INTEGRATED AIRPORT CAPACITY AND DELAY MODEL

Computer Package of The Federal Aviation Administration Advisory Circular 150/5060-5

by

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(Abstract)

A prototype computer software was created to predict airport hourly capacities and delays, taxiway hourly capacity, gate group hourly capacity, overall airport hourly capacity, and annual service volumes. The possibility to replace the existing Federal Aviation Administration Advisory Circular 150/5060-5 in the future was also explored.

The development of the computer software, ICAD--Integrated Airport Capacity and Delay Model was based primarily upon HyperCard as well as other supporting statistical and drafting computer software such as CA Cricket Graph III, Minitab 7.0, MacPaint and MacDraw II 1.1. A friendly user interfaces and internal computations were the two main concerns for ICAD development. In a typical application interface, runway use configuration is identified from various diagrams. Input parameter are inserted in the model and outputs are readily obtained in table and graphical form. ICAD scripts have been developed in HyperTalk, the language associated with HyperCard. Regression equations were used to convert graphs from the FAA AC 150/5060-5 into equations in ICAD.

This thesis presents descriptions and validations of the prototype model. Conclusions and recommendations are also included.

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Chapter 1

Introduction

1.1 Background

In the past several decades, the air transportation industry in the United States has experienced a significant growth. After World War II, domestic air transportation showed a strong tendency to expand at a very high pace[Ashford, N. and Wright, P.H., 1992]. Passenger miles increased from 4.3 billion passenger miles in 1945 to 104 billion passenger miles in 1969. These statistics showed a near exponential growth rate in this period of time. The average annual growth rate for these 25 years was 13.6%. In the next two decades from 1969 to 1988, the fast growth tapered down, as passenger miles tripled from 104 billion passenger miles in 1969 to 327 billion passenger miles in 1988 which looks more closely to a logistic trend. The average annual growth rate was 5.87% during this period. Federal Aviation Administration forecasts that the domestic air activity in the upcoming years, the revenue passenger mileage will reach 427 billion in 1995, 540 billion in 2000, and 881 billion in 2010. This expected increase will reach an average annual rate of 4.81% [FAA, Aviation Forecasts, fiscal year 1990~2001].

The rapid growth in demand has usually surpassed the capacity of airport infrastructure causing many delays. Delays are manifested in daily air operations and passenger activities as congested air corridors, overcrowded ground facilities, delayed flights, long waiting times for boarding planes, as well as sizable economic losses to both airlines and air travelers [Geinsenger, 1986]. It is not surprising that extensive research was focused on the adjustment and improvement of the air transportation system in order to optimize operations [Lisker, 1989; Mundra, 1990, etc.].

It is universally recognized that the effectiveness, reliability, and operation safety of the air transportation system depend on its basic elements, namely each individual airport. In most circumstances, the two most important parameters to evaluate the performance of an airport are: airport capacity and delay.

1.2 Basic Concepts

According to their physical characteristics, an airport can be divided into a group of components as follows,

Airside:
1) Air traffic and operation control system
2) Runway
3) Taxiway
4) Gates and holding area

Landside:
1) Terminal building
2) Parking area
3) Connecting and access roads

Traditionally, in the analysis of airport capacity and delay, every component is considered in isolation with little interaction with other airport components. This assumption is idealized as it simplifies airport planning. In reality, it is known that significant interactions occur between different components.

The term, capacity, refers to the maximum number of air operations that a certain airport component can handle over a period of time. More specifically, the definition of capacity has two meanings in response to different demand patterns and levels of service that is mostly measured by adopting another important term--delay. The first is called practical capacity, defined as the number of air operations that can be processed over a period of time relating to a certain level of delay; the second is ultimate capacity, implying the maximum number of continuos air operations that an airport component can accommodate during a specified period of time without consideration of a tolerable level of delay.

It might exist in reality that there is a consistent maximum demand over a period of time. But it will be proven to be economically unjustifiable if designers want the airport to have the capacity to handle this peak demand. In other words, most airport facilities must meet a strict tradeoff between the infrastructure performance and costs.

Because real traffic demands fluctuate, a certain level of delay is allowed according to a certain level of service to which airlines, airport authorities, or the passengers will all feel satisfied to accept. For economic reasons, analyzing and evaluating the magnitude of delays is more important and meaningful than estimating capacities although the two performance measures are inextricably related.

1.3 Research Scope

Since each airport component performance has little causal effect on others, as a result, component can be analyzed separately. In general, the runway component bears the most critical capacity because of generous intrail separation distance between consecutive arrival aircraft imposed for safety reasons. Taxing on the airport ground network, airplanes do not follow the same restrictive air intrail separation distances, and thus taxiway capacities tend to be much larger than that of runway. Gates are the last service facility in the airside component. They have the moderate processing capability compared to other components. The overall airport capacity should result from the most restrictive component that yields the least capacity.

Delays to aircraft at various airport components can be analyzed by using sequential processing facilities simulation or close form queuing models. The total delays imposed on an aircraft from takeoff to landing is the summation of the individual delays imposed on each airside component.

A great deal of factors influence airport capacity, some of the most relevant ones are,

1) Runway configuration and orientation
2) Weather conditions
3) Number of taxiways
4) Runway exits locations
5) Intrail approach separation distances
6) Sequencing of aircraft by ATC
7) Percentage of large or heavy aircraft
8) Percentage of arriving aircraft
9) The number of general aviation aircraft practicing touch and go operations.

