Forecasting aircraft stand requirements

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Forecasting Aircraft Stand Requirements

by

Salvador Martinez Viramontes

A Master's Thesis
Submitted in partial fulfilment of the requirements
for the award of Master of Science of the
Loughborough University of Technology

June 1980

Director of Research: Professor Norman Ashford
Department of Transport Technology

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SYNOPSIS

The aim of this thesis is to obtain from a simulation procedure a set of graphs to compute the number of aircraft stands required at an airport.

The scope of the study has been set within airports from the size of that of Birmingham up to those of the size of Manchester. A general approach has been taken hoping that the graphs may be used in the case of similar airports within the range.

A computer model is developed to compute stand requirements for 5 aircraft groups under 4 aircraft mixes and 5 flight type mixes. The basic input variables taken into account in the model are aircraft arrival time and stand occupancy time.

The model simulates the apron under three handling rules, the first one being that of stands mutually shared amongst the aircraft groups, the second without stand sharing and the last case for stands being partially shared.

With outputs from the simulation procedure a number of graphs are plotted with arrivals per hour as the independent variable and stands required as the dependent variable. The graphs are split into 4 groups according to the aircraft mixes.
CHAPTER ONE
INTRODUCTION

One of the first pieces of data required in the process of designing the apron of an airport is the number and type of aircraft stands to be provided. The apron layout itself is strongly influenced by the number of stands considered.

The number of stands required depends on the number of aircraft parking simultaneously on the apron.

Although there is an underlying schedule which may appear to make the problem of working out stand requirements a simple and deterministic one, for a number of reasons aircraft may arrive before or after the time they are due and the same happens when aircraft depart. Therefore, the problem is of a stochastic nature and its solution implies certain difficulties.\(^{(1)}\)

Also it should be recognized that schedules are available for the assessment of the current situation only; normally detailed schedules are not available for planning and design purposes.

Different ways of computing stand requirements have been developed through the years. These methods can be classified as Rough plots, Deterministic formulae and Probabilistic techniques.

**Rough plots.** These plots are made by relating annual enplanements and stand requirements. The data to build a plot must come from a range of airports.\(^{(2)}\)

Stand requirements are obtained by entering the chart with the forecast design annual enplanements.

In this procedure the airport planner faces two alternatives: to take averaged values or to choose the value for a particular airport comparable to the one under study in the design year.
If the decision is made to consider averaged values, inaccuracies are likely to occur. Individual plots reflect variations in the relationship across a number of airports. The growth of individual airports differs significantly from airport to airport and therefore averaged values may not yield very accurate figures.

The second alternative means that the planner considers two airports similar as far as stand requirements are concerned, and that the plotted annual enplanements of the model airport are equal or nearly equal to the figure forecast for the airport under study.

**Deterministic formulae.** There are a number of these formulae which have been determined by observation. Most of the formulae take into account aircraft arrivals or departures and weighted average occupancy times (during the design hour).

An example of these formulae is Horonjeff's\(^{(3)}\):

\[
G = \frac{VT}{U}
\]

where

- \(G\) = number of gates\(^a\)
- \(V\) = design volume for arrivals or departures in aircraft per hour
- \(T\) = weighted average gate occupancy time in hours
- \(U\) = utilization factor

The utilization factor is said to vary from 0.5 to 0.8 and it is related to the time gates are used.

Although it looks a very straightforward manner of computing stand requirements, the value chosen for the utilization factor produces significant differences in the outcome; (the author does not give any indication on how to select that figure).

Different results may be obtained also if other formulae available within this group are used.

---

\(^a\) Gates and stands are synonymous in this context
Piper's\(^{(4)}\) equation for example, is a formula similar in nature to Horonjeff's but it does not include the utilization factor. This is equivalent to setting the factor equal to 1.0 in Horonjeff's formula. Therefore, results obtained from Piper's equation are low in comparison with those obtained from Horonjeff.

Piper's formula is:

\[ n = mqt \]

where

- \( m \) = design hour volume for arrivals and departures (aircraft/hour)
- \( q \) = proportion of arrivals (total movements)
- \( t \) = mean stand occupancy (hr)

Another example is the European based formula\(^{(5)}\) which yields values conservative in comparison with Piper's and similar to the results obtained from Horonjeff with low utilization factors. This formula does not include occupancy times.

The European based formula is:

\[ n = 1.1m \]

where

- \( m \) = design hour volume for arrivals and departures

**Probabilistic techniques.** Such techniques would appear to be more in accordance with the stochastic nature of the phenomenon under study. The techniques involve Queueing models and Simulation.

Queueing models are mathematical expressions which relate average occupancy time and average rate of arrivals. These models give information on the number of aircraft desiring stands in a given time interval and delays which take place in the system during the same time interval.

However, simplifying assumptions must be made in order to use this method. It is necessary, for example, to assume an average arrival rate...
and steady state conditions in the period considered.

Unfortunately those assumptions make the model unable to satisfactorily represent real-life conditions and without those simplifying assumptions the mathematics of Queueing Theory become intractable.\(^6\)

Simulation, on the other hand, has become increasingly used in airport planning and design because it allows one to get a fairly good representation of the real-life conditions present in the various subsystems of the airport.

Simulation was used to determine the terminal allocation at Dallas-Fort Worth in the USA.\(^7\) Also the choice between two schemes for a new terminal complex at San Francisco International Airport in the USA was made with the aid of simulation.\(^8\)

Likewise, this technique was used at Sydney International Airport, Australia to determine the demand at which an additional stand would be economically justified.\(^9\)

It seems, however, that where Simulation has been applied to apron design it has not been with the purpose of finding the number of stands required. It has been used rather to assess proposed apron layouts or stand utilization levels and delays and queues involved.

Despite the importance of stand requirements in the process of designing the apron, it is still difficult to compute them accurately or with much confidence.

The aim of this thesis is to propose a generalized procedure for computing stand requirements under conditions which exist in typical small to medium sized European airports.

To achieve this aim a model to simulate an apron under different combinations of aircraft and flight mixes is calibrated on airports
which handle from one and a half to three million passengers a year, using data from Birmingham and Manchester Airports.

From the results of the simulation of the apron a set of graphs is plotted with hourly arrivals as the independent variable and stands required as the dependent variable.

A numerical example is given to compare results obtained from the procedure put forward and the results obtained by means of deterministic formulae currently available.

Finally, a sensitivity analysis is carried out to get insight into the relevance of changes in the inputs of the model.
CHAPTER TWO
APRON SIMULATION

Although there are many variables involved in determining aircraft stand requirements, the main variables, according to previous work\(^9\), are the pattern of arrivals and time on stands.

Departure pattern from the apron is not important because departure times are a function of arrival times and stand occupancy times.

A model to simulate the apron as a generalized means for determining stand needs, would require as inputs, apart from arrival pattern and occupancy times, information on aircraft and flight mixes, maximum permissible delay and number of aircraft per day.

The model would have two main parts: generation of data and the simulation procedure itself.

The output would be the number of stands required by aircraft group as a function of the number of arrivals per hour.

Due to the time-consuming nature of manual simulation and the amount of work foreseen, it was decided that the simulation should be carried out by means of a computer.

Accordingly, the computer models described in references 8 and 9 were considered for use in this study.

The form of model which appeared to be most suitable for this research was the one developed for the study at Sydney International Airport\(^9\) because it had been made to simulate the apron only; whereas the San Francisco model\(^8\) dealt with the whole airside.

For this study some deviations from the Sydney model were regarded as necessary. In fact, in that model the number of aircraft per day was simulated inside the procedure; but for this research it was necessary to handle the number of arrivals per day as input in order to get
outputs within a desired range. Also McKenzie et al dealt with one aircraft group only; all flights were turnaround. It was necessary for this study to take into account different aircraft groups and flight types in order to be able to compute stand requirements split into aircraft categories. Finally in the Sydney case the number of stands was fixed and delays were output variables. However, for this research it was decided to work the problem the other way round; i.e. to set a maximum permissible delay and get, as output, the number of stands needed. Moreover, because in the Sydney model there was only one aircraft group the procedures were developed on the basis of stands mutually shared; for purposes of this study it was considered important to be able to analyse different apron operating rules.

These differences, and the fact that many other changes would have been necessary to be made to use the Sydney model on a different computer from the one for which it was initially built, led to the decision to develop an entirely new model to perform this research, using the Sydney concept as a starting base. The equipment available was the ICL 1904S at Loughborough University of Technology and the programs were written in FORTRAN.

Two models were developed. In Model 1 two apron handling rules were defined. The first rule stated that stands were not shared between groups and the second stated that stands were partially shared. These operating rules became optional subroutines in this model.

In the real-life situation, stands are frequently shared in different ways between aircraft groups. A reasonable approach, therefore, in the program's operational procedure, is to have aircraft from one group handled on the stands of the next largest group whenever required and possible.
Model 2 dealt with the case where stands were mutually shared.

The models' programs are shown in Appendix C. The flow chart is shown in Figure 2.

MODEL 1
Data Generation

The Monte Carlo Sampling Technique was used. This was done by means of a library subroutine with inputs of the cumulative probability functions of arrival time, aircraft group, flight type and apron occupancy time.

Firstly aircraft arrivals were generated for the desired number of aircraft to be simulated per day.

Similarly, there was a Monte Carlo generation of aircraft group, flight type and, finally, occupancy time.

To carry out the Apron Simulation phase it was necessary that the data already generated (an arrival time, aircraft group, flight type and occupancy time per aircraft) were sorted according to arrival times. This was done by means of another library subroutine.

Bearing in mind that some aircraft stay overnight on the apron and that their departure times do not depend therefore on arrival times and occupancy times as in the case of aircraft which do not stay overnight on the apron, an early morning departures procedure was set, which was similar to that which generated arrival times.

Apron Simulation

The apron stands were divided into categories, one for each aircraft group. The first stand number of the different categories was fed in such a way that stands from one category could not get mixed up...
with stands from another category as stand requirements built up during the day.

**Departures**

Generated departure times were split amongst the aircraft groups according to their share in the traffic mix, and were allocated as departure times from the respective stands starting with the first one of each category.

It was possible that no departure times were allocated to a certain aircraft group due to its small share in the mix or the small number of movements to be generated in the day, or even for both reasons. The procedure then allocated one stand only to that aircraft group so that the first aircraft belonging to the group in question would find a vacancy on arrival.

**Arrivals and Departures**

Stands not shared.- Under the operation of this subroutine the first aircraft came and found whether the first stand of those allocated to its group was still occupied by an aircraft which had stayed overnight at the airport. This was done by comparing whether its arrival time (AT) was greater than the departure time (DT) already allocated to that stand.

If AT was greater than DT, the aircraft took that stand, and the new DT from that stand was DT = AT + OT, where OT was the time the aircraft was going to stay on the apron (occupancy time).

If, on the other hand, DT was greater than AT, and there were already more stands allocated to that aircraft group, the enquiring process went on stand by stand, until in one of them DT was smaller than AT. Then the procedure was the same as stated in the previous paragraph.

If, however, all departure times (DTi) happened to be greater than AT, the minimum difference (Dmin) was found amongst the differences
\( D_1 = D_{11} - AT \). Then this minimum waiting time was compared with the maximum permissible delay, \( PD \), set to be 6 min.

If \( D_{\text{min}} \) was smaller than or equal to \( PD \), the aircraft occupied the stand where the minimum difference was found and the new departure time \( DT \) from that stand was \( DT = AT + D_{\text{min}} + OT \), where \( D_{\text{min}} \) was the delay that that aircraft was going to have. A record of the aircraft group and its delay was taken.

However, if \( D_{\text{min}} \) happened to be greater than \( PD \) then the procedure allocated a new stand for the group of the aircraft in question and the aircraft occupied that stand.

From then onwards whenever during the day another aircraft from the same group came it would take that stand into account when enquiring about vacancies and waiting times.

The same procedure was repeated at the arrival of subsequent aircraft.

When the day was over (i.e. when the last aircraft had arrived and been accommodated), the number of stands allocated to the different categories was recorded as the number of stands required to cope with that day's traffic.

Whenever, from a certain group, no aircraft were generated, then the procedure recorded zero stands required on that day for that

---

For this research it was considered appropriate to allow approximately 3 min average delay because of apron congestion so that in the event of the same aircraft being delayed at the runway and at the apron, such an aircraft would bear a total average delay of 7 min. This delay is regarded as likely to occur given the levels of demand at which airports work nowadays.

By setting a maximum permissible delay of 6 min, the average delay of 3 min was expected to be achieved as the delays should be equally distributed in the range of delays up to 6 min. Therefore a maximum permissible delay of 6 min was set.
particular group.

Stands partially shared.- The changes that this operating rule made in the Arrivals and Departures process were as follows:

If an aircraft found that there were no vacant stands in its category, instead of finding how long it had to wait until one became vacant it examined that category designated to the next largest group size and found whether there was any stand vacant there.

Only if there were no vacancies in that category did it re-examine its own category and follow the normal procedure.

When it was apparent within the routine that there could be a delay longer than was permissible, instead of the procedure allocating a new stand for that aircraft within its own group, the minimum time it had to wait to occupy a stand of the next largest group was calculated and checked to see if this was within the permissible limit. Only if that was not the case, then a new stand was allocated to the category of the aircraft in question.

The group of the largest aircraft of the mix under study followed the same procedure as that for the case of stands not shared (because there was not any group of larger aircraft).

Storing, on a daily basis, of data generated

The day was considered as a suitable time unit for purposes of achieving steady state conditions. Additionally the simulation procedure was concerned with the study of a given situation under repetitive conditions. Therefore overall averages were computed from summaries of full days.

Insignificant difference in outputs was found if a period of 50 or 25 days was set. Therefore a 25-day period was selected for the study of any given situation.
Averaged valued of the maximum number of arrivals per hour and stand requirements were computed (from information generated).

The rest of the data included in this process helped in monitoring both the Data Generation phase and delays in respect of the Apron Simulation procedure.

MODEL 2

This model was similar in many ways to Model 1; the only difference was that in Model 2 any aircraft was sent to any unoccupied position. With this model it was possible to get only total stand requirements (i.e. not stand requirements for the different aircraft groups as in the case of Model 1).
CHAPTER THREE
DATA COLLECTION

To carry out the simulation of the apron, by means of the model described in Chapter Two, it was necessary to collect information on the arrival pattern and occupancy times only.

AIRCRAFT ARRIVAL PATTERN

It was assumed that the arrival pattern was independent of aircraft sizes\(^a\) and therefore a single arrival pattern for all aircraft was used.

