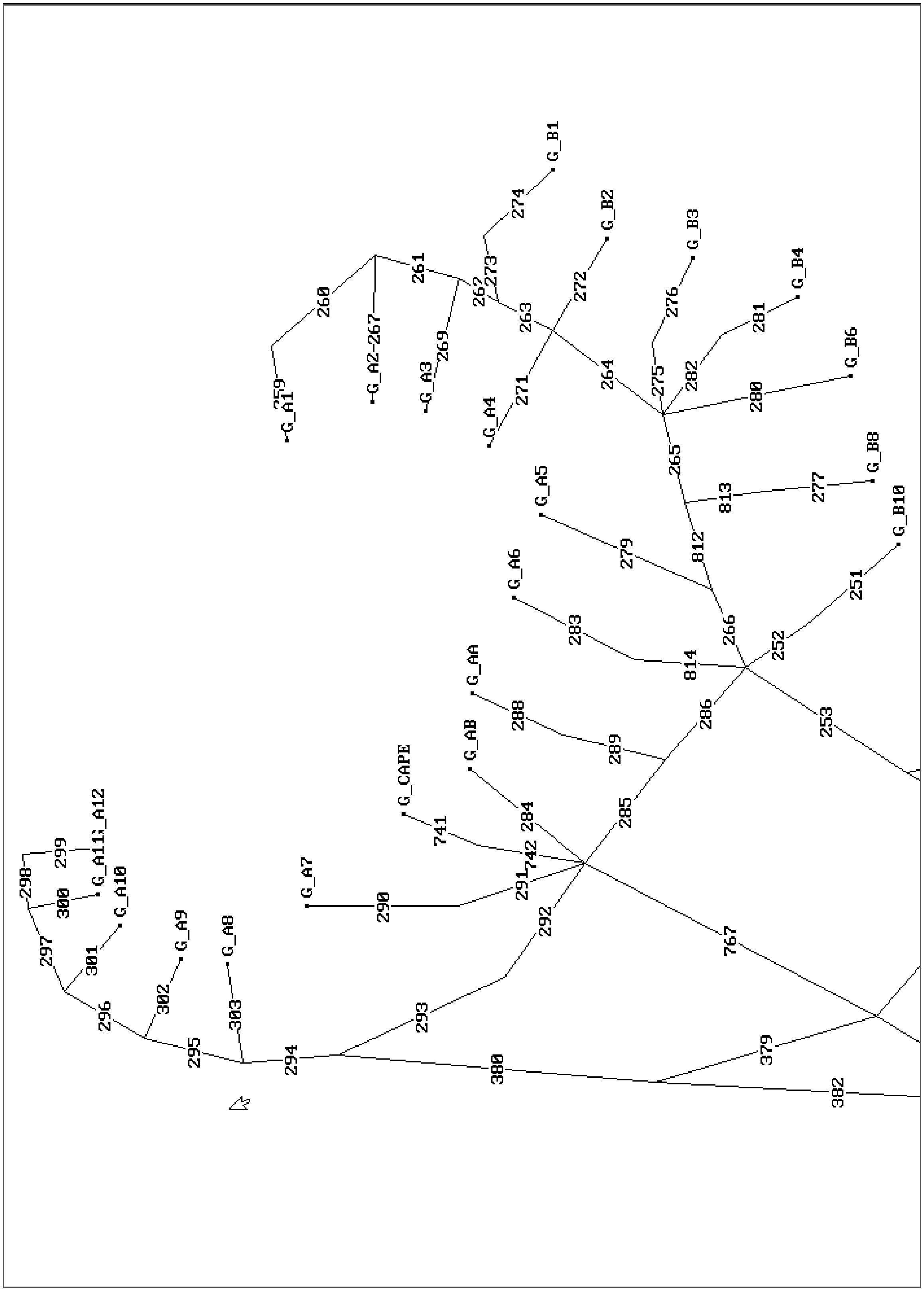
Map 3: Map of the network in the North of the airport, runways and taxiways