1.4 Research Objective and Approach

This research is aimed at implementing an electronic version of the original Federal Aviation Administration document -- Airport Capacity and Delay, Advisory Circular 150/5060-5 to facilitate the estimation of airport capacity and delay at the conceptual design phase.

The computer software used in this development is HyperCard 2.1. HyperCard has the ability to generate its own information interfaces on the screen. Users can store data and graphic information into the components of the interfaces to establish links and to switch quickly among each other. With HyperCard, users are given the freedom to create fast, reliable, and fully functional computer application software packages.

HyperTalk, the language specific to HyperCard, is an advanced language like BASIC, FORTRAN, and C with general simple English type syntax to create interactive programs. HyperTalk has the capability to navigate among stacks and cards; to instruct actions; to manipulate files, screen, keyboard; to perform math calculations and so forth. In most cases, it is used solely inside a handler, formally a button that is designed to execute a serial command targeting at a particular object or on a certain action. HyperCard uses object-oriented scripts that offer users latitude in creating unique computer application packages of their personal characteristics.

Chapter 2

Literature Review

There are several methods currently used in determining runway capacity and delays.

1) Queuing theory
2) Analytical models
3) Graphic approaches
4) Computerized simulations

The following paragraphs describe some of the basic notions behind each method.

2.1 Queuing Theory

Early airport runway capacity estimation models used queuing theory. There are two types of queuing models based on steady-state queuing theory. The first model deals exclusively with either arrivals or departures on runway, while the second model can take care of mixed operations with the priority given to landing aircraft rather than departing aircraft. For arrivals only, the demand patterns have been observed to follow a Poisson probability distribution. When a runway serves both takeoffs and landings, the demand pattern for takeoffs almost conforms to a Poisson distribution, meanwhile the aircraft in the landing process wait to be served in the queuing system[R.Horonjeff, 1983].

Due to the lack of more pertinent air operation parameters such as aircraft mix index, percent arrivals and so on, these models can not provide satisfactory predictions. Furthermore the assumptions of idealized steady-state demand patterns for incoming and outgoing aircraft in airports today operated under flight banks rarely exist. The following equation has been derived for delay of arrival aircraft on the runway [FAA, 1963],

$$W_a = \frac{\lambda_a(\sigma_a^2 + 1/\mu_a^2)}{2(1-\lambda_a/\mu_a)} \qquad \ldots (2-1-1)$$

where,

W_a = mean delay for arrival aircraft

λ_a = mean arrival rate

μ_a = mean service rate for arrival aircraft which could be the largest of either runway occupancy time or air separation in approach path

σ_a = standard deviation of service time for arrival aircraft

Similarly the above equation also can be used estimate aircraft departure delays on a runway [FAA, 1963] ,

$$W_d = \frac{\lambda_d(\sigma_d^2 + 1/\mu_d^2)}{2(1-\lambda_d/\mu_d)} \qquad \ldots (2-1-2)$$

where,

W_d = mean delay for departure aircraft

λ_d = mean departure rate

μ_d = mean service rate for departure aircraft which could be the largest of either runway occupancy time or air separation in approach path

λ_d = standard deviation of mean service rate for departure aircraft

The average delay to arriving aircraft under mixed operation is given by Eq.(2-2-3) [FAA, 1963],

$$W_d = \frac{\lambda_d(\sigma_j^2 + j^2)}{2(1-\lambda_d j)} + \frac{g(\sigma_f^2 + f^2)}{2(1-\lambda_a f)} \qquad \ldots (2-1-3)$$

where,

W_d = mean delay to departure aircraft

λ_a = mean arrival rate

λ_d = mean departure rate

σ_j = standard deviation of mean departure rate between two successive aircraft

σ_f = standard deviation of mean interval of time for failed departures

j = mean interval time between two successive departures

g = mean rate of gaps between successive arrivals

f = mean interval of time for failed departures

It is important to be aware that these equations are valid only if the mean arrival or departure rates are less than the mean service rate.

2.2 Analytical Models

This mathematical model, or landing interval model contains some important factors that have significant effect on the capacity of runway accommodating incoming aircraft. These factors are aircraft approach speed characteristics, aircraft group percentage, current air flight rules, and the magnitude of various errors such as speed errors along common approach path, arrival time errors at the entry gate, and landing distance errors from runway threshold. The output from this model yields the maximum processing capability of the runway system. Models with different assumptions are presented below:

2.2.1 Runway Capacity for Arrivals with Free Position Errors

A pair of leading and trailing aircraft entering the final approach path with speeds V_i and V_j will attempt to maintain a precise spacing between them. It is understandable to establish a matrix to represent various separation time between aircraft of discrete speed classes at runway threshold. These matrix are [R. Harris, 1972],

$$T_j - T_i = [T_{ij}] = [M_{ij}] \qquad \ldots (2-2-1)$$

where,

T_i = time when the leading aircraft of class i reaches the runway threshold
T_j = time when the trailing aircraft of class j reaches the runway threshold
$[T_{ij}]$, $[M_{ij}]$ = a matrix of minimum separation times between pairs of landing aircraft

Because the percentage of various aircraft groups may differ. probabilities of aircraft of class i followed by aircraft of class j, or reciprocally can be obtained [R. Harris, 1972],

$$P_j - P_i = [P_{ij}] \qquad \ldots (2-2-2)$$

where,

P_i = percentage of aircraft of speed class i

P_j = percentage of aircraft of speed class j

$[P_{ij}]$ = a matrix of probabilities of aircraft of speed class i followed by aircraft of speed class j