Grouping arrival times in 1-hour intervals, different averaged arrival patterns were obtained, by means of a computer program built for this purpose (Appendix C), with data from Birmingham Airport. These patterns were from Birmingham Airport records from January 1978 (low activity month) and August 1978 (peak month). The patterns from weekdays and weekends from August 1978 were similarly obtained from airport records.

It was found that these averaged patterns tended to be flatter than real ones. In the light of this, it was concluded that averaged patterns did not properly represent real-life conditions. Consequently it was decided to select one pattern from a typical day from a peak month. The typical day chosen came from Birmingham Airport records, August 1979.

Although Birmingham Airport works round the clock it was decided that the study should include only movements which occurred from 5:00 to 21:00 GMT. Ninety four percent of the arrivals on the typical day took place within this period and for purposes of simulating maximum stand requirements the dead night hours can be neglected.

---

\(^a\)Strictly speaking aircraft separations on arrival are dependent on aircraft sizes; but in this context arrival pattern means overall flow rates.
The typical arrival pattern was as shown in Table 3.1.

The observed distribution of arrival times was converted to a probability distribution and the cumulative distribution function was the probability of obtaining arrival times up to the time intervals given in Table 3.1, during the arrival time generation procedure, described on page 8, Chapter Two.

The probability distribution and its cumulative function were as shown in Table 3.2.

The cumulative distribution function was held constant throughout the study.

STAND OCCUPANCY TIME

Because the aim of the study was to compute the number of stands split into categories as they are relevant for stand sizing purposes, the aircraft which operated at Birmingham and Manchester Airports were split into five categories.

The classification adopted was as similar as possible to that generally accepted for apron design (Ref 2, Table 2.3). The differences between this classification and that of the FAA are that in Birmingham small aircraft such as PA-31 stayed on the apron. This group did not appear in the FAA classification; (at busier airports such small aircraft may be handled elsewhere, i.e. on a secondary apron).

Additionally the FAA classification allocated aircraft DC-8 series 63 to Group D and both DC-10 and L-1011 to Group E. In this case due to the small proportion of those aircraft in the traffic it was decided that the DC-8-63s should be put in Group 4 along with smaller DC-8s, B707s, B720s, VC10s, Tridents and IL-62s. The DC-10s were put in the same group as B747s. No L-1011s were found either at Birmingham or at Manchester.
Airports.

Because the size of aircraft is important not only in determining the size of stand required but also in relation to the time spent on apron, it was decided to take aircraft groups into account not only for purposes of aircraft mix but for purposes of recording occupancy time as well.

Apart from their size, another factor which affects the time aircraft spend on apron stands is the kind of flight.

Two kinds of flight were considered here, turnaround and through flights.

Turnaround flights are those in which aircraft are given a more complete range of services and checks while on the apron. Therefore aircraft on those flights are expected to stay longer than those of the second group.

On through flights, aircraft are given fewer services and usually stay for a shorter time at the airport than the first group.

To differentiate one type of flight from another, in airport records, flights numbers can be used.

An inbound flight number different from the outbound number, indicated a turnaround flight; if the numbers were the same a through flight was recorded.

According to the aircraft groups and flight types mentioned above, the stand occupancy times were stratified into 10 groups.

Stand occupancy times were defined as the time between "chocks on" and "chocks away". These times were recorded by the Marshalling Office at Birmingham and the corresponding office at Manchester Airport.

A sample size of 50 was set for each of the 10 groups. However

\[\text{In general terms the larger the aircraft, the longer the stay, because amongst other reasons refueling and cleaning times are longer than for smaller aircraft.}\]
because some aircraft groups and flight types were less frequent than others, it was not possible to achieve that number in three of the groupings (Table 3.4).

Because a stand cannot become vacant and immediately afterwards occupied, for purposes of apron design it is important to know not only the time aircraft spend on stands but the total time aircraft spend on the apron. Therefore, time must be allowed for manoeuvres.

According to observations made at Birmingham Airport one minute was spent on the apron as aircraft arrived and a further minute when aircraft departed; two more minutes were spent on the stands while the pushback operation and routine checks took place. Consequently to allow for manoeuvres four minutes was added to the recorded times.

A maximum of four hours was set to allow for minor mechanical repairs or any other reason that might make aircraft stay longer than usual on stands. If it was necessary for an aircraft to stay longer than four hours at the airport, it was assumed that such an aircraft would be removed from the apron, if necessary (eight percent of the B747 turnaround flights were found to be longer than four hours on the apron).

Occupancy times were grouped in 5-minute intervals and handled by means of a computer program built for this purpose (Appendix C). The cumulative probability functions, obtained in a manner similar to the case of arrival time, are shown in Table 3.5. These functions were held constant throughout the study.

Data gathered from Gatwick Airport regarding occupancy times were not used in this study because they were found longer than at airports of the size of Manchester and Birmingham. In fact Gatwick is a major terminal airport. Scheduling and overall checks may explain these observed differences. This fact suggests that occupancy times may vary.
from airport to airport and that they should be checked, if at all possible, before any study involving these times is attempted.
TABLES AND GRAPHS

The apron was simulated under a number of different mixes of aircraft and flight type.

The aircraft mixes were chosen in a way that reflected changes likely to take place across a range of airport throughputs from an airport of the size of Birmingham (1.5 million passengers a year) up to one of the size of Manchester (3.5 million). The aircraft mix at Birmingham was obtained from information contained in "Airlines Planned Air Transport Movements" for August 1979, and that of Manchester from "Manchester International Schedule of Services", for the same month.

The mixes found were as shown in Table 4.1

There is a trend for the smallest aircraft to decrease their share in the mix as airports grow, whereas for the big aircraft the contrary applies. This fact is supported by Table 4.1

The aircraft mixes chosen for the study are shown in Table 4.2

It was believed that the mixes shown in Table 4.2 covered those of airports of sizes between Birmingham and Manchester and even those for airports slightly outside this range of operations.

The flight type mixes were selected as follows 0%-100%, 25%-75%, 50%-50%, 75%-25% and 100%-0%, where the first value was the share of turnaround flights.

Four aircraft mixes and five flight type mixes made the twenty combinations under which the apron was simulated.

The number of simulated aircraft per day varied from 30 to 140\(^a\) in steps of 10.

\(^a\)From 5:00 to 21:00 GMT, Birmingham Airport handled about 50 aircraft in a typical day of a peak month, and Manchester 90.
Each combination was simulated for an equivalent of 25 days, under the three handling rules mentioned in the Chapter Two: Shared, partially shared and unshared.

The results of the simulation appear in Tables 4.3 to 4.14. These results were plotted in graph form.

These results were run through a regression program (13) and its outputs are shown in the same tables, at the bottom.

High correlation was obtained and for design purposes a linear relationship was assumed between arrivals per hour and stands required.

With information in the tables and library subroutines (14) it was possible to plot Figures 4.1 to 4.28.

By examining Figures 4.1 to 4.8, it is possible to visualize the influence of aircraft mix, percentage of turnaround flights and apron handling rules on stand requirements.

From these graphs it is possible to estimate the total number of stands required.

The graphs in Figures 4.9 to 4.28 were made to get a more detailed picture of stand requirements, as they provide information on requirements per aircraft group and include the upper 95% prediction limit and two apron handling rules; (for the case of stands not shared, observations plotted represent the outputs of the simulation procedure, full lines represent calculated values and lines with long dashes the 95% upper prediction limit. The lines with shorter dashes represent calculated values for the case of stands partially shared).

In general, by allowing stands to be partially shared savings are obtained in stand requirements for all aircraft groups but one, the one which includes the biggest aircraft.
COMPUTING STAND REQUIREMENTS

As an example, it was assumed that stand requirements at Birmingham
Airport were to be estimated given the following data:

Aircraft arrivals at the design hour = 10
Aircraft mix = 18% 67% 12% 3% 0%
Flight type mix = 75% turnaround flights

By means of the graphs

Stands mutually shared

From Figures 4.1 and 4.3, total stands required are 9 for both Mix 1
and 2. Therefore 9 was chosen for the case under study.

Dealing with total stand requirements it is normally not possible to
make an accurate interpolation between two aircraft mixes.

Stands not shared and Stands partially shared

It is necessary to interpolate between Mixes 1 (18% 74% 6% 2% 0%)
and 2 (12% 60% 16% 9% 3%) for the case of 75% turnaround flights
(Figures 4.12 and 4.17 respectively).

a) From Fig 4.12

<table>
<thead>
<tr>
<th>Mix 1</th>
<th>18% 74% 6% 2% 0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>95%</td>
<td>2.9 8.2 1.8 0.6</td>
</tr>
<tr>
<td>av</td>
<td>2.3 7.1 1.6 0.3</td>
</tr>
<tr>
<td>sps</td>
<td>1.6 6.6 1.2 0.7</td>
</tr>
</tbody>
</table>

b) From Fig 4.17

<table>
<thead>
<tr>
<th>Mix 2</th>
<th>12% 60% 16% 9% 3%</th>
</tr>
</thead>
<tbody>
<tr>
<td>95%</td>
<td>2.2 7.2 3.3 2.3</td>
</tr>
<tr>
<td>av</td>
<td>1.9 6.2 3.0 2.1</td>
</tr>
<tr>
<td>sps</td>
<td>1.2 5.6 2.2 1.6</td>
</tr>
</tbody>
</table>

c) Interpolating

<table>
<thead>
<tr>
<th>Aircraft Group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>95%</td>
<td>2.9 7.7 2.7 0.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>av</td>
<td>2.3 6.7 2.4 0.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sps</td>
<td>1.6 6.1 1.8 0.8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

d) Rounding figures

<table>
<thead>
<tr>
<th>Aircraft Group</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
</tr>
</tbody>
</table>

NOTE: 95% is the upper prediction limit, Stands not shared (SNS),
av are calculated values, SNS, and
sps, calculated values, Stands partially shared.
T = total
By means of Horonjeff's formula (3)

\[ G = \frac{V T}{U} \]

where
- \( V \) = design hour volume for arrivals or departures
- \( T \) = weighted mean occupancy time (hours)
- \( U \) = utilization factor

In this example, \( V = 10 \) and \( T \) is calculated as follows:

\[ T = (0.44 \times 0.75 + 0.45 \times 0.25) \times 0.18 + (0.87 \times 0.75 + 0.69 \times 0.25) \times 0.67 + (1.36 \times 0.75 + 1.16 \times 0.25) \times 0.12 + (1.37 \times 0.75 + 1.10 \times 0.25) \times 0.03 = 0.83 \]

Average occupancy times taken in the calculation are those which appear in Table 3.4 plus 4 min (0.07 hour).

Stands mutually shared

\( U \) is said to vary from 0.6 to 0.8

If \( U = 0.6 \)

\[ G = \frac{10 \times 0.83}{0.6} = 13.8, \text{ say 14} \]

If \( U = 0.8 \)

\[ G = \frac{10 \times 0.83}{0.8} = 10.4, \text{ say 10} \]

Groups of stands being used exclusively

\( U \) is said to vary from 0.5 to 0.6

If \( U = 0.5 \)

\[ G = \frac{10 \times 0.83}{0.5} = 16.6, \text{ say 17} \]

If \( U = 0.6 \)

\[ G = 14 \]

By means of Piper's formula (4)

\[ n = m q t \]

where
- \( m \) = design volume for arrivals and departures (aircraft/hour)
- \( q \) = proportion of arrivals (total movements)
- \( t \) = mean stand occupancy (hr)
Supposing design hour volume for departures is 3 and for arrivals, 10.

\[ n = 10 + 3 = 13 \]
\[ q = \frac{10}{13} = 0.77 \]
\[ t = 0.83 \]
\[ n = 13 \times 0.77 \times 0.83 = 8.31, \text{ say 8} \]

By means of the European based formula (5)

\[ n = 1.1m \]

where

\[ n = \text{design hour volume for arrivals and departures (aircraft/hr)} \]

In this example \( m = 13 \), therefore

\[ n = 1.1 \times 13 = 14.3, \text{ say 14} \]

By means of the model

The model was run with 50 aircraft per day. The three handling rules were applied and the 95% confidence limits for the number of stands required were computed. The results appear in Table 4.15

Results obtained by Horonjeff's method and from the European based formula are conservative, whereas results obtained from Piper's equation are low.

TESTING THE MODEL

It was decided to test the model by comparing results calculated against those that were observed. The day chosen was that which had been used for the arrival pattern.

The aircraft mix was 18% 69% 10% 3% 0%, flight type 66%-34%, and the number of aircraft arrivals 50. The results appear in Table 4.16

The "Stands partially shared" condition was not used for purposes.
of this test. The apron at Birmingham is handled in a different manner from that which is defined here as being stands partially shared (page 7).

According to Table 4, 16 stand requirements obtained from the model are acceptably close to the requirements observed on the calibration day.
CHAPTER FIVE
SENSITIVITY ANALYSIS

So far the inputs which have been changed through the study are: aircraft mix, flight type and apron handling rules. Aircraft arrival pattern and distribution of occupancy times have remained unchanged and so has maximum permissible delay.

In this chapter a sensitivity analysis of these input parameters is made.

To perform this analysis, one combination of aircraft mix and flight type was chosen: Aircraft mix 6% 46% 25% 16% 6%, 7% turnaround flights.

OCCUPANCY TIME

Taking into account observations made at Birmingham Airport, 4 min (0.07 hour) was added to actual times to allow for manoeuvres on apron and the study was carried out with those added times.

For the purposes of sensitivity analysis, the model was run with actual time distributions and its outputs are shown in Fig 5.1 and Table 5.1

By examining Table 5.1 it is possible to see that changes of 4 min in stand occupancy times can affect stand requirements up to 7%. Therefore this is not a highly sensitive variable in this context.

MAXIMUM PERMISSIBLE DELAY

To get an idea of the importance of changes in permissible delay, the model, which was run with a maximum permissible delay of 6 min throughout the study, in this analysis was run with 12 min as maximum permissible delay. The outputs are shown in Fig 5.2 and Table 5.2

Savings up to 5% can be obtained in total stand requirements if the
maximum permissible delay is raised from 6 to 12 min.