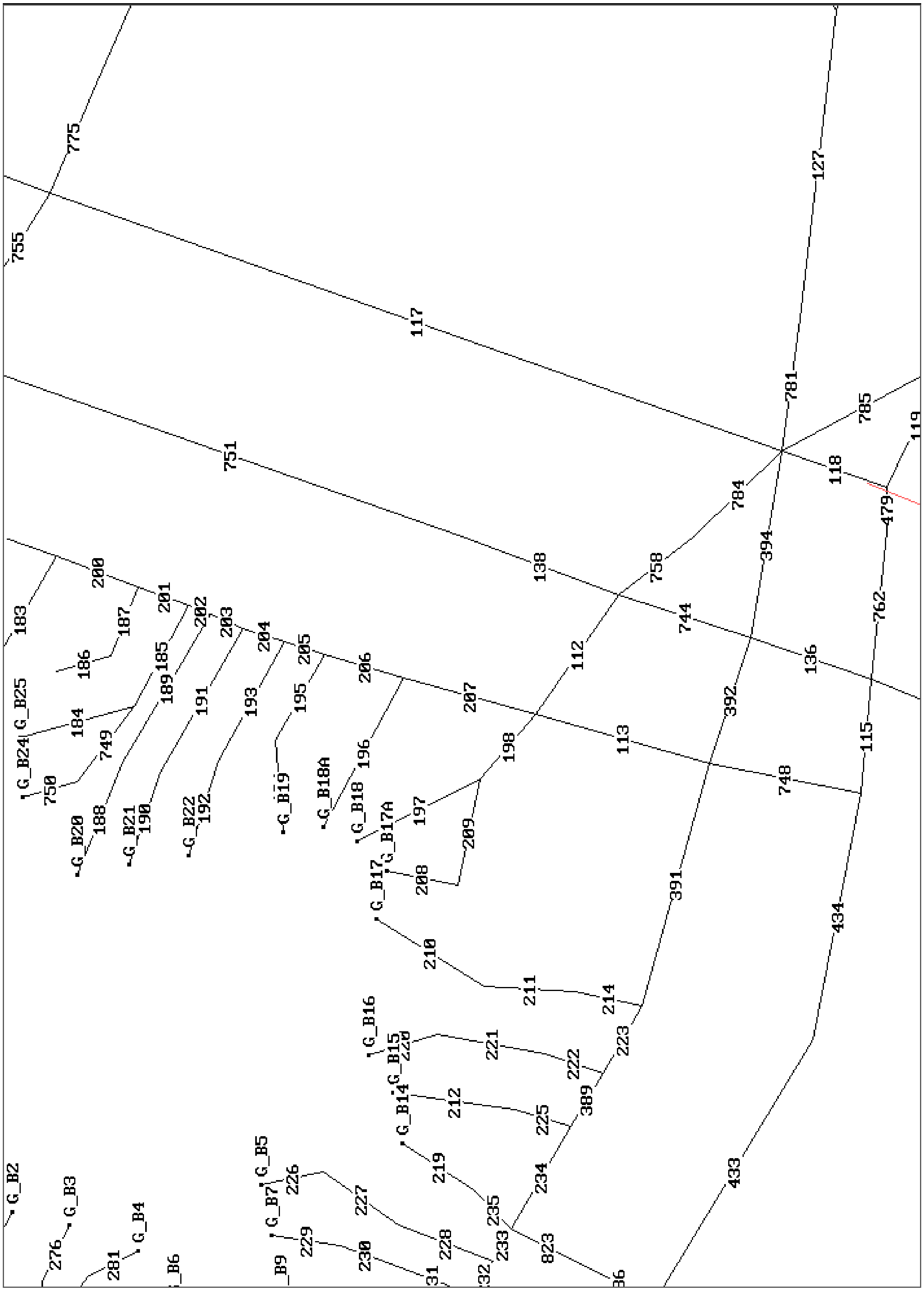
Map 4: Map of the network in the South West corner.