The multiplication of the separation time matrix by the probability matrix determines the average weighted times at runway threshold [R. Harris, 1972],

$$E[T_{ij}] = \Sigma P_{ij} M_{ij} = \Sigma P_{ij} T_{ij} \qquad \ldots (2-2-3)$$

where,

$E[T_{ij}]$ = average weighted separation time matrix at runway threshold for aircraft of various speed classes

Finally the goal is achieved that the maximum runway landing capacity without error is the inverse of the average weighted separation time at threshold, and given below [R. Harris, 1972],

$$C = \frac{1}{E[T_{ij}]} \qquad \ldots (2-2-4)$$

where,

C = maximum runway capacity for arrivals only

2.2.2 Runway Capacity for Arrivals with Position Error

When δ_{ij} is the minimum acceptable spacing between two consecutive landing aircraft along a common approach path. It could also be the mean distance for the trailing aircraft away from the leading aircraft if no errors in separation are involved. In practice, variations in separation are likely to occur due to human, environmental, or mechanical uncertainties where aircraft are vectored to the final approach. This implies that aircraft position could be randomly located, either ahead or behind of the normal schedule. If the trailing aircraft is ahead of its schedule, or violates the minimum safe separation distance from the one ahead, the situation might be precarious. Therefore air traffic control personnel usually add a buffer time to increase the headway to avoid the possible loss of separation due to position errors. Assuming the position error is normally distributed, and the mean value of this normal distribution corresponds to the minimum separation distance. It is easy to find that 50% of the aircraft trailing would violate the separation criteria. To reduce the probability of position violation to an acceptable level, trailing aircraft are inevitably assigned a buffer time to reach a scheduled position later, so that only a small number of aircraft could be ahead of a prescribed position (i.e., 5% is usually acceptable). In general, the aircraft separation time matrix with position errors has been demonstrated to be [R. Harris, 1972],

$$T_{ij} = M_{ij} + B_{ij} + e_0 \quad \ldots (2-2-5)$$

where,

B_{ij} = buffer time of aircraft of speed class i followed by aircraft of speed class j

e_0 = a position error from normal distribution

2.2.3 Runway Capacity with Mixed Operations

For mean successive arrival time gap $E[T_{ij}]$ to release n departures between two landing aircraft, along with a gap spacing error, the mathematical expression is [R. Harris, 1972],

$$E[T_{ij}] > E[R_i] + E\left[\frac{\delta_d}{V_j}\right] + \sigma_G q_v + (n-1)E[t_d] \quad \ldots (2-2-6)$$

where

$E[T_{ij}]$ = average separation time for landing aircraft to release a departure

$E[R_i]$ = average weighted runway occupancy time for aircraft of various speed classes

$E\left[\frac{\delta_d}{V_j}\right]$ = mean time value for landing aircraft at least 2 nmi from runway threshold when an aircraft may takeoff

σ_G = standard deviation of gap spacing error in time

q_v = a value which corresponds to a cumulative standard normally distribution that has the value $(1-P_v)$

n = number of departures being released

$E[t_d]$ = mean service time for departures

2.3 Graphical Approach

A simple graphical method to determine the capacities and delays of airports is based upon the FAA Advisory Circular 150/5060-5 which was published in 1967 by Federal Aviation Administration after long time extensive research and numerous computer simulations. Also, this is the cornerstone and the original data source for implementing this work. This official document provides many shortcuts to analyze and estimate hourly, yearly, and overall capacities and delays of airport components like runways, taxiways, or terminal facilities.

The FAA AC 150/5060-5 contains charts and tables generated through computer models and simulations outside the document itself. Some input parameters are important and shared by all charts in the calculation of runway capacities and delays. There are,

a) Weather conditions, (VFR or IFR)
b) Aircraft mix index, defined as,

$$MI = C + 3D$$

where,

C = percentage of aircraft belonging to group C
D = percentage of aircraft belonging to group D

c) Percentage of arriving aircraft
d) Percentage of Touch and Go operations
e) Number and locations of runway exits

Some other input parameters like exit distance from departure end of runway, non-widebodied aircraft gate occupancy time, and so forth are still needed in order to estimate taxiway, gate capacity and runway delay.

To estimate runway hourly capacity, the following equation is used [FAA AC 150/5060-5],

$$C = C^{*}TE$$

where,

C = hourly runway capacity;
C^{*} = hourly runway capacity base;

T = Touch and Go factor;

E = exit factor.

To estimate the hourly delay on runways, the FAA AC 150/5060-5 uses the following equation,

$$\text{DTH} = HD(PA*DAHA+(100-PA)*DAHD)/100$$

where,

DTH = hourly delay on aircraft;

HD = hourly demand;

PA = percentage of arrival aircraft;

$DAHA$ = average arrival delay;

$DAHD$ = average departure delay.

Similarly to find the capacity of a taxiway crossing an active runway, the result can be checked directly from those diagrams, knowing aircraft mix index, runway operation rate, and distance of taxiway from departure end of runway.

The terminal or gate hourly capacity can be found by using the equation [FAA AC 150/5060-5],

$$\text{G} = G^{*}\ \text{S N}$$

where,

G = hourly gate group capacity;

G^{*} = hourly gate group capacity base;

S = gate size factor;

N = number of gates.