ARRIVAL PATTERN

The distributions of arrival times taken into account for this analysis are ten, as follows:

<table>
<thead>
<tr>
<th>Peak condition</th>
<th>Off peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birmingham</td>
<td></td>
</tr>
<tr>
<td>1 August 1978</td>
<td>4 January 1978</td>
</tr>
<tr>
<td>2 Weekday (21-08-79)</td>
<td>5 Weekday (28-11-78)</td>
</tr>
<tr>
<td>3 Weekend (25-08-79)</td>
<td>6 Weekend (26-11-78)</td>
</tr>
<tr>
<td>Manchester</td>
<td></td>
</tr>
<tr>
<td>7 Weekday (16-08-79)</td>
<td>9 Weekday (8-02-79)</td>
</tr>
<tr>
<td>8 Weekend (12-08-79)</td>
<td>10 Weekend (4-02-79)</td>
</tr>
</tbody>
</table>

Cumulative probability functions are shown in Table 5.3 (21-08-79 was the "typical" day chosen to get arrival pattern from for the whole study), and outputs from the simulation model appear in Table 5.4 and Fig 5.3.

Figure 5.3 shows that it is possible to get, for a given number of arrivals per hour, a wide range of answers. In fact, the range varies up to 48%.

But this statement may be misleading. What happens in fact is that there is a strong interaction between peak arrival rates, overall daily arrival patterns and stand requirements.

For example if Manchester stand requirements were studied, for a weekday in the peak month, pattern No. 7 should be chosen. In this case, 12% of the day's arrivals are likely to take place in the design hour. If the given number of aircraft per day were 90, the number of arrivals to enter the chart (Fig 5.3) should be 11, and 20 would be the number of stands required.

If under the same conditions (arrivals per day, weekday, peak month) another airport were studied, and the overall daily arrival
If, for example, in the case of Birmingham, pattern No. 2 is used, 18% of the daily arrivals are likely to take place in the design hour. Therefore the number of arrivals to enter the chart is 16, and the number of stands required 21.

There was no reason to expect that stand requirements in both cases would be the same. But the differences are not as severe as they first appeared from Figure 5.3

Following the same procedure if 50 aircraft per day were set, 12 stands would be required at Manchester and 14 at Birmingham. For 140 aircraft per day, stand requirements would be 29 and 31 respectively.

These figures confirm Steuart's findings that a more uniform pattern is always advantageous from the viewpoint of gate provision.

It is therefore important to note that it is necessary to tie arrivals per hour to overall daily arrival patterns to obtain stand requirements.

The implications of these findings are very significant. Thus it can be stated that a principal disadvantage of deterministic formulae is their inability to relate the number of arrivals per hour to the underlying overall daily arrival pattern.

This can be shown by a short example. Deterministic formulae were applied to the examples given above and the results appear in Table 5.5

By examining Table 5.5 it is possible to see that deterministic formulae based on hourly design volumes are likely to be severely inaccurate.
NUMBER OF DAYS SIMULATED

Although strictly speaking this variable is different from the ones previously mentioned in this chapter and it was thought that the number of days simulated should not affect the results, the more the days simulated the greater the reliability in the results obtained, as the standard deviation about the mean decreases.

Twenty five days were set as suitable period to perform the simulation of a given situation throughout the study. For purposes of this analysis, the model was run for 25 days again, everything else left as it was and the results were then plotted (Fig 5.4 ) together with the results obtained previously in the main part of the study.

Although a formal statistical analysis has not been carried out, apparently the differences likely to occur in the results are up to about 2% and are not considered serious. These differences may be due not only to the length of the period chosen, but to the stochastic nature of the phenomenon under study.

Therefore the results obtained using a period of 25 days can be viewed with confidence.
CHAPTER SIX
CONCLUSIONS AND FUTURE RESEARCH

By means of Simulation it was possible to represent arrival patterns and occupancy times, and this technique was shown to be a suitable procedure for computing stand requirements.

Simulation models such as that developed for this research can be run to study a specific situation or to deal more generally with a range of variation of certain input variables.

Design graphs can be constructed from information obtained from the simulation procedure. The design graphs put forward are applicable for computing stand requirements, providing the pattern of arrivals approximates to that used in this research, which is typical for a medium sized European airport.

Given an assumed typical overall daily arrival pattern, high correlation was found between stand requirements and peak arrival rates, and a linear relationship between these variables is assumed.

Stand requirements are sensitive to aircraft size, flight type and apron handling rules.

The advantages of a simulation model over the use of deterministic formulae are that aircraft mixes are considered explicitly and that there is no need for utilization factors.

The design graphs appear to be sensitive to overall daily arrival patterns; but so are the deterministic methods.

The work carried out to date has indicated that more accurate modelling of servicing times of aircraft by flight type and aircraft groupings should be done.

The sensitivity analysis of this work unearthed a problem, the interaction between peak arrival rate and overall daily arrival patterns.
The effect of this interaction should be investigated to determine whether any serious inaccuracies occur if the design graphs are used with slightly different overall daily arrival patterns.

This future research would indicate the general validity of the use of design graphs for computing stand requirements.
Table 3.1 Aircraft arrivals at Birmingham Airport on a typical day in August 1979.

<table>
<thead>
<tr>
<th>Time</th>
<th>5-6</th>
<th>6-7</th>
<th>7-8</th>
<th>8-9</th>
<th>9-10</th>
<th>10-11</th>
<th>11-12</th>
<th>12-13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrivals</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>13-14</th>
<th>14-15</th>
<th>15-16</th>
<th>16-17</th>
<th>17-18</th>
<th>18-19</th>
<th>19-20</th>
<th>20-21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrivals</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>9</td>
<td>5</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 3.2 Probability distribution of arrival times and its cumulative function.

<table>
<thead>
<tr>
<th>Time</th>
<th>5-6</th>
<th>6-7</th>
<th>7-8</th>
<th>8-9</th>
<th>9-10</th>
<th>10-11</th>
<th>11-12</th>
<th>12-13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prob</td>
<td>.00</td>
<td>.04</td>
<td>.06</td>
<td>.06</td>
<td>.04</td>
<td>.12</td>
<td>.02</td>
<td>.08</td>
</tr>
<tr>
<td>Cum Prob</td>
<td>.00</td>
<td>.04</td>
<td>.10</td>
<td>.16</td>
<td>.20</td>
<td>.32</td>
<td>.34</td>
<td>.42</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>13-14</th>
<th>14-15</th>
<th>15-16</th>
<th>16-17</th>
<th>17-18</th>
<th>18-19</th>
<th>19-20</th>
<th>20-21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prob</td>
<td>.02</td>
<td>.06</td>
<td>.10</td>
<td>.06</td>
<td>.18</td>
<td>.10</td>
<td>.04</td>
<td>.08</td>
</tr>
<tr>
<td>Cum prob</td>
<td>.44</td>
<td>.50</td>
<td>.60</td>
<td>.60</td>
<td>.76</td>
<td>.88</td>
<td>.92</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Table 3.3 Aircraft Groups.

<table>
<thead>
<tr>
<th>Aircraft Group</th>
<th>FAA(1) equivalent</th>
<th>Typical aircraft included&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>PA-31 Navajo, DHC&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>B</td>
<td>B 727, B 737, DC-9, TU-154, CVL, Convair 990, Comet</td>
</tr>
<tr>
<td>4</td>
<td>C</td>
<td>DC-8, B707, B720, VC 10, Trident, IL-62</td>
</tr>
<tr>
<td>5</td>
<td>E</td>
<td>DC-10, B 747</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>See Table 3.4 for aircraft used in calibration process.

<sup>b</sup>The aircraft included in this group were those on scheduled flights; (when there were vacancies on the apron, at Birmingham Airport, small aircraft on private flights were brought to the apron on arrival or departure. These aircraft were not taken into account, being considered beyond the scope of this study.)
Table 3.4 Stand occupancy time. Sample sizes, averages, standard deviations and airports where data were collected from.

<table>
<thead>
<tr>
<th>Aircraft Aircraft of</th>
<th>Birmingham Turnaround</th>
<th>Through</th>
<th>Manchester Turnaround</th>
<th>Through</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group which data were collected</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>PA 31 Navajo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample</td>
<td>50</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.37</td>
<td>0.38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Std dev</td>
<td>0.20</td>
<td>0.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>BAC 1-11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample</td>
<td>50</td>
<td>50</td>
<td></td>
<td></td>
</tr>
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NOTE: Times are in hours.
Table 3.5 Stand occupancy time. Cumulative probability functions.

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NOTE: Time is in hours.
Flight type 1 = turnaround
Flight type 2 = through
Table 4.1 Observed aircraft mixes.

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<th>Manchester</th>
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<td>Aug 79</td>
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<td>16%</td>
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Table 4.2 Aircraft mixes chosen for the study.

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<th>3</th>
<th>4</th>
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</table>
### Table 4.3: Total aircraft arrivals during the design hour (x) and stands required (y) for the different aircraft groups, stands not being shared between groups.

**Aircraft mix:** 18% Group 1  74% Group 2  6% Group 3  2% Group 4  0% Group 5

**Turnaround flights:**

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**NOTE:** a and b are the constants in the equation \( y^* = a + bx \), r is the correlation coefficient and se the standard error of estimate.
Table 4.4  Total aircraft arrivals during the design hour (x) and stands required (y) for the different aircraft groups, stands being partially shared between groups.

Aircraft mix: 18% Group 1 74% Group 2 6% Group 3 2% Group 4 0% Group 5

### Turnaround Flights:

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### Notes:
- a and b are the constants in the equation \( y^* = a + bx \), \( r \) is the correlation coefficient and se the standard error of estimate.
Table 4.5 Total aircraft arrivals during the design hour (x) and stands required (y), stands being mutually shared amongst the different aircraft groups.

Aircraft mix: 18% Group 1 74% Group 2 6% Group 3 2% Group 4 0% Group 5

Turnaround flights:

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<td>21.8</td>
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</tbody>
</table>

| a    | 0.59 | 0.20  | 1.41  | 0.94  | 0.99  |
| b    | 0.80 | 0.81  | 0.15  | 0.19  | 0.19  |
| r    | 0.99 | 0.99  | 1.00  | 1.00  | 1.00  |
| se   | 0.70 | 0.54  | 0.43  | 0.51  | 0.56  |

NOTE: a and b are the constants in the equation y' = a + bx, r is the correlation coefficient and se the standard error of estimate.
Table 4.5  Total aircraft arrivals during the design hour (x) and stands required (y) for the different aircraft groups, stands not being shared between groups.

Aircraft mix: 12% Group 1  60% Group 2  16% Group 3  9% Group 4  3% Group 5

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NOTE: a and b are the constants in the equation y' = a + bx, r is the correlation coefficient and se the standard error of estimate.
Table 4.7 Total aircraft arrivals during the design hour (x) and stands required (y) for the different aircraft groups, stands being partially shared between groups.

**Aircraft mix:** 12% Group 1, 60% Group 2, 16% Group 3, 9% Group 4, 3% Group 5

**Turnaround flights:**

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**NOTE:** a and b are the constants in the equation \( y' = a + bx \), r is the correlation coefficient and se is the standard error of estimate.
Table 4.8 Total aircraft arrivals during the design hour \( (x) \) and stands required \( (y) \), stands being mutually shared amongst the different aircraft groups.

**Aircraft mix:** 12% Group 1  60% Group 2  16% Group 3  9% Group 4  3% Group 5

**Turnaround flights:**

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**NOTE:** \( a \) and \( b \) are the constants in the equation \( y' = a + bx \), \( r \) is the correlation coefficient and \( se \) the standard error of estimate.
Table 4.9  Total aircraft arrivals during the design hour (x) and stands required (y) for the different aircraft groups, stands not being shared between groups.

Aircraft mix:  6 % Group 1  46 % Group 2  26 % Group 3  16 % Group 4  6 % Group 5

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NOTE: a and b are the constants in the equation \( y^* = a + bx \), \( r \) is the correlation coefficient and se the standard error of estimate.
Table 4.10 Total aircraft arrivals during the design hour (x) and stands required (y) for the different aircraft groups, stands being partially shared between groups.

Aircraft mix: 6% Group 1 46% Group 2 26% Group 3 16% Group 4 6% Group 5

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| b | 0.93 | 0.92 | 0.91 | 0.91 | 0.91 |
| r | 0.97 | 0.97 | 0.97 | 0.97 | 0.97 |
| se | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |

NOTE: a and b are the constants in the equation y' = a + bx, r is the correlation coefficient and se the standard error of estimate.
Table 4.11: Total aircraft arrivals during the design hour (x) and stands required (y), stands being mutually shared amongst the different aircraft groups.

**Aircraft mix:** 6% Group 1 46% Group 2 26% Group 3 16% Group 4 6% Group 5

**Turnaround flights:**

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**Note:** a and b are the constants in the equation y^* = a + bx, r is the correlation coefficient and se the standard error of estimate.
Table 4.12 Total aircraft arrivals during the design hour (x) and stands required (y) for the different aircraft groups, stands not being shared between groups.

Aircraft mix: 0 % Group 1 32 % Group 2 36 % Group 3 23 % Group 4 9 % Group 5

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NOTE: a and b are the constants in the equation \( y' = a + bx \), \( r \) is the correlation coefficient and \( se \) the standard error of estimate.
Table 4.13 Total aircraft arrivals during the design hour (x) and stands required (y) for the different aircraft groups, stands being partially shared between groups.

Aircraft mix: 0 % Group 1 32 % Group 2 36 % Group 3 23 % Group 4 9 % Group 5

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</table>

NOTE: a and b are the constants in the equation \( y' = a + bx \), \( r \) is the correlation coefficient and se the standard error of estimate.
Table 4.14 Total aircraft arrivals during the design hour (x) and stands required (y), stands being mutually shared amongst the different aircraft groups.

Aircraft mix: 0% Group 1 32% Group 2 36% Group 3 23% Group 4 9% Group 5

Tunraround flights:

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<th>75%</th>
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<td>0.31</td>
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NOTE: a and b are the constants in the equation \( y' = a + bx \), r is the correlation coefficient and se the standard error of estimate.
Table 4.15 Stand requirements computed in different ways.

<table>
<thead>
<tr>
<th>Handling rule</th>
<th>Graphs</th>
<th>Horonjeff</th>
<th>Piper</th>
<th>European based</th>
</tr>
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<td>2</td>
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<tr>
<td>3</td>
<td>9-15</td>
<td>14-15</td>
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</tr>
</tbody>
</table>

NOTE: Rule 1 = Stands mutually shared
Rule 2 = Stands partially shared
Rule 3 = Stands not shared

Table 4.16 Stand requirements calculated vs observed.