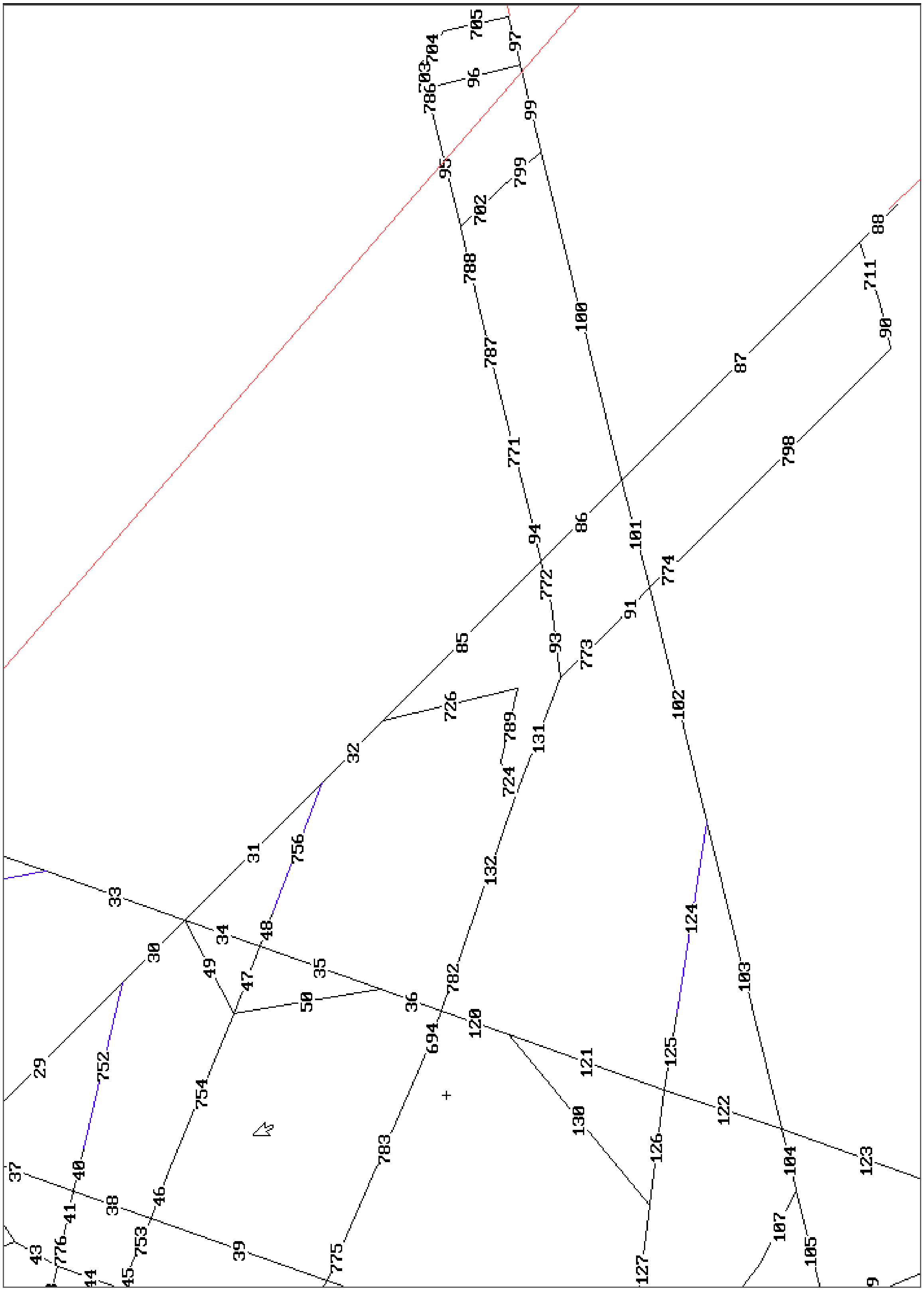
Map 5: Map of the network in the South West area, terminal B, taxiway Alpha and Kilo.



Map 6: Map of the network for the terminal A.



Map 7: Map of the network in the SouthWest area, terminal B.



Map 8: Map of the network in the Western part, runway 27 and 33L