2.4 Computerized Simulations

In the study of aircraft operations, airport facility design, adoption and justification of new procedures, computer simulations appear to be a fast and dependable approach. SIMMOD is one of the outstanding software packages ever used in this field. Co-sponsored by Federal Aviation Administration, SIMMOD was developed to have a great variety of advantages in analyzing and estimating airway and airport capacities.

SIMMOD has the capability to simulate the movement of individual aircraft, detecting and instructing air traffic flows to maintain prescribed separations, measuring fuel consumption in airspace or at ground, etc. Its primary outputs are delays and fuel consumption. And it can also evaluate more specific problems such as newly added gates, runway exits and other ground facilities. SIMMOD has good flexibility to change or modify input parameters at any level of modeling process and enables users to study various alternatives by comparing their effects on airport system delays.

SIMMOD is microscopic in nature and requires explicit definition of various airspace and airfield structures. The air transport system including airways, airport runways, taxiways, or ground terminals are all symbolized as a network of nodes interconnected by links, where airspace holding strategies for aircraft and their movement control can be performed. Nodes are described differently between airspace and airfield. A node in airspace determines locations of air flight direction, holding queues, air separations, while a node on the ground represents locations of airport terminals, intersections of runways, taxiways and runway exits, as well as departure queues. Links in the airspace form flight routes whereas links at ground represent runways, taxiways, exits.

Chapter 3

Methodology

The purpose of this work is to convert the Federal Aviation Administration Advisory Circular 150/5060-5 into an electronic document which has a user friendly interface, and makes all the necessary calculations internally rather than relying on manual computations. This computer package is named ICAD--Integrated Airport Capacity and Delay Model. To achieve this user friendly interface, HyperCard with its distinct functions and utilities is the software environment used in the development of ICAD. Some other supporting computer software packages were also used to supplement HyperCard graphically.

3.1 HyperCard

Initially marketed in August, 1987, HyperCard was launched by Bill Atkinson as a simple programming environment to develop user interfaces [D. Goodman, 1990]. About four years later an upgraded version known as HyperCard 2.0 was published as a group effort. The newest version of HyperCard has eventually been used to develop ICAD. HyperCard is a special computer application software with the capability to store and retrieve digital, textural and graphical information, as well as sound playing. With these elements, HyperCard can handle and present vast amounts of information through a simple navigation interface composed of cards and grouped in stacks. HyperCard serves as a multimedia information processing center and provides a constructive environment to users.

To understand HyperCard, first attention should be paid to building environment or authoring tools like drawing, painting, and field and button manipulating as these allow a user to work with objects rather than with code. Practically all the items listed in the menu bar belong to this category. Some of them act for general purposes as those of other computer software's like file and edit, while some of the menu items deal with sending special command to the computer, searching among cards, and concatenating between cards, and the rest part of authoring tools are inclined to assist in switching and finding information among buttons and fields, creating new buttons, new fields, new backgrounds, and drawing graphics on cards. The basic elements comprising HyperCard will be presented in the next paragraphs for the sake of completeness.

3.1.1 Stacks

Each HyperCard stack is an independent file which contains a certain amount of information of particular interest. There are two types of stacks, homogeneous, and heterogeneous. The former is the kind of stack with only one background design throughout the whole stack while pictures or texts on different cards may change. The latter has several or unlimited number of different background displays. Because of the nature of the applications, ICAD uses a heterogeneous stack strategy.

3.1.2 Background

Background is defined as a property in a card where users can draw and paint pictures, type texts in fields, make buttons to execute certain actions, and all these entities in a card's background will be eventually designated to be shared by many other cards. In other words, all cards have some similar look and functions regardless of what type of information they contain. In ICAD, backgrounds contain table frames and fields for input and output parameters of the model.

3.1.3 Cards

Physically a stack consists of only cards that contain graphics, fields, and buttons on them. As the basic units of a stack, cards can be ordered to flip forward or backward by Menu command or by using a button. A card may have both background and foreground picture, text, and buttons together at the same time. But the content at the card foreground belongs to the card itself and is usually not shared with others.

3.1.4 Fields

Fields are places to hold text, and the most obvious and direct method to enter or retrieve information. Fields also serve as data storage blocks being able to link to scripts written inside buttons for the purpose of executing an action. For computation purposes in ICAD, all fields are used as data storage cells, and are named or sequenced.

3.1.5 Buttons

Button is an element at a card background or foreground. HyperTalk scripting is frequented mostly inside buttons. A button has the ability to carry out users' commands to perform certain actions such as navigating between cards, searching and loading information from fields and even executing mathematical calculations.

3.2 HyperTalk

HyperTalk is a computer language developed exclusively for HyperCard. Its vocabulary is English and its syntax is a complete sentence. Programming in HyperCard only deals with scripting inside buttons, fields, cards, and stacks.

3.2.1 HyperTalk Modularity

In HyperCard, there is absolutely no a computer language controlling entire activities throughout a stack. Each object like stack, background, card, field, and button has their own scripts and has to obey and act according to the instructions from the scripts attached to them. Thus HyperTalk is a peculiar language targeting at an action for a certain object whose change of status prompts the action. This modularity makes HyperTalk advantageous over many other computer languages especially when users are to test the scripts while observing the interactions of numerous objects in one or several stacks, and have little time to write a single script without programming code for entire objects.

3.2.2 HyperCard Hierarchy

Hierarchy here implies the message order in which commands are carried out upon different objects in HyperCard (See Fig. 3-1). Another way to describe the nature of HyperCard hierarchy is to look at the flow direction of a message in it. When a message is read by an object and not fit to the script, it will be passed out through the hierarchy until encountering the matching one with the same command or the same mouse action.