<table>
<thead>
<tr>
<th>Aircraft Group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stands mutually shared</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Model</td>
<td>8-10</td>
<td>9</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Observed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stands not shared</td>
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<tr>
<td>Model</td>
<td>2</td>
<td>6-7</td>
<td>2</td>
<td>1</td>
<td>11-12</td>
</tr>
<tr>
<td>Observed</td>
<td>3</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>13</td>
</tr>
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</table>
Table 5.1 Relevance of occupancy time.
Total aircraft arrivals during the design hour (x) and stands required (y).

<table>
<thead>
<tr>
<th>Occupancy time + 4 min</th>
<th>Actual occupancy time</th>
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<tbody>
<tr>
<td>x</td>
<td>y</td>
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<tr>
<td>6.6</td>
<td>10.8</td>
</tr>
<tr>
<td>7.4</td>
<td>12.4</td>
</tr>
<tr>
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<td>24.4</td>
<td>29.9</td>
</tr>
<tr>
<td>24.8</td>
<td>31.0</td>
</tr>
</tbody>
</table>

\[ y' = a + bx \]

NOTE: \(a\) and \(b\) are the constants in the equation \(y' = a + bx\).
Table 5.2 Relevance of permissible delays.
Total aircraft arrivals during the design hour (x) and stands required (y).

Maximum permissible delay

<table>
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<td>x  y</td>
<td>x  y</td>
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<tr>
<td>1.6  10.8</td>
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<td>1.4  12.7</td>
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</tr>
<tr>
<td>9.9  15.4</td>
<td>9.8  14.5</td>
</tr>
<tr>
<td>12.0 16.1</td>
<td>11.7 16.2</td>
</tr>
<tr>
<td>13.1 19.1</td>
<td>12.4 18.8</td>
</tr>
<tr>
<td>15.1 20.8</td>
<td>14.0 19.0</td>
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<td>16.6 22.1</td>
<td>17.2 21.8</td>
</tr>
<tr>
<td>19.0 24.1</td>
<td>18.6 22.5</td>
</tr>
<tr>
<td>20.5 25.1</td>
<td>20.2 24.6</td>
</tr>
<tr>
<td>21.7 27.1</td>
<td>23.0 26.6</td>
</tr>
<tr>
<td>24.1 29.9</td>
<td>26.0 28.1</td>
</tr>
<tr>
<td>24.8 31.0</td>
<td>25.0 28.5</td>
</tr>
</tbody>
</table>

a  4.66  
b  1.05  

a and b are the constants in the equation \( y' = a + bx \).
Table 5.3  Probability distributions and cumulative functions of arrival times.

<table>
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<th>Time</th>
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<th>Manchester</th>
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<tr>
<td>10-11</td>
<td>.05 .24</td>
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Table 5.4  Relevance of arrival pattern.  
Total aircraft arrivals during the design hour \((x)\) and stands required \((y)\).

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<tbody>
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<td>(x) (y)</td>
<td>(x) (y)</td>
<td>(x) (y)</td>
<td>(x) (y)</td>
<td>(x) (y)</td>
<td>(x) (y)</td>
<td>(x) (y)</td>
<td>(x) (y)</td>
<td>(x) (y)</td>
<td>(x) (y)</td>
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<td>19.9 30.2</td>
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**NOTE:** \(a\) and \(b\) are the constants in the equation \(y' = a + bx\).
Table 5.5 Relevance of the interaction between peak arrival rates, overall daily arrival patterns and stand requirements.

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<td>Fig 5.3 c</td>
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Arrivals per day 50

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<th>Stands required</th>
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Arrivals per day 90

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<tr>
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Arrivals per day 140

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<th>Stands required</th>
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<td>24</td>
</tr>
</tbody>
</table>

NOTE: The model was run under the "stands not shared" condition
Aircraft mix 5% 46% 26% 16% 6%, 75% turnaround flights
Weighted mean occupancy time = 1.1 h
U = 0.7 in Horonjeff's formula
q = 0.75 in Piper's equation
Departures were supposed to be 30% of the arrivals in the design hour
Table 5.6  Relevance of the number of days simulated.  
Total aircraft arrivals during the design hour \( (x) \) and stands required \((y)\).

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.6</td>
<td>10.8</td>
</tr>
<tr>
<td>7.4</td>
<td>13.1</td>
</tr>
<tr>
<td>9.9</td>
<td>15.4</td>
</tr>
<tr>
<td>12.0</td>
<td>16.7</td>
</tr>
<tr>
<td>13.7</td>
<td>19.1</td>
</tr>
<tr>
<td>15.1</td>
<td>20.8</td>
</tr>
<tr>
<td>16.6</td>
<td>22.1</td>
</tr>
<tr>
<td>19.0</td>
<td>24.1</td>
</tr>
<tr>
<td>20.5</td>
<td>25.7</td>
</tr>
<tr>
<td>21.1</td>
<td>27.1</td>
</tr>
<tr>
<td>24.1</td>
<td>29.9</td>
</tr>
<tr>
<td>24.8</td>
<td>31.0</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
a &= 4.66 \\
b &= 1.05
\end{align*}
\]

\[
\begin{align*}
a &= 4.73 \\
b &= 1.06
\end{align*}
\]

**NOTE:** \( a \) and \( b \) are the constants in the equation \( y' = a + bx \).
APPENDIX B

FIGURES
Figure 2 Flow Chart of Models 1 and 2.

### Input
- Aircraft mix
- Flight type mix
- Maximum permissible delay
- Aircraft per day (N)

### Data Generation
- Arrival time, Aircraft group, Flight type and Occupancy time are sorted according to arrival times

### Apron Simulation
- An aircraft enters and finds whether there is any vacant stand in the first available stand.
- The aircraft stays on the first available stand until its occupancy time is up.
- If not, it finds whether the minimum waiting time was found and it stays there until its occupancy time and the waiting time are up.
- It finds how long it has to wait until the nearest departure takes place and whether the waiting time is within the permissible limit.
- If it is, it continues to wait; if not, it is given a new stand.

### Output
- Peak arrival rate
- Stand requirements

---

*Stands partially shared condition

b There are no stand categories in Model 2
Figure 4.1 Total aircraft arrivals during the design hour and stands required.
Figure 4.2 Total aircraft arrivals during the design hour and stands required.
Figure 4.3 Total aircraft arrivals during the design hour and stands required.
Aircraft mix
12% 60% 16% 9% 3%

Figure 4.4 Total aircraft arrivals during the design hour and stands required.
Figure 4.5 Total aircraft arrivals during the design hour and stands required.
Figure 4.6 Total aircraft arrivals during the design hour and stands required.
Figure 4.7 Total aircraft arrivals during the design hour and stands required.
Figure 4.8 Total aircraft arrivals during the design hour and stands required.
Figure 4.9 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Figure 4.10 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Figure 4.11 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Aircraft mix
18% 74% 6% 2% 0%

75% Turnaround Flights

Key
+ Aircraft Group 1
v Group 2 x Group 4
Group 3 o Group 5

Figure 4.12 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Aircraft mix
18% 74% 6% 2% 0%
100% Turnaround flights

Key
+ Aircraft Group 1
v Group 2 * Group 4
o Group 3 o Group 5

Figure 4.13 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Figure 4.14 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Aircraft mix
12% 60% 16% 9% 3%

25% Turnaround Flights

Key
+ Aircraft Group 1
▼ Group 2 ★ Group 4
□ Group 3 ○ Group 5

Figure 4.15 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Aircraft mix:
12% 60% 16% 9% 3%
50% Turnaround Flights

Key
+ Aircraft Group 1
▼ Group 2 ★ Group 4
□ Group 3 ◆ Group 5

Figure 4.16 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Figure 1.17 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Figure 4.18 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Figure 4.19 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Aircraft mix
6% 46% 26% 16% 6%
25% Turnaround Flights

Key
+ Aircraft Group 1
v Group 2 * Group 4
o Group 3 o Group 5

Figure 4.20 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Figure 4.21 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Figure 4.22 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Figure 4.23 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Aircraft mix
0% 32% 36% 23% 9%

0% Turnaround Flights

Key
+ Aircraft Group 1
• Group 2 ★ Group 4
□ Group 3 ○ Group 5

Figure 4.24 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Figure 4.25 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Figure 4.26 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Figure 4.27 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Aircraft mix
0% 32% 36% 23% 9%
100% Turnaround Flights

Key
+ Aircraft Group 1
v Group 2 * Group 4
o Group 3 o Group 5

Figure 4.28 Total aircraft arrivals during the design hour and stands required for the different aircraft groups.
Figure 5.1 Total aircraft arrivals during the design hour and stands required.
Figure 5.2 Total aircraft arrivals during the design hour and stands required.

NOTE: PD = maximum permissible delay.
Relevance of arrival pattern

Figure 5.3 Total aircraft arrivals during the design hour and stands required.

NOTE: For numbers on the graph see page 25.
Relevance of the number of days simulated

Figure 5.4 Total aircraft arrivals during the design hour and stands required.
APPENDIX C

COMPUTER PROGRAMS
MASTER APRON SIMULATION

REAL MIN, MAX

DIMENSION ADPA(5), AMAX(25), AMH(5), ANNH(2), APP(21), APPR(21), A1TY(14), B(123), FT(140), II(5), KK(5), MM(5), NNN(2), NSR(5), S(1225), SAT(140), SDT(25), SOT(140), WORK1(4), WORK2(4), XMIN(5), A3(4,40), AA(40,4), AG(25,5), CC(5,2), FTT(25,2), OT5(5,2), SR(25,46), TAPP(25,21), OT5(5,2,140), OTTP(5,2,48)

COMMON/ROOM1/ AT1, AT2, AT3, AT4, AT5, FTT1, FTT2, ISUB, IUAG, NM, 1 PD, E(9), NN(5), PRST(21), X(21), XX(48), XY(9)

COMMON/ROOM2/ AADA, AADAR, AAT1, AAT2, AAT3, AAT4, AAT5, FTT1, FFT2, PD, T4, XHNS, XSD5, ADA(5), ADAR(5), APRTST(21), BPRST(21), 2REL(21), TT(5), XMN(21), XMN(2), XMN(4), XMN(5), XSS(21), XSS(2), 36, XSS(4), XSS(5), CCT(5,2), CCTR, 5,2, OTTA(5,2), 40TSS(5,2,48)

COMMON/ROOM3/ ISET, NDAS, AAT(5,2), P(5,2,48)

THT(I)=IFIX(X)*(X-IFIX(X))*60./100.

CALL G05CCF
CALL READER
DO 520 IJ=1, ISET

DATA GENERATION

C DEPARTURE TIME
DO 165 I=1, NM

148 R=0.55CAF(X)
IF(R.EQ.0.) GO TO 148
DO 150 I=5,8
IF(R.EQ.0.) GO TO 155
IF(R.GT.0.) AND.R.LT.E(I+1) GO TO 160

150 CONTINUE

155 SDT(I)=XY(I)
GO TO 165

160 SDT(I)=XY(I)*((R-F(I))*((XY(I+1)-XY(I))/(E(I+1)-E(I))))

165 CONTINUE

C ARRIVAL TIME
DO 185 I=1, NDAS

168 R=0.55CAF(X)
IF(R.EQ.0.) GO TO 168
DO 170 I=5,20
IF(R.EQ.0.) GO TO 175
IF(R.GT.0.) AND.R.LT.PRST(I+1) GO TO 180

170 CONTINUE

175 SAT(I)=XY(I)
GO TO 195

180 SAT(I)=XY(I)*((R-PRST(I))*((X(I+1)-X(I))/(PRST(I+1)-PRST(I))))

185 CONTINUE

C AIRCRAFT GROUP
DO 190 I=1, 5

190 MM(I)=0
DO 215 I=1, NDAS
R=0.55CAF(X)
IF(R.GE.AT5) GO TO 195
IF(R.GE.AT4) GO TO 200

90
IF(R, GE, AT3) GO TO 205
IF(R, GE, AT2) GO TO 210
ATVC(L)=1
MM(1)=MM(1)+1
GO TO 215
195 ATVC(L)=5
MM(5)=MM(5)+1
GO TO 215
200 ATVC(L)=4
MM(4)=MM(4)+1
GO TO 215
205 ATVC(L)=3
MM(3)=MM(3)+1
GO TO 215
210 ATVC(L)=2
MM(2)=MM(2)+1
215 CONTINUE

FLIGHT TYPE
DO 220 I=1,2
220 NNN(I)=0
DO 230 I=1,NDAS
R=GSOMAF(X)
IF(P, GE, FT2) GO TO 225
FT(1)=1
MM(1)=MM(1)+1
GO TO 230
225 FT(1)=2
MM(2)=MM(2)+1
230 CONTINUE

OCCUPANCY TIME
DO 235 N=1,5
DO 235 N=1,2
DO 235 N=1,NDAS
235 OT(K,N,1)=0.
DO 255 I=1,NDAS
233 R=GSOMAF(X)
IF(R, EQ, 0.) GO TO 238
M=ATC(L)
N=FT(L)
DO 240 I=1,47
IF(R, EQ, P(M,N,I)) GO TO 250
IF(R, GT, P(M,N,I)) AND R, LT, P(M,N,I+1)) GO TO 245
240 CONTINUE
245 SOT(L)=XX(I)+(R-P(M,N,I))*XX(I+1)-XX(I)/(P(M,N,I+1)-P(M,N,I))
OT(K,N,1)=SOT(L)
GO TO 255
250 SOT(L)=XX(I)
OT(K,N,1)=SOT(L)
255 CONTINUE

DATA SORTING ACCORDING TO ARRIVAL TIMES
DO 260 I=1,NDAS
A(1,N)=ATC(N)
A(2,N)=ATC(N)
A(3,N)=FT(N)
260 CONTINUE
A(4,N)=SOT(K)
ICOI = 1
IFAIL = 0
DO 265 J = 1, NDAS
DO 265 J = 1, 4
265 AA(1, J) = (J, 1)
CALL H01AFF(AA, NDAS, 4, ICOI, WORK1, WORK2, IFAIL)
DO 270 K = 1, NDAS
SAT(K) = AA(K, 1)
ATY(K) = AA(K, 2)
FT(K) = AA(K, 3)
270 SOT(K) = AA(K, 4)

APRON SIMULATION

WRITE(2, 685)
WRITE(2, 690) JJ
AAT1 = AT1
AAT2 = AT3 - AT2
AAT3 = AT4 - AT3
AAT4 = AT5 - AT4
AAT5 = (1.00 - AT5) + .01
FTT1 = FTT1
FTT2 = (1.00 - FTT2) + .01
WRITE(2, 695)
WRITE(2, 700)
DO 275 I = 1, 5
KK(I) = NM(I)
275 CONTINUE