3.2.3 Structure of A Script

Every script whether inside a stack, a card, a field , or a button, it always begins with "on ..." and ends with " end ...". The content after "on" and "end" varies due to the discrete scripts in different objects. Most commonly, for a button, the initial and final syntax instructing the computer to carry out and to terminate an action is,

```
on mouseUp
    Set numberFormat to 0.00
   Global VFRMI, IFRMI, VFRPA, IFRPA, VFRCap, IFRCap, VFRDem, IFRDem
    Put the value of (field A3+field B3+3*(field A4+field B4))*100/(field A1+field A2+field A3+field A4+field
    B1+field B2+field B3+field B4) into VFRMI -- MI for VFR
    .
    .
    .
   Put field A1+field A2+field A3+field A4+field A5+field B1+field B2+field B3+field B4 into VFRDem
   Put field C1+field C2+field C3+field C4+field C5+field D1+field D2+field D3+field D4 into IFRDem
end mouseUp
```

These two lines of script, "on" and "end", are always close to the left margin. The rest of commands between these two lines are subject to be indented. The scripting environment does not require users to mark the number or the sequence of each command. HyperTalk can soon recognize any message users typed in each line and make them into correct line format. Moreover by knowing this kind of scripting format, users can easily debug their programs.

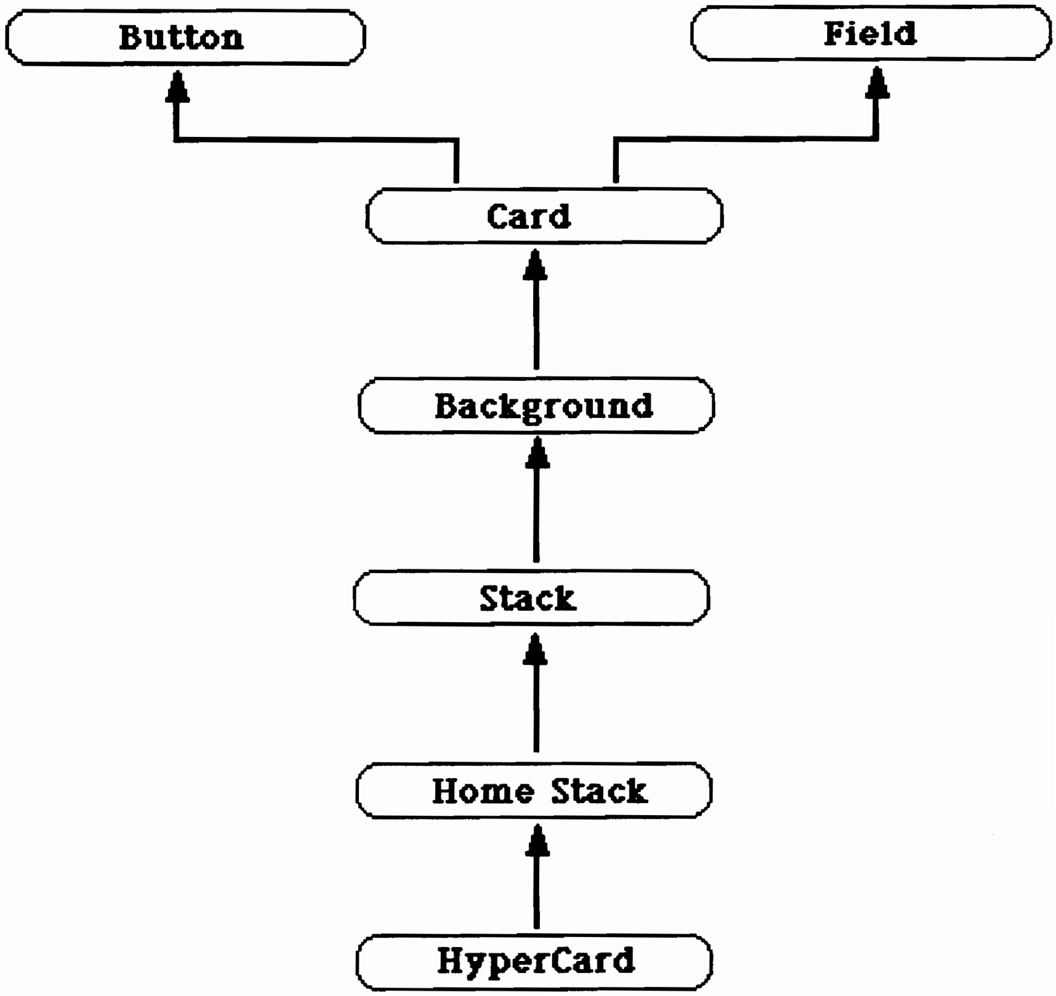


Fig. 3-1 HyperCard Hierarchy

3.2.4 Commands

Commands in HyperTalk are, just like imperatives in English, used to instruct HyperCard to do something. They can instruct file manipulation, navigation, searching and sorting and so on. In order for commands to fulfill an action, they must be followed by a series of numeric parameters. Commands in ICAD only have a small portion of HyperTalk commands.

3.2.5 Functions

The difference between functions and commands is that functions have concrete, meaningful content prepared or ready to be calculated from the computer system, and can be recognized by simply typing it into message box with or without a parameter. In contrast, commands are not able to perform any task without parameters or functions behind them.

3.2.6 Parameters

Parameters are typed in script lines or message box. Parameter could be either a number or an object depending upon whichever command or function is in front of it.

3.2.7 Variables

When the computational structure in a script becomes complicated, it is definitely necessary to assign numeric values at various levels of the script, named and placed into temporary holding blocks in HyperCard. These values are called variables.

Essentially there are two different kinds of variables associated with HyperCard. The first ones are local variables which only function inside a block of script. When a series of local variables in the script are required to be defined, users do not need to use a specific command--declare, but just name them. After execution of the script is finished, those local variables' names and contents no longer exist in HyperCard. The second type variables in HyperCard are global variables. When intending to create a series of global variables, users must use a command to declare them anywhere in the script before they are used, and redeclare them at the beginning of other scripts using them. HyperTalk treats any undeclared variables as local variables. Once the process of script execution is completed, those global variables and their contents are still within HyperCard as long as users do not quit the application program. The noticeable difference between local variables and global variables lies then in that the former is only valid in a single script, it disappears as the handler goes off; the latter can cross beyond the boundary of the handler in which they are created and be recognized and understood by other handlers only if HyperCard remains loaded.

3.3 FAA AC 150/5060-5

The content here in this chapter only deals with method of the interpretation from the graphs in FAA AC 150/5060-5 into mathematical equations for the internal calculation use of HyperTalk scripts. The method adopted in the creation of ICAD is to convert graphs into equations by using standard curve fitting techniques. This work was accomplished with the use of two computer software packages--CA Cricket Graph III and Minitab 7.0. All the input data for this statistical process was manually collected from the graphs in FAA AC 150/5060-5. The next paragraphs will focus on the methods to execute curve fitting equations to estimate Runway Hourly Capacity, Hourly Delay on Runway, Taxiway Hourly Capacity, and Gate Group Hourly Capacity.

3.3.1 Runway Hourly Capacity

The runway hourly capacity, whether under VFR or IFR conditions, is determined by the multiplication of these three factors--runway hourly capacity base C^*, touch and go factor T, and exit factor E. [FAA AC 150/5060-5].

A typical graph to estimate runway hourly capacity base in FAA AC 150/5060-5 contains three curves representing various percentages of arriving aircraft. In most circumstances, these three curves in a graph do not follow the same trend. In some extreme cases, they even intersect. Therefore, in order to have exact regression equations, each curve should be treated separately in terms of their discrete arrival percentages. CA Cricket Graph III demonstrated its versatility and precision in converting columns of data into curves, and depicting and matching those curves with polynomial regression equations, One of those is shown below,

```
Put -61.972*(field I1/100)^5+337.566*(field I1/100)^4-713.865*(field I1/100)^3+714.803*(field I1/100)^2-414.693*(field I1/100)+218.260 into holder1--VFR 40% arrivals
```

In ICAD, fifth order regression equations were commonly used to approximate the runway capacity base.

The concept of building a decision structure for runway exit factors must be emphasized and connected between their practical values and regression equations. In HyperTalk, if a script consists of too many decision structures which could result from equations having fewer parameters, scripting errors are liable to happen. Most data groups in the exit factor tables follow the same trends. Minitab has multiple polynomial regression functions and simplified the problem. After being plotted and statistically tested, those regression equations were proven to be significantly accurate. The way to improve the accuracy of exit factor output in a newer version of ICAD will be mentioned in Chapter 6. By comparison, there is no need to find regression equations for touch and go factors but leave them as explicit HyperTalk scripts.

3.3.2 Hourly Delays to Aircraft on The Runways

Curves in arrival delay index and departure delay index graphs show more nonlinearities than those representing hourly capacity bases. The nonlinearity caused some difficulties in having more parameters involved in regressions. The way to find out the best regression equation was to plot a polynomial curve, match it with the one plotted from data points of origins, and then to estimate the best it fits. The same method was also used to find the regression equations to estimate average delays to an aircraft.

3.3.3 Taxiway Hourly Capacity

Taxiway hourly capacity can be found directly from the graphs in FAA AC. Most curves that belong to two different aircraft operation modes in the taxiway hourly capacity graphs follow predictable trends quite well. Multiple polynomial regressions include every independent parameter such as mix index, distance of taxiway from departure end of runway, and number of runway operation rate, except for a few cases, in which two adjacent curves go asunder as both the number of runway aircraft operations and the distance of taxiway from runway departure threshold increase. Thus, linear interpolations were used to find values between curves.

3.3.4 Gate Group Hourly Capacity

All curves in gate group hourly capacity base graphs conform each other perfectly in the same trends. Regression equations are continuos and contain all independent parameters like gate occupancy time ratio of wide-body aircraft vs. non-wide-body aircraft, non-wide-body aircraft gate occupancy time, and percent of non-wide-body aircraft. Each gate size factor curve was treated separately.

3.3.5 Airport Overall Hourly Capacity and Annual Service Volume

All parameters needed for computations of airport capacity are taken from previous analysis. The overall airport capacity is the most critical of runway, taxiway, and gate capacities.

3.4 Graphic User Interface

Graphic user interfaces are concerned with the creation and design of single application windows, and the concatenations of entire ICAD stacks and cards. The purpose in ICAD was to let users have quick access to various applications, identify correctly the runway use configurations, and perform parameter entry and scenario analysis in a streamlined fashion.