DEPARTURES

NM1 = NINT(NM * AT1)
IF(NM1 .EQ. 0) GO TO 330
GO TO 370
280 NM2 = NINT(NM * AAT2)
IF(NM2 .EQ. 0) GO TO 350
NMT = NM1 + NM2
IF(NMT .LT. NM) GO TO 340
NM2 = NM - NM1
IF(NM2 .LT. 0) GO TO 350
GO TO 340
285 NM3 = NINT(NM * AAT3)
IF(NM3 .EQ. 0) GO TO 370
NMT = NM1 + NM2 + NM3
IF(NMT .LT. NM) GO TO 360
NM3 = NM - (NM1 + NM2)
IF(NM3 .LT. 0) GO TO 370
GO TO 360
290 NM4 = NINT(NM * AAT4)
IF(NM4 .EQ. 0) GO TO 390
NMT = NM1 + NM2 + NM3 + NM4
IF(NMT .LT. NM) GO TO 380
NM4 = NM - (NM1 + NM2 + NM3)
IF(NM4 .LT. 0) GO TO 390
GO TO 380

92
CONTINUE
NMT=NMT+NM2+NM3+NM4
IF(NMT.GE.NM) GO TO 310
NM5=NM-NMT
KK(5)=NM(5)+NM5-1
NMS5=NM1+NM2+NM3+NM4+1
CALL TS(S,SDT,5.0,NMS5,NM,NN(5))
GO TO 400

CONTINUE
DO 315 J=NN(5),KK(5)
S(J)=5.
315 CONTINUE
GO TO 400

CONTINUE
KK(1)=NM1
CALL TS(S,SDT,1.0,1,NM1,NN(1))
GO TO 280

CONTINUE
DO 335 J=NN(1),KK(1)
S(J)=5.
335 CONTINUE
GO TO 280

CONTINUE
KK(2)=NM(2)+NM2-1
NMS2=NM1+1
NMS52=NM1+NM2
CALL TS(S,SDT,2.0,NMS2,NMS52,NN(2))
GO TO 285

CONTINUE
DO 355 J=NN(2),KK(2)
S(J)=5.
355 CONTINUE
GO TO 285

CONTINUE
KK(3)=NM(3)+NM3-1
NMS3=NM1+NM2+1
NMS53=NM1+NM2+NM3
CALL TS(S,SDT,3.0,NMS3,NMS53,NN(3))
GO TO 290

CONTINUE
DO 375 J=NN(3),KK(3)
S(J)=5.
375 CONTINUE
GO TO 290

CONTINUE
KK(4)=NM(4)+NM4-1
NMS4=NM1+NM2+NM3+1
NMS54=NM1+NM2+NM3+NM4
CALL TS(S,SDT,4.0,NMS4,NMS54,NN(4))
GO TO 300

CONTINUE
DO 395 J=NN(4),KK(4)
S(J)=5.
395 CONTINUE
GO TO 300

CONTINUE
GO TO 300

CONTINUE
ARRIVALS AND DEPARTURES

NNSR=0
IF(ISUB.EQ.2) GO TO 410
DO 405 T=1,NDAS
CALL STANDSNOTSHARED(I,NN,KK,SAT,S,D,MIN,PD,SOT,XMIN,ATY,FT,II)
405 CONTINUE
GO TO 420

410 CONTINUE
DO 415 T=1,NDAS
CALL STANDSPARTIALLYSHARED(I,NN,KK,SAT,S,D,MIN,PD,SOT,XMIN,ATY,FT,II,IUAG)
415 CONTINUE
DO 420 I=1,5
IF(MM(I).EQ.0) GO TO 425
NSR(I)=KK(I)-NN(I)+1
GO TO 430
420 CONTINUE
DO 435 I=1,5
NNSR=NNSR+NSR(I)
435 CONTINUE
WRITE(2,710)(NSR(I),I=1,5)
WRITE(2,715)NNSR
DO 440 T=1,5
SR(JJ,J)=NSR(I)
440 CONTINUE
SR(JJ,6)=NNSR

STORING, ON A DAILY BASIS, OF DATA GENERATED

C
C ARRIVAL PATTERN
N=1
T=5.
AS=0.
IAS=AS
DO 445 I=6,21
APP(I)=0.
DO 460 I=6,21
T=T+1.
AP=N.
DO 450 J=N,NDAS
IF(IAS.EQ.NDAS) GO TO 455
IF(SAT(J)-T) 0, 0, 455
N=N+1
AP=AP+1.
APP(I)=AP
TAPP(JJ,J)=APP(I)
450 CONTINUE
455 CONTINUE
IAS=IAS+AP
IAS=AS
DO 465 K=6,21
APP(K)=APP(K)/NDAS
MAX=APP(I)
DO 470 I=7,21
IF(MAX.GE.APP(I)) GO TO 470
MAX=APP(I)

470 CONTINUE
AMAX(JJ)=MAX
WRITE(2,720)(APP(I),I=6,21)
WRITE(2,725)(APRST(I),I=6,21)
WRITE(2,730) MAX

C
C AIRCRAFT GROUP
DO 475 I=1,5
AG(JJ,I), AMM(I)=FLOAT(MM(I))/FLOAT(NDAS)
475 CONTINUE
WRITE(2,735)
WRITE(2,740) (MM(I),I=1,5)
WRITE(2,745) (AMM(I),I=1,5)

C
C FLIGHT TYPE
DO 480 I=1,2
480 FTT(JJ,I), ANN(1)=FLOAT(ANN(I))/FLOAT(NDAS)
WRITE(2,750)
WRITE(2,755) (ANN(I),I=1,2)
WRITE(2,760) (ANN(1),I=1,2).

C
C OCCUPANCY TIME
DO 490 M=1,5
DO 490 N=1,2
490 CC(M,N)=0.
DO 515 M=1,5
DO 515 N=1,2
DO 505 I=1,NDAS
T=5./60.
DO 500 J=1,48
IF(OT(M,N,I).EQ.0) GO TO 505
IF(OT(M,N,I).EQ.0) T=0.0, 495
OTPP(M,N,J)=OTPP(M,N,J)+1
OTT(M,N)=OTT(M,N)+OT(M,N,I)
CC(M,N)=CC(M,N)+1
CCT(M,N)=CCT(M,N)+1
GO TO 505

495 T=T+.5./60.
500 CONTINUE
505 CONTINUE
515 CONTINUE
WRITE(2,765)
WRITE(2,770)((CC(M,N),M=1,5),N=1,2)

520 CONTINUE
C
C SUMMARY, STORING OF DATA GENERATED DURING THE PERIOD
C
C ARRIVAL PATTERN
DO 522 I=6,21
APRST(I)=APRST(I)-PRST(I-1)
BPST(I)=APRST(I)*NDAS
DO 522 JJ=1,1SET
522 XMN(I)=XMN(I)+TAPP(JJ,I)
DO 525 I=6,21
XMN(I)=XMN(I)/1SET
REL(I)=XMN(I)/NDAS
DO 525 JJ=1,1SET
525 XSD(I)=XSD(I)+(TAPP(JJ,I)-XMN(I))*2
DO 530 I=6,21
XSD(I)=SORT(XSD(I)/1SET)
530 CONTINUE
DO 535 JJ=1,1SET
535 XMN5=XMN5+AMAX(JJ)
XMN5=XMN5/1SET
DO 540 JJ=1,1SET
540 XSD5=XSD5+(AMAX(JJ)-XMN5)*2
XSD5=SORT(XSD5/1SET)
C
C AIRCRAFT GROUP
DO 545 T=1,5
DO 545 JJ=1,1SET
545 XMN4(I)=XMN4(I)+AG(JJ,I)
DO 550 I=1,5
XMN4(I)=XMN4(I)/1SET
DO 550 JJ=1,1SET
550 XSD4(I)=XSD4(I)+(AG(JJ,I)-XMN4(I))*2
DO 555 T=1,5
XSD4(I)=SORT(XSD4(I)/1SET)
555 CONTINUE
C
C FLIGHT TYPE
DO 560 I=1,2
DO 560 JJ=1,1SET
560 XMN2(I)=XMN2(I)+FTT(JJ,I)
DO 565 I=1,2
XMN2(I)=XMN2(I)/1SET
DO 565 JJ=1,1SET
565 XSD2(I)=XSD2(I)+(FTT(JJ,I)-XMN2(I))*2
DO 570 T=1,2
XSD2(I)=SORT(XSD2(I)/1SET)
570 CONTINUE
C
C AIRCRAFT PER GROUP AND FLIGHT TYPE
DO 580 M=1,5
DO 580 N=1,2
580 CCTR(M,N)=CCT(M,N)/(NDAS*1SET)
C
C OCCUPANCY TIME
C AVERAGES
DO 585 M=1,5
DO 585 N=1,2
IF(CCTR(M,N,FO,O).LT.0.) GO TO 585
OTTA(M,N)=OTT(M,N)/CCT(M,N)
585 CONTINUE
C
C CUMULATIVE PROBABILITY FUNCTIONS
DO 587 M=1,5
DO 587 N=1,2
587 OTSS(M, N, 1) = OTPP(M, N, 1)
DO 590 M = 1, 5
DO 590 N = 1, 2
DO 590 J = 2, 48

590 OTSS(M, N, J) = OTSS(M, N, J-1) + OTPP(M, N, J)
DO 595 M = 1, 5
DO 595 N = 1, 2
DO 595 J = 1, 48
IF(CCT(M, N), .EQ., 0.) GO TO 595
OTSS(M, N, J) = OTSS(M, N, J) / CCT(M, N)
CONTINUE

C
C DELAYS
PDM = PD\* .60
C PER AIRCRAFT
DO 600 T = 1, 5
TMN = TMN + XMN(I)

600 IIT = IIT + II(I)
IF(IIT, .EQ., 0.) GO TO 610
AADPA = TMN / IIT
T4 = TIM(AADPA)
DO 605 J = 1, 5
IF(IJ(J), .EQ., 0.) GO TO 605
ADPA(J) = XMN(J) / IJ(J)
TT(J) = TIM(ADPA(J))
CONTINUE

610 CONTINUE
C
C PER DAY
AADPA = FLOAT(IIT) / FLOAT(ISET)
AADAR = AADA / NDAS
DO 615 J = 1, 5
ADPA(J) = FLOAT(IJ(J)) / FLOAT(ISET)
ADAR(J) = AADA(J) / NDAS
CONTINUE

C
C STANDS REQUIRED
DO 620 T = 1, 6
DO 620 JJ = 1, ISET

620 XMN1(I) = XMN1(I) + SR(JJ, I)
DO 625 T = 1, 6
XMN1(I) = XMN1(I) / ISET
DO 625 JJ = 1, ISET

625 XSM1(I) = XSD1(I) + (SR(JJ, I) - XMN1(I)) \* 2
CD = SQRT(FLOAT(ISET))
DO 630 T = 1, 6
XSD1(I) = SQRT(XSD1(I) / ISET)
XSM1(I) = XSD1(I) / CD
CONTINUE

C
C CALL WRITER

675 FORMAT(214)
685 FORMAT(H1, 4X, 'APRON SIMULATION')
690 FORMAT(16/13)
695 FORMAT(21X, 'AIRCRAFT AIRCRAFT FLIGHT STAND ARRIVAL DELAY 1 OCCUPANCY DEPARTURE')
1, ' TIME ')  
710 FORMAT(80X, 'STANDS REQUIRED ', 51X)  
715 FORMAT(116X, 14)  
720 FORMAT(' ARRIVALS PER HOUR ', 16F6.0)  
725 FORMAT(19X, 16F6.2)  
730 FORMAT(116X, 3.0/)  
735 FORMAT(' FLEET MIXTURE ')  
740 FORMAT(10X, 515)  
745 FORMAT(11X, 5FS.2)  
750 FORMAT(' FLIGHT TYPE ')  
755 FORMAT(12X, 215)  
760 FORMAT(13X, 2FS.2/)  
765 FORMAT(' AIRCRAFT PER GROUP AND FLIGHT TYPE ')  
770 FORMAT(10X, 5FS.0)
STOP
END
SUBROUTINE READER
COMMON/ROOM1/ AT1, AT2, AT3, AT4, AT5, FTT1, FTT2, ISUB, IUAG, NM,
1 PR, E(9), NN(5), PRST(21), XX(21), XX(48), XY(9)
COMMON/ROOM3/ ISET, NDAS, AAOT(5,2), P(5,2,48)
C DEPARTURE PATTERN, CUMULATIVE PROBABILITY FUNCTION (CPF)
READ(1,445)(XY(K),K=5,9)
READ(1,445)(F(K),K=5,9)
C ARRIVAL PATTERN, CPF
READ(1,450)(X(K), K=5,21)
READ(1,450)(PRST(K), K=5,21)
C UPPER AIRCRAFT GROUP IN THE MIXTURE AND SUBROUTINE TO BE USED
READ(1,675) IUAG, ISUB
C AIRCRAFT GROUP, CPF
READ(1,445) AT1, AT2, AT3, AT4, AT5
C FLIGHT TYPE, CPF
READ(1,480) FTT1, FTT2
C AVERAGE OCCUPANCY TIMES, IN HOURS
READ(1,455)((AAOT(M,N),N=1,2),M=1,5)
C OCCUPANCY TIME, CPF
READ(1,450)(XX(I), I=1,48)
DO 100 M=1,5
DO 100 N=1,2
100 READ(1,450)((M,N,I),I=1,48)
C MAXIMUM PERMISSIBLE DELAY PER AIRCRAFT, IN HOURS
READ(1,460) PD
C STAND ALLOCATION
READ(1,465)(NN(I), I=1,5)
C NUMBER OF ARRIVALS PER DAY TO BE SIMULATED
READ(1,670) NDAS
C NUMBER OF EARLY MORNING DEPARTURES
NM=INT(NDAS*0.14)
C NUMBER OF DAYS TO BE SIMULATED
READ(1,670) ISET
RETURN
645 FORMAT(5F0.0)
650 FORMAT(13F0.0)
655 FORMAT(10F0.0)
660 FORMAT(5F0.0)
665 FORMAT(5I4)
670 FORMAT(14)
675 FORMAT(2I4)
680 FORMAT(2F0.0)
END
SUBROUTINE TS(S,SDT,C,N1,N2,L)
DIMENSION S(175), SDT(25)
TIM(X)=FIX(X)+(X-FIX(X))*60./100.
J=L
DO 100 K=N1,N2
S(J)=SDT(K)
T=TIM(SDT(K))
WRITE(2,705) C,J,T
J=J+1
100 CONTINUE
RETURN
705 FORMAT(34X,F2.0,12X,14,35X,F5.2)
END
SUBROUTINE STANDSNOTSHARED(I, NN, KK, SAT, S, D, MIN, PD, SOT, XMIN, ATY, FT, 
     111)
     REAL MIN
     INTEGER ATY(140), D(125), FT(140), II(5), KK(5), NN(5), S(125), 
     1 SOT(140), XMIN(5)
     T1H(X) = IFIX(X) + (X - IFIX(X)) * 60. / 100.
     JK = ATY(I)
     DO 100 .J = NN(JK), KK(JK)
        IF (SAT(I) .GT. S(J)) GO TO 130
     100 CONTINUE
     DO 110 .J = NN(JK), KK(JK)
        D(J) = S(I) - SAT(I)
     110 CONTINUE
     MIN = D(NN(JK))
     K = NN(JK)
     DO 120 .J = NN(JK), KK(JK)
        IF (MIN .LE. D(J)) GO TO 120
        MIN = D(J)
        K = .J
     120 CONTINUE
     IF (MIN .GT. PD) GO TO 140
     S(K) = SAT(I) + MIN + SOT(I)
     TT = ATY(I)
     U = FT(I)
     T1 = T1H(SAT(I))
     BMIN = T1H(D(K))
     XMIN(JK) = XMIN(JK) + MIN
     II(JK) = II(JK) + 1
     T2 = T1H(SOT(I))
     T3 = T1H(S(JK))
     WRITE(2, 150) I, TT, U, K, T1, BMIN, T2, T3
     RETURN
     130 S(J) = SAT(I) + SOT(I)
     K = .J
     TT = ATY(I)
     U = FT(I)
     T1 = T1H(SAT(I))
     T2 = T1H(SOT(I))
     T3 = T1H(S(JK))
     WRITE(2, 160) I, TT, U, K, T1, T2, T3
     RETURN
     140 KK(JK) = KK(JK) + 1
     S(KK(JK)) = SAT(I) + SOT(I)
     K = KK(JK)
     TT = ATY(I)
     U = FT(I)
     T1 = T1H(SAT(I))
     T2 = T1H(SOT(I))
     T3 = T1H(S(KK(JK)))
     WRITE(2, 160) I, TT, U, K, T1, T2, T3
     RETURN
     150 FORMAT(23X, I4, 7X, F2.0, 7X, F2.0, 3X, I4, 6X, F5.2, 5X, F4.2, 4X, F5.2, 6X, F5.2)
     160 FORMAT(23X, I4, 7X, F2.0, 7X, F2.0, 3X, I4, 6X, F5.2, 14X, F4.2, 6X, F5.2)
     END