3.4.1 ICAD Hierarchy

The basic concept to establish ICAD hierarchy was derived from that in FAA Advisory Circular 150/5060-5 itself. In the program, there are three main parts: Preliminary Procedures deal with long range estimation of airport capacity and delay to aircraft. Airport Capacity and Delay to aircraft calculations analyze air operations occurring hourly and annually on airport components. Special Applications focus on airport capacity under poor weather conditions, lack of instrument coverage, or with runway use restrictions. ICAD only reflects these three main applications in FAA AC 150/5060-5 as mentioned above. Fig.3-2 illustrates the organization of ICAD.

3.4.2 Application Interface

Two things were emphasized primarily in designing the application windows. The first was to provide users standard input and output parameter tables, runway use configurations and graphs. The second was to provide visual feedback every time the user makes a selection.

Parameter input and output tables act as the main items in the application interfaces. Because of screen limitations on small Mac computers like Macintosh Classic II, input and output tables were sized relatively small in order to leave enough room to place runway use configurations and graphs that appear on the top part of the window as feedback to the users. Most of ICAD drawings were done in MacDraw II 1.1 and MacPaint, graphs were generated in CA Cricket Graph III. These figures are also important in guiding users correctly to the application or supplementing the calculations for users to see the parameter's trend as well. Runway use configuration on each card is used exclusively by the card on which it is drawn and stands for the whole script behind the Result button on that card. Output graphs are limited to runway hourly capacity bases and hourly delay indices.

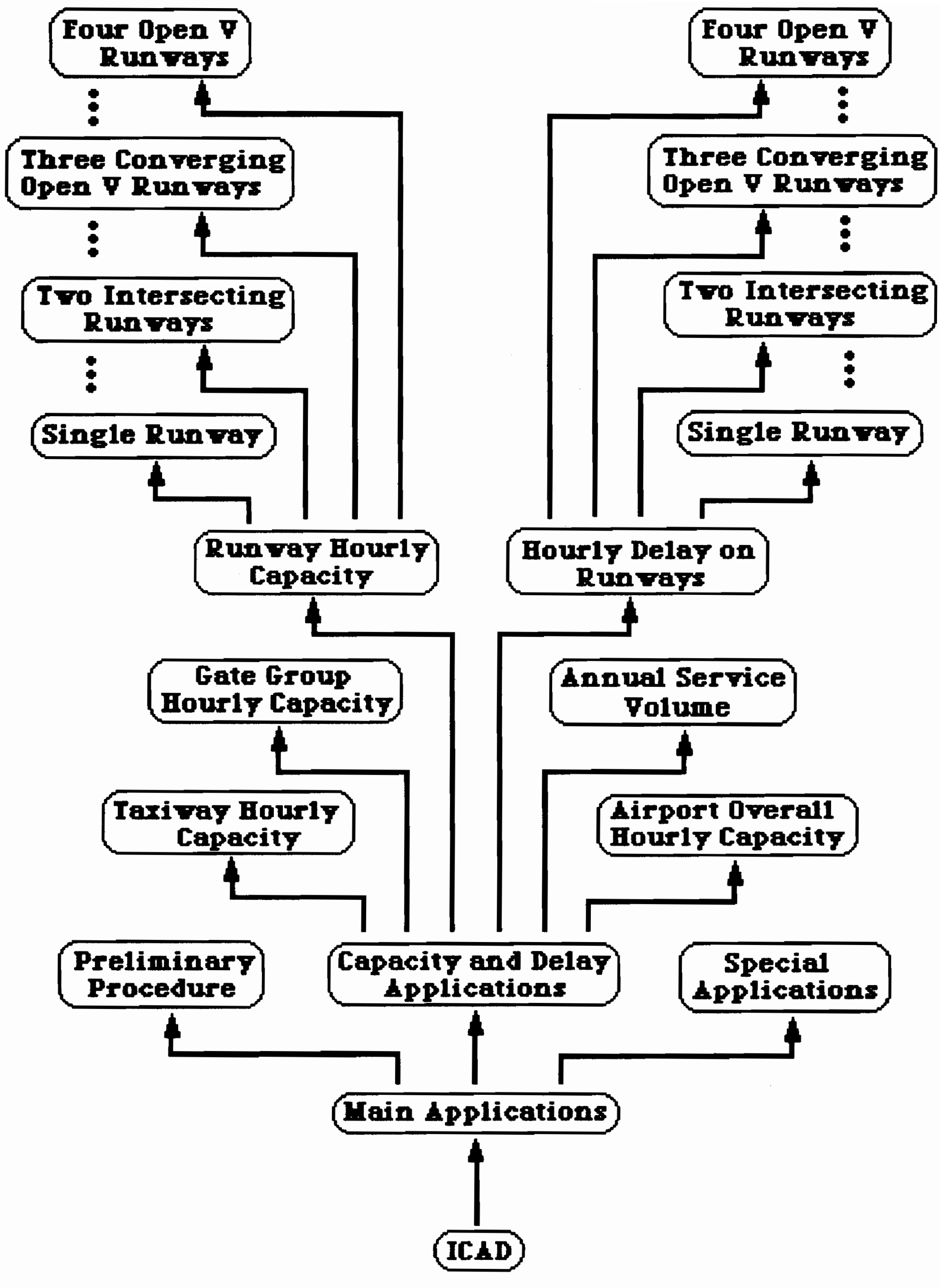


Fig. 3-2 ICAD Hierarchy

Chapter 4

ICAD Application Description

In this chapter, the emphasis is at describing the input and output interfaces of ICAD. Internal computational flow logic charts are illustrated, and source code of typical ICAD applications are also explained. The following paragraphs describe the computational modules comprising ICAD. The ICAD hierarchy shown in Fig.3-2 is followed here in this chapter.