101
SUBROUTINE STANDSPARTIALLYSHARED(I, NN, KK, SAT, S, D, MIN, PD, SOT, XMIN, AITY, FT, IJ, IUAG)
REAL MIN
DIMENSION AITY(140), D(125), FT(140), II(5), KK(5), NN(5), S(125),
SAT(140), SOT(140), XMIN(5)
TIM(X)=FIX(X)+(X-FIX(X))*60./100.
JK=ATY(I)
DO 100 J=NN(JK),KK(JK)
IF(SAT(I).GT.S(J)) GO TO 140
100 CONTINUE
IF(JK.EQ.IUAG) GO TO 110
JK=JK+1
GO TO 170
110 CONTINUE
DO 120 J=NN(JK),KK(JK)
D(J)=S(J)-SAT(I)
120 CONTINUE
MIN=D(NN(JK))
K=NN(JK)
DO 130 J=NN(JK),KK(JK)
IF(MIN.EQ.D(J)) GO TO 130
MIN=D(J)
K=J
130 CONTINUE
IF(MIN.GT.PD) GO TO 150
S(K)=SAT(I)+MIN+SOT(I)
TT=ATY(I)
U=FT(I)
T1=TIM(SAT(I))
BMIN=TIM(N(K1))
XMIN(JK)=XMIN(JK)+MIN
II(JK)=II(JK)+1
T2=TIM(SOT(I))
T3=TIM(S(K))
WRITE(2,230) I, TT, U, K, T1, BMIN, T2, T3
RETURN
140 S(J)=SAT(I)+SOT(I)
K=J
TT=ATY(I)
U=FT(I)
T1=TIM(SAT(I))
T2=TIM(SOT(I))
T3=TIM(S(K))
WRITE(2,240) I, TT, U, K, T1, T2, T3
RETURN
150 CONTINUE
IF(JK.EQ.IUAG) GO TO 160
JK=JK+1
GO TO 100
160 KK(JK)=KK(JK)+1
S(KK(JK))=SAT(I)+SOT(I)
K=KK(JK)
TT=ATY(I)
U=FT(I)
T1=TIM(SAT(I))
T2=TIM(SOT(I))
T3=TIM(S(KK(JK)))
```
WRITE(2,240) I, TT, U, K, T1, T2, T3
RETURN
170 CONTINUE
DO 180 J=NN(JK),KK(JK)
   IF(SAT(I).GT.S(J)) GO TO 140
180 CONTINUE
   JK=JK-1
   GO TO 110
190 CONTINUE
DO 200 J=NN(JK),KK(JK)
   D(J)=S(J)-SAT(I)
200 CONTINUE
   MIN=D(NN(JK))
   K=NN(JK)
   DO 210 J=NN(JK),KK(JK)
      IF(MIN.IF.D(J)) GO TO 210
      MIN=D(J)
      K=J
   210 CONTINUE
   IF(MIN.GT.PD) GO TO 220
   S(K)=SAT(I)+MIN+SOT(I)
   TT=ATV(I)
   U=FT(I)
   T1=TIM(SAT(I))
   BMIN=TIM(D(K))
   XMIN(JK-1)=XMIN(JK-1)+MIN
   IT(JK-1)=IT(JK-1)+1
   T2=TIM(SOT(I))
   T3=TIM(SAT(I))
   WRITE(2,230) I, TT, U, K, T1, BMIN, T2, T3
RETURN
220 CONTINUE
   JK=JK-1
   GO TO 160
230 FORMAT(73X,14.7X,F2.0,7X,F2.0,3X,14,6X,F5.2,5X,F4.2,4X,F5.2,6X,F5.2)
240 FORMAT(73X,14.7X,F2.0,7X,F2.0,3X,14,6X,F5.2,14X,F4.2,6X,F5.2)
END
```
SUBROUTINE WRITER

COMMON /ROOM2/ AADA, AADAR, AAT1, AAT2, AAT3, AAT4, AAT5, FFTT1, FFTT2, PD, T4, XMN5, XSS5, ADA(5), ADAR(5), PRST(21), BPRST(21), 2REL(21), FT(5), XMN(21), XMN1(6), XMN2(2), XMN4(5), XSSD(21), XSSD(36), XSSD(6), XSSD(2), XSSD(5), CCT(5,2), CCTR(5,2), OTTA(5,2), OTSS(5,2,48)

COMMON /ROOM3/ ISET, NDAS, AAOT(5,2), P(5,2,48)

WRITE (2,775)
WRITE (2,780), ISET
WRITE (2,785), NDAS
WRITE (2,800) (XMN4(I), I=1,5)
WRITE (2,805) (XMN2(I), I=1,2)
WRITE (2,810), XMN5
WRITE (2,815) XSS5
WRITE (2,820) (XMN4(I), I=1,6)
WRITE (2,825) (XSSD(I), I=1,6)
WRITE (2,825) (XMN4(I), I=1,6)
WRITE (2,830)
WRITE (2,835)
WRITE (2,840)
WRITE (2,845) (APRST(K), K=6,21)
WRITE (2,850) (BPRST(K), K=6,21)
WRITE (2,855) (REL(I), I=6,21)
WRITE (2,860) (XMN(I), I=6,21)
WRITE (2,865) (XSSD(I), I=6,21)
WRITE (2,875) XMN5, XSS5
WRITE (2,735)
WRITE (2,745) AAT1, AAT2, AAT3, AAT4, AAT5
WRITE (2,745) (XMN4(I), I=1,5)
WRITE (2,745) (XSSD4(I), I=1,5)
WRITE (2,750)
WRITE (2,870), FFTT1, FFTT2
WRITE (2,870) (XMN2(I), I=1,2)
WRITE (2,870) (XSSD2(I), I=1,2)
WRITE (2,765)
WRITE (2,785) (CCT(M,N), M=1,5), N=1,2)
WRITE (2,745) (CCTR(M,N), M=1,5), N=1,2)
WRITE (2,880)
WRITE (2,885)
WRITE (2,745) (AAOT(M,N), M=1,5), N=1,2)
WRITE (2,745) (OTTA(M,N), M=1,5), N=1,2)
WRITE (2,790)
DO 440 M=1,5
DO 440 N=1,2
WRITE (2,675) M,N
WRITE (2,895) (P(M,N,J), J=1,48)
WRITE (2,895) (OTSS(M,N,J), J=1,48)

440 CONTINUE

WRITE (2,900)
WRITE (2,905)
WRITE (2,910)
WRITE (2,915) PD
WRITE (2,920) (TT(I), I=1,5), T4
WRITE (2,925) (ADA(I), I=1,5), AADA
WRITE (2,930) (ADAR(I), I=1,5), AADAR
RETURN

675 FORMAT(214)
725  FORMAT(19X,16F6.2) 
735  FORMAT(//' FLIGHT MIX '/) 
745  FORMAT(11X,5F6.2) 
750  FORMAT(//' FLIGHT TYPE '/) 
755  FORMAT(//' AIRCRAFT PER GROUP AND FLIGHT TYPE '/) 
765  FORMAT(1H1,12X,44X,' A P R O N S I M U L A T I O N ') 
780  FORMAT(///, ' NUMBER OF DAYS SIMULATED ',10X,14/) 
785  FORMAT(//' AIRCRAFT PER DAY ',15X,14/) 
800  FORMAT(//' FLIGHT MIX ',4X,5F5.2/) 
805  FORMAT(//' FLIGHT TYPE ',4X,2F5.2/) 
810  FORMAT(78X,' MAXIMUM NUMBER OF ARRIVALS PER HOUR ',F5.1) 
815  FORMAT(75X,F5.2/) 
820  FORMAT(40X,' STANDS REQUIRED ',5F6.1,5X,F6.1) 
825  FORMAT(78X,5F6.2,5X,F6.2) 
830  FORMAT(1H1,7('), DATA GENERATION CHECK ////) 
835  FORMAT(//' ARRIVAL PATTERN '/) 
840  FORMAT(//' ARRIVALS/TIME 5-6 6-7 7-8 8-9 9-10 10-11 11-12 12-13 13-14 14-15 15-16 16-17 17-18 18-19 19-20 20-21 '/) 
845  FORMAT(//' OBSERVED ',9X,16F6.2) 
850  FORMAT(18X,16F6.0) 
855  FORMAT(//' GENERATED ',8X,16F6.2) 
860  FORMAT(19X,16F6.1) 
865  FORMAT(104X,F5.1,F6.2) 
870  FORMAT(13X,2F5.2) 
875  FORMAT(11X,5F6.0) 
880  FORMAT(//' OCCUPANCY TIME '/) 
885  FORMAT(//' AVERAGES '/) 
890  FORMAT(//' CUMULATIVE PROBABILITY FUNCTIONS '/) 
895  FORMAT(74F5.2) 
900  FORMAT(//' DELAYS '/) 
905  FORMAT(//' DELAYS/AIRCRAFT GROUP 1 2 3 4 5 ' ALL ') 
910  FORMAT(//' PER AIRCRAFT ') 
915  FORMAT(5X,' MAXIMUM ',5X,F5.2) 
920  FORMAT(5X,' AVERAGE ',10X,5F7.2,12X,F7.2) 
925  FORMAT(//' PER DAY ',15X,5F7.1,11X,F7.1) 
930  FORMAT(24X,5F7.2,12X,F7.2) 
END
MASTER APRON SIMULATION

REAL MIN, MAX

DIMENSION ADPA(5), AMAX(25), AMMN(2), NNNN(2), APPR(21), APPR(21), A1TY(140), B1(125), FF1(140), II(5), NM(5), NNNN(2), NSR(5), S1(125), SA2T(140), SDT(25), SNT(140), SR(25), WORK1(4), WORK2(4), XMIN(5), A3(4,40), A4(40,4), A5(25,5), CC(5,2), FTT(25,2), OTT(5,2), TAPP(245,21), OTT(5.2,140), OTTP(5.7,48)

COMMON/ROOM/ AT1, AT2, AT3, AT4, AT5, FFT1, FFT2, NM, PD, E(9), P1RST(21), X(21), XX(48), XY(9)

COMMON/ROOM2/ AADA, AADAR, AAT1, AAT2, AAT3, AAT4, AAT5, FFT1, FF1T2, PDM, T4, XMN1, XMN5, XSD1, XSD1R, XSD5, ADA(5), ADAR(5), APR2ST(21), BPRST(21), REL(21), TT(5), XMN(21), XMN4(5), XSD(321), XSN2(2), XSN4(5), CCT(5,2), CCTR(5,2), OTTA(5,2), OTSS(5,2,448)

COMMON/ROOM3/ ISET, NDAS, AAT(5,2), P(5,2,48)

TIM(X)=IFIX(X)*(X-IFIX(X))*60./100.

CALL G5CCF

CALL REAEC

DO 385 JJ=1,1SET

DATA GENERATION

DEPARTURE TIME

DO 160 L=1, NM

143 R=G5CAF(X)

IF(R.EQ.0.) GO TO 143

DO 145 I=5,8

IF(R.GT.E(1).AND.R.LT.E(I+1)) GO TO 155

145 CONTINUE

150 SDT(L)=XY(I)

GO TO 160

155 SDT(L)=XY(I)+((R-E(I))*XY(I+1)-XY(I))/((E(I+1)-E(I))

160 CONTINUE

ARRIVAL TIME

DO 180 L=1, NDAS

163 R=G5CAF(X)

IF(R.EQ.0.) GO TO 163

DO 165 I=5,20

IF(R.EQ.PRST(I)) GO TO 170

IF(R.GT.PRST(I).AND.R.LT.PRST(I+1)) GO TO 175

165 CONTINUE

170 SAT(L)=X(I)

GO TO 180

175 SAT(L)=X(I)+((R-PRST(I))*X(I+1)-X(I))/((PRST(I+1)-PRST(I)))

180 CONTINUE

AIRCRAFT GROUP

DO 185 I=1,5

MM(I)=0

185 CONTINUE

DO 210 L=1, NDAS

R=G5CAF(X)

IF(R.GE.AT5) GO TO 190
IF(R.GE.AT4) GO TO 195
IF(R.GE.AT3) GO TO 200
IF(R.GE.AT2) GO TO 205

ATV(L)=1
MM(1)=MM(1)+1
GO TO 210

190 ATV(L)=5
MM(5)=MM(5)+1
GO TO 210

195 ATV(L)=4
MM(4)=MM(4)+1
GO TO 210

200 ATV(L)=3
MM(3)=MM(3)+1
GO TO 210

205 ATV(L)=2
MM(2)=MM(2)+1

210 CONTINUE

C
C FLIGHT TYPE
DO 215 I=1,2

215 NNN(I)=0
DO 225 L=1,NDAS
R=G05CAF(X)
IF(R.GE.FT2) GO TO 220
FT(I)=1
NNN(I)=NNN(I)+1
GO TO 225

220 FT(I)=2
NNN(2)=NNN(2)+1

225 CONTINUE

C
C OCCUPANCY TIME
DO 230 M=1,5
DO 230 N=1,2
DO 230 L=1,NDAS

230 OT(M,N,L)=0.
DO 250 L=1,NDAS

R=G05CAF(X)
IF(R.EQ.0.) GO TO 232
M=ATY(L)
N=FT(L)
DO 235 I=1,47
IF(R.EQ.P(M,N,I)) GO TO 245
IF(R.GT.P(M,N,I).AND.R.LT.P(M,N,I+1)) GO TO 240

235 CONTINUE

240 SOT(L)=XX(I)+((R-P(M,N,I))*XX(I+1)-XX(I))/(P(M,N,I+1)-P(M,N,I))
OT(M,N,L)=SOT(L)
GO TO 250

245 SOT(L)=XX(I)
OT(M,N,L)=SOT(L)

250 CONTINUE

C
C DATA SORTING ACCORDING TO ARRIVAL TIMES
DO 255 M=1,NDAS
A(1,N)=CAT(N)
A(2,N)=ATY(N)

255 CONTINUE
A(3,N)=T(N)
A(4,N)=SOT(N)
ICOL=1
IFAIL=0
DO 260 J=1,NDAS
DO 260 J=1,4
260 AA(I,J)=A(I,J)
CALL H01AFF(AA,NDAS,4,ICOL,WORK1,WORK2,IFAIL)
DO 265 K=1,NDAS
SAT(K)=AA(K,1)
ATV(K)=AA(K,2)
FT(K)=AA(K,3)
SOT(K)=AA(K,4)

APRON SIMULATION
WRITE(2,2540)
WRITE(2,2545) JJ
AAT1=AT1
AAT2=AT3-AT2
AAT3=AT4-AT3
AAT4=AT5-AT4
AAT5=(1.00-AT5)*.01
FFTT1=FTT1
FFTT2=(1.00-FTT2)*.01
WRITE(2,2550)
WRITE(2,2555)

DEPARTURES
JK=KM
DO 270 J=1,KK
S(J)=SDT(J)
T=TIM(SOT(J))
WRITE(2,2560) J, T
270 CONTINUE

ARRIVALS AND DEPARTURES
DO 305 J=1,NDAS
JK=ATY(I)
DO 275 J=1,KK
IF(SAT(J).GT.S(J)) GO TO 295
275 CONTINUE
DO 280 J=1,KK
280 D(J)=S(J)-SAT(I)
MIN=D(J)
K=1
DO 285 J=1,KK
IF(MIN.LT.D(J)) GO TO 285
MIN=D(J)
K=J
285 CONTINUE
IF(K.EQ.1) GO TO 290
IF(MIN.GT.P(J)) GO TO 300
S(K)=SA(I)+MIN+SOT(I)
T=ATV(I)
U=FT(I)
T1=TIM(SAT(I))
BMIN=TIM(D(K))
XMIN(JK)=XMIN(JK)+MIN
II(JK)=II(JK)+1
T2=TIM(SOT(I))
T3=TIM(S(K))
WRITE(2.565) I, T, U, K, T1, BMIN, T2, T3
GO TO 305

290 CONTINUE
IF(MIN.GT.PD) GO TO 300
S(I)=SAT(I)+MIN+SOT(I)
T=ATY(I)
U=FT(I)
T1=TIM(SAT(I))
AMIN=TIM(D(I))
XMIN(JK)=XMIN(JK)+MIN
II(JK)=II(JK)+1
T2=TIM(SOT(I))
T3=TIM(S(I))
WRITE(2.565) I, T, U, K, T1, AMIN, T2, T3
GO TO 305

295 S(J)=SAT(I)+SOT(I)
K=J
T=ATY(I)
U=FT(I)
T1=TIM(SAT(I))
T2=TIM(SOT(I))
T3=TIM(S(J))
WRITE(2.570) I, T, U, K, T1, T2, T3
GO TO 305

300 KK=KK+1
S(KK)=SAT(I)+SOT(I)
T=ATY(I)
U=FT(I)
T1=TIM(SAT(I))
T2=TIM(SOT(I))
T3=TIM(S(KK))
WRITE(2.570) I, T, U, KK, T1, T2, T3
GO TO 305

305 CONTINUE
WRITE(2.575) KK
SRC(JJ)=KK
C

C STORING ON A DAILY BASIS, OF DATA GENERATED
C
C ARRIVAL PATTERN
N=1
T=S.
AS=D.
IAS=AS
DO 310 I=6,24

310 APP(I)=0.
DO 325 I=6,24
T=T+1.
AP=0.
DO 315 J=N, NDAS
IF(IAS.EQ.NDAS) GO TO 320
IF(SAT(J)-T) 0, 0, 320
N=N+1
AP=AP+1
APP(I)=AP
TAPP(JJ,1)=APP(I)
315 CONTINUE
320 CONTINUE
AS=AS+AP
IAS=IAS
325 CONTINUE
DO 330 K=6,21
330 APPR(K)=APP(K)/NDAS
MAX=APP(6)
DO 335 I=7,21
IF(MAX.GE.APP(I)) GO TO 335
MAX=APP(I)
335 CONTINUE
AMAX(JJ)=MAX
WRITE(2,580)(APP(I),I=6,21)
WRITE(2,585)(APPR(I),I=6,21)
WRITE(2,590) MAX
C
C AIRCRAFT GROUP
DO 340 I=1,5
AG(JJ,1),AMM(I)=FLOAT(MM(I))/FLOAT(NDAS)
340 CONTINUE
WRITE(2,595)
WRITE(2,600) (MM(I),I=1,5)
WRITE(2,605) (AMM(I),I=1,5)
C
C FLIGHT TYPE
DO 345 I=1,2
345 FTT(JJ,2),ANNN(I)=FLOAT(NNN(I))/FLOAT(NDAS)
WRITE(2,610)
WRITE(2,615) (NNN(I),I=1,2)
WRITE(2,620) (ANNN(I),I=1,2)
C
C OCCUPANCY TIME
DO 355 H=1,5
DO 355 N=1,2
355 CC(M,N)=0.
DO 380 H=1,5
DO 380 N=1,2
DO 370 I=1,NDAS
T=S/60
DO 365 J=1,48
IF(DT(M,N,I).EQ.0) GO TO 370
IF(DT(M,N,I)-T) 0, 0, 360
OTP(M,N,J)=OTP(M,N,J)+1
OTT(M,N)=OTT(M,N)+OT(M,N,I)
CC(M,N)=CC(M,N)+1
CCT(M,N)=CCT(M,N)+1
GO TO 370
360 T=T+S/60.
365 CONTINUE
CONTINUE

WRITE(2,425)
WRITE(2,430)((CC(H,N),M=1,5),N=1,2)

CONTINUE

SUMMARY. STORING OF DATA GENERATED DURING THE PERIOD

ARRIVAL PATTERN
DO 390 I=6,21
APRSS(T(I)=PRST(T(I)-PRST(T(I-1))
BPRST(T(I)=APRSS(T(I)*NDAS
DO 390 JJ=1,ISET
390 XMN(I)=XMN(I)+TAPP(JJ,I)
DO 395 J=6,21
XMN(I)=XMN(I)/ISET
RLL(I)=XMN(I)/NDAS
DO 395 JJ=1,ISET
395 XSD(J)=XSD(J)+(TAPP(JJ,I)-XMN(I))**2
DO 400 J=6,21
XSD(I)=SORT(XSD(I)/ISET)

CONTINUE

DO 405 JJ=1,ISET
405 XMN5=XMN5+AMAX(JJ)
XMN5=XMN5/ISET
DO 410 JJ=1,ISET
410 XSD5=XSD5+(AMAX(JJ)-XMN5)**2
XSD5=SQRT(XSD5/ISET)

AIRCRAFT GROUP
DO 415 JJ=1,15

DO 415 JJ=1,1SET
415 XMN4(I)=XMN4(I)+AG(JJ,I)
DO 420 JJ=1,15
XMN4(I)=XMN4(I)/ISET
DO 420 JJ=1,1SET
420 XSD4(I)=XSD4(I)+(AG(JJ,I)-XMN4(I))**2
DO 425 J=1,15
XSD4(I)=SORT(XSD4(I)/ISET)

CONTINUE

FLIGHT TYPE
DO 430 J=1,12
DO 430 JJ=1,1SET
430 XMN2(I)=XMN2(I)+FTT(JJ,I)
DO 435 J=1,12
XMN2(I)=XMN2(I)/ISET
DO 440 JJ=1,1SET
440 XMN2(I)=XMN2(I)/ISET
DO 440 J=1,12
DO 440 JJ=1,1SET
440 XSD2(I)=XSD2(I)+(FTT(JJ,I)-XMN2(I))**2
DO 445 J=1,12
XSD2(I)=SORT(XSD2(I)/ISET)

CONTINUE

AIRCRAFT PER GROUP AND FLIGHT TYPE
DO 450 M = 1, 5
DO 450 N = 1, 2
C
CCRT(M, N) = CCT(M, N) / (NDAS * ISET)
C
C OCCUPANCY TIME
C AVERAGES
DO 455 M = 1, 5
DO 455 N = 1, 2
IF (CCT(M, N) .EQ. 0.0) GO TO 455
OTT(A(M, N)) = OTT(M, N) / CCT(M, N)
455 CONTINUE
C
C CUMULATIVE PROBABILITY FUNCTIONS
DO 458 M = 1, 5
DO 458 N = 1, 2
458 OTSS(M, N, 1) = OTPP(M, N, 1)
DO 460 M = 1, 5
DO 460 N = 1, 2
DO 460 J = 2, 4
460 OTSS(M, N, J) = OTSS(M, N, J-1) + OTPP(M, N, J)
465 CONTINUE
IF (CCT(M, N) .EQ. 0.0) GO TO 465
OTT(M, N, J) = OTSS(M, N, J) / CCT(M, N)
465 CONTINUE
C
C DELAYS
PDN = PD * 60
PER AIRCRAFT
DO 470 I = 1, 5
TMN = TMN + XMIN(I)
476 II = II + II(J)
IF (II .LT. II(J)) GO TO 480
AADPA = TMN / II
T4 = TM(CAADPA)
DO 475 J = 1, 5
IF (II(J) .LT. II) GO TO 475
AADPA(J) = XMIN(J) / II(J)
T(J) = TM(AADPA(J))
475 CONTINUE
480 CONTINUE
C
PER DAY
AADF = FLOAT(II) / FLOAT(ISET)
AADAR = AADA / NDAS
DO 485 I = 1, 5
AAD(J) = FLOAT(II(J)) / FLOAT(ISET)
AADAR(J) = AADA(J) / NDAS
485 CONTINUE
C
C STANDS REQUIRED
DO 490 JJ = 1, IISET
490 XMM1 = XM * 1 + SR(JJ)
XMM1 = XM * 1 / ISET
DO 495 JJ = 1, IISET
495 X:0.1 = X:0.1 + (SR(JJ) - XMM1) * 2
CD = SQRT(FLOAT(ISET))
CALL WRJTR

502 FORMAT(714)
540 FORMAT(1H1, 45X, 'APRON SIMULATION '///)
545 FORMAT///13)
550 FORMAT(71X, 'AIRCRAFT AIRCRAFT FLIGHT STAND ARRIVAL DELAY'
10OCUPANCY DEPARTURE ')
555 FORMAT(72X, 'NUMBER GROUP TYPE ', 11X, ' TIME ', 13X, ' TIME ', 4X'
1 ', ' TIME ')
560 FORMAT(48X, 14, 35X, F5.2)
565 FORMAT(73X, 14, 7X, F2.0, 7X, F2.0, 3X, I4, 6X, F5.2, 5X, F4.2, 4X, F5.2, 6X, F5.2)
570 FORMAT(73X, 14, 7X, F2.0, 7X, F2.0, 3X, I4, 6X, F5.2, 14X, F4.2, 6X, F5.2)
575 FORMAT(80X, ' STANDS REQUIRED ', 514)
580 FORMAT(' ARRIVALS PER HOUR ', 16F6.0)
585 FORMAT(19X, 16F6.2)
590 FORMAT(115X, F3.0)
595 FORMAT(///FLIGHT MIX ')
600 FORMAT(10X, 515)
605 FORMAT(11X, 5F5.2)
610 FORMAT(///FLIGHT TYPE ')
615 FORMAT(12X, 215)
620 FORMAT(13X, 2F5.2)
625 FORMAT(///AIRCRAFT PER GROUP AND FLIGHT TYPE ')
630 FORMAT(5F5.0)
STOP
END
SUBROUTINE READER
COMMON/ROOM1/ AT1, AT2, AT3, AT4, AT5, FTT1, FTT2, NM, PD, E(9), P
1RST(21), X(21), XX(48), XY(9)
COMMON/ROOM3/ ISET, NDAS, AAOT(5,2), P(5,2,48)
C DEPARTURE PATTERN, CUMULATIVE PROBABILITY FUNCTION (CPF)
READ(1,505) (XY(K), K=5,9)
READ(1,505) (F(K), K=5,9)
C ARRIVAL PATTERN, CPF
READ(1,510) (X(K), K=5,21)
READ(1,510) (PRST(K), K=5,21)
C AIRCRAFT GROUP, CPF
READ(1,505) AT1, AT2, AT3, AT4, AT5
C FLIGHT TYPE, CPF
READ(1,530) FTT1, FTT2
C AVERAGE OCCUPANCY TIMES, IN HOURS
READ(1,515) (AAOT(M,N), N=1,2, M=1,5)
C OCCUPANCY TIME, CPF
READ(1,510) (XX(I), I=1,48)
DO 100 J=1,5
DO 100 K=1,2
100 READ(1,510) (P(M,N,K), K=1,48)
C MAXIMUM PERMISSIBLE DELAY PER AIRCRAFT, IN HOURS
READ(1,520) PD
C NUMBER OF ARRIVALS PER DAY TO BE SIMULATED
READ(1,525) NDAS
C NUMBER OF EARLY MORNING DEPARTURES
NM=INT(NDAS*0.14)
C NUMBER OF DAYS TO BE SIMULATED
READ(1,525) ISET
RETURN
505 FORMAT(5F0.0)
510 FORMAT(13F0.0)
515 FORMAT(10F0.0)
520 FORMAT(F0.0)
525 FORMAT(14)
530 FORMAT(2F0.0)
END
SUBROUTINE WRITER
COMMON/ROOM2/ AADA, AADAR, AAT1, AAT2, AAT3, AAT4, AAT5, FFTT1, FFTT2, PDM, T4, XMN1, XMN5, XSD1, XSD1R, XSD5, ADA(5), ADAR(5), APR2ST(21), BPRST(21), REL(21), TT(5), XMN(21), XMN2(2), XMN4(5), XSD(321), XSD2(2), XSD4(5), CCT(5,2), CCTR(5,2), OTTA(5,2), OTSS(5,2,448)

COMMON/ROOM3/ JSET, NDAS, AAO(5,2), P(5,2,48)

WRITE(2,635)
WRITE(2,640) JSET
WRITE(2,645) NDAS
WRITE(2,650) (XMN4(1),I=1,5)
WRITE(2,655) (XMN2(1),I=1,2)
WRITE(2,660) XMN5
WRITE(2,665) XSD5
WRITE(2,670) XMN1
WRITE(2,675) XSD1
WRITE(2,675) XSD1R
WRITE(2,680)
WRITE(2,685)
WRITE(2,690)
WRITE(2,695) (APRST(K),K=6,21)
WRITE(2,700) (BPRST(K),K=6,21)
WRITE(2,705) (REL(I),I=6,21)
WRITE(2,710) (XMN(I),I=6,21)
WRITE(2,585) (XSD(I),I=6,21)
WRITE(2,715) XMN5, XSD5
WRITE(2,595)
WRITE(2,605) AAT1, AAT2, AAT3, AAT4, AAT5
WRITE(2,605) (XMN4(1),I=1,5)
WRITE(2,605) (XSD4(1),I=1,5)
WRITE(2,610)
WRITE(2,620) FFTT1, FFTT2
WRITE(2,620) (XMN2(1),I=1,2)
WRITE(2,620) (XSD2(1),I=1,2)
WRITE(2,625)
WRITE(2,720) ((CCT(M,N),M=1,5),N=1,2)
WRITE(2,605) ((CCTR(M,N),M=1,5),N=1,2)
WRITE(2,725)
WRITE(2,730)
WRITE(2,605) ((AAOT(M,N),M=1,5),N=1,2)
WRITE(2,605) ((OTTA(M,N),M=1,5),N=1,2)
WRITE(2,735)
DO 500 M=1,5
DO 500 N=1,2
WRITE(2,500) M,N
WRITE(2,740) (P(M,N,J),J=1,48)
WRITE(2,740) (OTSS(M,N,J),J=1,48)
500 CONTINUE
WRITE(2,745)
WRITE(2,750)
WRITE(2,755)
WRITE(2,760) PDM
WRITE(2,745) (TT(I),I=1,5), T4
WRITE(2,770) (ADA(I),I=1,5), AADA
WRITE(2,775) (ADAR(I),I=1,5), AADAR
RETURN
500 FORMAT(2I4)
MASTER ARRIVAL PATTERN
DIMENSION APT(25), AST(25), PRST(25), PRT(25), X(25), APP(31,25),
1: ASS(31,25), AT(31,60), PR(31,25), PRP(31,25)
CALL LP120
READ(1,300) IIT, IFT
C IIT, INITIAL TIME IFIT, FINAL TIME
READ(1,290) NDD
C NDD, NUMBER OF DAYS CONSIDERED
WRITE(2,250)
WRITE(2,260) IIT, IFT
WRITE(2,270)
WRITE(2,280)
C
DO 140 JJ=1, NDD
READ(1,300) ND, NAD
C ND, DAY'S NUMBER NAD, NUMBER OF AIRCRAFT ARRIVALS ON THE DAY JJ
WRITE(2,310) ND, NAD
NADT=NADT+ NAD
C NADT, TOTAL NUMBER OF ARRIVALS IN THE PERIOD CONSIDERED
READ(1,320) CAT(JJ, I), I=1, NAD
C AT(JJ, I), ARRIVAL TIME NUMBER I ON THE DAY JJ
DO 100 I=1, NAD
J=AT(JJ, I)
T=AT(JJ, I)-J
AT(JJ, I) = J+ (T*100.)/60.
100 CONTINUE
C 'DO' 100 TRANSFORMS ARRIVAL TIMES FROM HOURS AND MINUTES INTO HOURS
WRITE(2,330) (AT(JJ, I), I=1, NAD)
N=1
T=IIT
IITP=IIT+1
AS=0.
IAS=AS
DO 130 I=IITP, IFT
T=T+1
AP=0.
DO 110 J=N, NAD
IF(IAS.EQ. NAD) GO TO 120
IF(AT(JJ, J)-T).LT.0.0, 120
N=N+1
AP=AP+1
APP(JJ, I)=AP
PRP(JJ, I)=APP(JJ, I)/NAD
110 CONTINUE
120 CONTINUE
AS=AS+AP
IAS=AS
ASS(JJ, I)=AS
PR(JJ, I)=ASS(JJ, I)/NAD
130 CONTINUE
140 CONTINUE
C
WRITE(2,350) IIT, IFT
DO 150 I=IITP, IFT
M=I-1
WRITE(2,360) M, (APP(JJ, I), JJ=1, NDB)
150 CONTINUE
WRITE(2,370)
DO 160 II=IITP,IFT
M=1-1
WRITE(2,380) M, I, (PRP(JJ,I), JJ=1, NDD)
160 CONTINUE
WRITE(2,390) IITP, IFT
DO 190 II=IITP,IFT
XMN=0.0
XSD=0.0
DO 170 JJ=1, NDD
170 XMN=XMN+PR(JJ,I)
XMN=XMN/NDD
DO 180 JJ=1, NDD
180 XSD=XSD+(PR(JJ,I)-XMN)**2
XSD=SORT(XSD/NDD)
WRITE(2,400) II, (PR(JJ,I), JJ=1, NDD)
WRITE(2,410) XMN, XSD
190 CONTINUE
DO 210 K=IITP,IFT
DO 200 II=1, NDD
200 APT(K)=APP(L,K)*APT(K)
210 PRT(K)=APT(K)/NADT
WRITE(2,415)
WRITE(2,420) IIT, IFT
WRITE(2,430) (APT(K), K=IIT, IFT)
WRITE(2,440)
WRITE(2,450) (PRT(K), K=IIT, IFT)
DO 230 K=IITP,IFT
X(K)=FLOAT(K)
DO 220 JJ=1, NDD
220 AST(K)=ASS(L,K)+AST(K)
230 PRST(K)=AST(K)/NADT
WRITE(2,460) IIT, IFT
WRITE(2,470) (AST(K), K=IIT, IFT)
WRITE(2,480) (PRST(K), K=IIT, IFT)
C
250 FORMAT(1H1,7C/), ' BIRMINGHAM AIRPORT, AUGUST 1978 ///)
260 FORMAT(15X, ' INITIAL TIME ', I3, ' FINAL TIME ', I3)
270 FORMAT(15X, ' ONF HOUR INTERVALS ///)
280 FORMAT(15X, ' AIRCRAFT ARRIVAL TIMES, IN HOURS ///)
290 FORMAT(15X, ' DAY ', I4, ' ARRIVALS ', I4/)
300 FORMAT(15X, ' PERIOD ', I3, ' HOURLY ARRIVALS, FROM ', I3, ' TO ', I3/)
310 FORMAT(15X, ' PERIOD ', I3, ' HOURLY ARRIVALS DIVIDED BY DAILY ARRIVALS ///)
320 FORMAT(15X, ' CUMULATIVE PROBABILITY, FROM ', I3, ' TO ', I3/)
330 FORMAT(15X, ' TOTAL HOURLY ARRIVALS UP TO THE TIME, FROM ', I3, ' TO ', I3)
340 FORMAT(15X, ' SUM M A R Y ///)
350 FORMAT(15X, ' MEAN ', F4, 2X, ' S D E V ', F4, 2)
360 FORMAT(15X, ' TOTAL HOURLY ARRIVALS UP TO THE TIME, FROM ', I3, ' TO ', I3)
370 FORMAT(15X, ' MEAN ', F4, 2X, ' S D E V ', F4, 2)
380 FORMAT(15X, ' TOTAL HOURLY ARRIVALS UP TO THE TIME, FROM ', I3, ' TO ', I3)
390 FORMAT(15X, ' MEAN ', F4, 2X, ' S D E V ', F4, 2)
400 FORMAT(15X, ' TOTAL HOURLY ARRIVALS UP TO THE TIME, FROM ', I3, ' TO ', I3)
410 FORMAT(15X, ' MEAN ', F4, 2X, ' S D E V ', F4, 2)
420 FORMAT(15X, ' TOTAL HOURLY ARRIVALS UP TO THE TIME, FROM ', I3, ' TO ', I3)
430 FORMAT(15X, ' TOTAL HOURLY ARRIVALS UP TO THE TIME, FROM ', I3, ' TO ', I3)
440 FORMAT(/1' TOTAL HOURLY ARRIVALS UP TO THE TIME, DIVIDED BY TOTAL ARRIVALS')
450 FORMAT(/12F10.2)
460 FORMAT(/1' TOTAL ARRIVALS UP TO THE TIME, FROM '1,15,1 TO '1,13)
470 FORMAT(/1' TOTAL ARRIVALS UP TO THE TIME DIVIDED BY TOTAL ARRIVALS')
AFT = FLOAT(IFT)
CALL HISCHA(APT,IFT,0,1.0,1.0,AFT)
CALL PICCLE
CALL HISCHA(AST,IFT,0,1.0,1.0,AFT)
CALL PICCLE
CALL GRAF(X,PRST,IFT,0)
CALL DEVEND
STOP
END
MASTER APRONOCCTIME
DIMENSION OP(50), OPT(50), OT(50), P(50), X(50), XX(50), Y(50)
CALL LP120
WRITE(2,210)
WRITE(2,220)
WRITE(2,230)
READ(1,240) NATG
C
NATG, NUMBER OF AIRCRAFT TYPE GROUPS
DO 360 M=1,NATG
READ(1,250) NATV, NO
C
NATV, AIRCRAFT GROUP NO, SAMPLE SIZE
WRITE(2,260) NATV, NO
READ(1,270)(X(I);VCJ>,I=1,NO)
DO 110 I=1,NO
J=X(I)
T1=X(I)-J
100 X(I)=J+(T1*100.)/60.
DO 110 I=1,NO
J=Y(I)
T1=Y(I)-J
110 Y(I)=J+(T1*100.)/60.
DO 120 I=1,NO
120 OT(I)=Y(I)-X(I)
WRITE(2,280)
WRITE(2,290)(OT(I),I=1,NO)
DO 130 I=1,NO
130 OT(I)=OT(I)+0.07
WRITE(2,300)
WRITE(2,290)(OT(I),I=1,NO)
XMN=0.0
XSD=0.0
DO 140 I=1,NO
140 XMN=XMN+OT(I)
XMN=XMN/NO
DO 150 I=1,NO
150 XSD=XSD+(OT(I)-XMN)**2
XSD=SQRT(XSD/NO)
CV=XSD/XMN
DO 155 I=1,48
OP(J)=0.
155 OP(J)=OP(J)+1.
GO TO 1110
160 T=T+5.60.
170 CONTINUE
180 CONTINUE
OP(T)=OP(T)/NO
DO 190 J=2,48
190 OP(J)=OP(J)+1.
GO TO 180
200 XX(J)=J*5.60.
WRITE(2,310)
WRITE(2,320)
WRITE(2,330)XX(J),OP(J),OPT(J),P(J),J=1,48)
WRITE(2,340)XX(J),J=1,48)
WRITE(2,350)XMN, XSD, CV

210 FORMAT(1H1,7C/),40X,'APRON OCCUPANCY TIMES'/I
220 FORMAT(1H1,' BIRMINGHAM AND MANCHESTER AIRPORTS, 1979 '/)
230 FORMAT(1H1,5-MIN TIME INTERVALS '/)
240 FORMAT(1H1)
250 FORMAT(1H1)
260 FORMAT(///11/AIRCRAFT GROUP ',14,4X,' SAMPLE SIZE ',14)
270 FORMAT(12F0.0)
280 FORMAT(10X,'STAND OCCUPANCY TIMES, IN HOURS '/)
290 FORMAT(12F10.2)
300 FORMAT(10X,'STAND OCCUPANCY TIMES PLUS 4 MINUTES, IN HOURS '/)
310 FORMAT(///66X,'OCCUPANCY ',3X,' FREQUENCY ',2X,' CUMULATIVE ',3X,
11'CUMULATIVE ')
320 FORMAT(68X,'TIME ',4X,' FREQUENCY ',4X,' PROBABILITY '/)
330 FORMAT(67X,F6.2,9X,F6.0,8X,F6.0,8X,F6.2)
340 FORMAT(13F6.2)
350 FORMAT(1H1,MEAN ',F4.2,3X,' S DEV ',F4.2,3X,' S DEV/MEAN ',F4.2)
CALL HISCHA(OP,48,0,1.0,5.,240.)
CALL PICCLE
CALL MOVTO2(0.0,0.0)
CALL HISCHA(OP,48,0,1.0,5.,240.)
CALL PICCLE
CALL MOVTO2(0.0,0.0)
CALL GRAF(XX,P,48.,08,4.0)
CALL PICCLE
CALL MOVTO2(0.0,0.0)
360 CONTINUE

WRITE(3,340)XX(J),J=1,48)
CALL DEVEND
STOP
END
REFERENCES


10. Subroutine G05CCF and Routine G05CAF(X) of the Numerical Algorithms Group (NAG) Library. NAGFLIB:1445/0:MK 7:May 77 and NAGFLIB:1443/0:MK 7:May 77, respectively.


12. Airport Capacity Criteria used in preparing the National Airport Plan, AC 150/5260-1A. Federal Aviation Administration, July 1968.