4.1 Runway Hourly Capacity

The computation of runway hourly capacities is physically differentiated for various runway configurations. Factors affecting runway hourly capacity are: the separation distance between two adjacent single runways, the distances from arrival and departure thresholds, the angles between two intersecting or converging runways when applicable, the number of arrivals, departures, touch and go aircraft operations under VFR weather condition, aircraft population mix, the percentage of arrival aircraft, and airport arrival runway exit locations.

Because all individual applications have almost the same input and output interfaces except for differences in the number of active exit locations according to their different runway configurations, it is absolutely unnecessary to repeat every discrete application, instead, one representative application will be chosen and introduced.

4.1.1 Input and Output Parameters of Runway Hourly Capacity

Input and output parameter requirements are inextricably related to ICAD's user interface. In this chapter, it is intended to describe the relationship between input and output parameters of the model. In general, the number of input parameters needed in ICAD for internal calculations are more than those of output results, and in every application, many intermediate parameters such as mix index, percent arrivals, and capacity base are estimated from regression equations.

Fig. 4-1 shows a typical interface screen where the input and output parameters are located on the lower side of the screen. There are two input categories, the first is, the number of arriving and departing aircraft from different classification groups as well as the number of touch and go aircraft under VFR condition; the second is arrival runway exit locations.

The input area defining the numbers of arriving and departing aircraft for VFR and IFR conditions is divided into four columns. Group A represents general aviation of aircraft weighing less than 12,500 lbs and with approach speeds below 91 Knots; Group B stands for small aircraft weighing between 12,500 lbs and 60,000 Ibs, and with approach speeds between 91 and 120 Knots; Group C belongs to small and medium-sized transport-type aircraft weighing between 12,500 lbs and 300,000 Ibs, and with approach speeds between 121 and 140 Knots; Group D applies to wide-body aircraft weighing more than 300,000 lbs and with approach speeds between 141 to 165 Knots. Category E is not included in this analysis as only one commercial aircraft (The Concord) falls into it and there are no significant number. Touch and go aircraft are usually operated for pilot training purposes, but also need to be considered in runway hourly capacity estimations.

Runway exit locations, whose distances are measured from arrival runway thresholds are defined in columns 5 through 8 in Fig. 4-1. The number of input columns available for arrival runway exit locations, which could range from one to four columns, depend totally upon the runway use configurations. Arrival runway exit location table was designed generally for any kind of runway use configurations so as to accommodate the maximum possible number of arrival runways found in FAA AC 150/5060-5.

Intermediate parameters such as Mix Indices, Percent Arrivals, Touch and Go percentages, Hourly Capacity Base(C*), Touch and Go Factors(T), and Exit Factors(E) are shown in columns 9 to 10 (See Fig. 4-1). Mix indices reflect the percentages of large and wide-body transport type aircraft operating hourly at the airport. Percent of arriving aircraft, and percent of touch and go aircraft indicate hourly aircraft operation patterns. Touch and Go factors and runway exit factors present multipliers of hourly capacity base to finally predict runway hourly capacity. The output hourly capacity values are shown in column 10 of

Hourly Capacity of Two Parallel Runways

Itms / Terp	VFR		IFR		Ar. Rwy Exits Locations (ft)						VFR	IFR	Cap.
	Ar	De	Ar	De	#1	1000	1000			MI	75.0	81.8	VFR
A	11	13	6	5	#2	2000	2000			PA	47.7	54.0	109.9
B	8	6	3	4	#3	3000	3000			TG	11.1	12.0	
C	15	18	12	9	#4	4000	4000			C*	109.	53.7	IFR
D	4	5	3	2	#5	5000	5000			T	1.10	1.00	53.74
T'nG	10		6		#6	6500	6500			E	0.91	1.00	

Result | Graphs | Menu | S-Menu | Help

Fig. 4-1 Two Parallel Runway Hourly Capacity

Fig.4-1. Only two values are shown for runway hourly capacity during VFR and IFR conditions.

4.1.2 Computational Flow Logic

Computational flow logic dictates the priority and sequence of scripts assigned to perform different commands inside the **Result** button and also associates with the design of input and output table. The flow process starts at initial input parameter stage. A chart representing computational flow logic is shown in Fig. 4-2.

4.1.3 Sample Script Information of Runway Hourly Capacity

In order to explain the functionality of a series of scripts, a scenario consisting of two parallel runways spaced between 700 to 2499 ft with two arrival and two departure streams is chosen . The analysis below applies to those scripts inside the Result button.

The first message, a standard event handling mechanism in HyperCard, for a button sent to the computer to carry out an action is,

```
on mouseUp
```

The precision of parameters are defined internally at the beginning of those scripts. Touch and Go and Exit factor need to have two significant figures. This statement controls the precision over all parameters in every series of scripts. The command is,

```
Set numberFormat to 0.00
```

Sometimes parameters from one series of scripts need to be used or passed to other sections of scripts. In this case, those parameters are defined as global variables. The following command declares eight variables as global variables,

```
Global VFRMI, IFRMI, VFRPA, IFRPA, VFRCap, IFRCap, VFRDem, IFRDem
```

where,

VFRMI = Mix Index under VFR condition

IFRMI = Mix Index under IFR condition

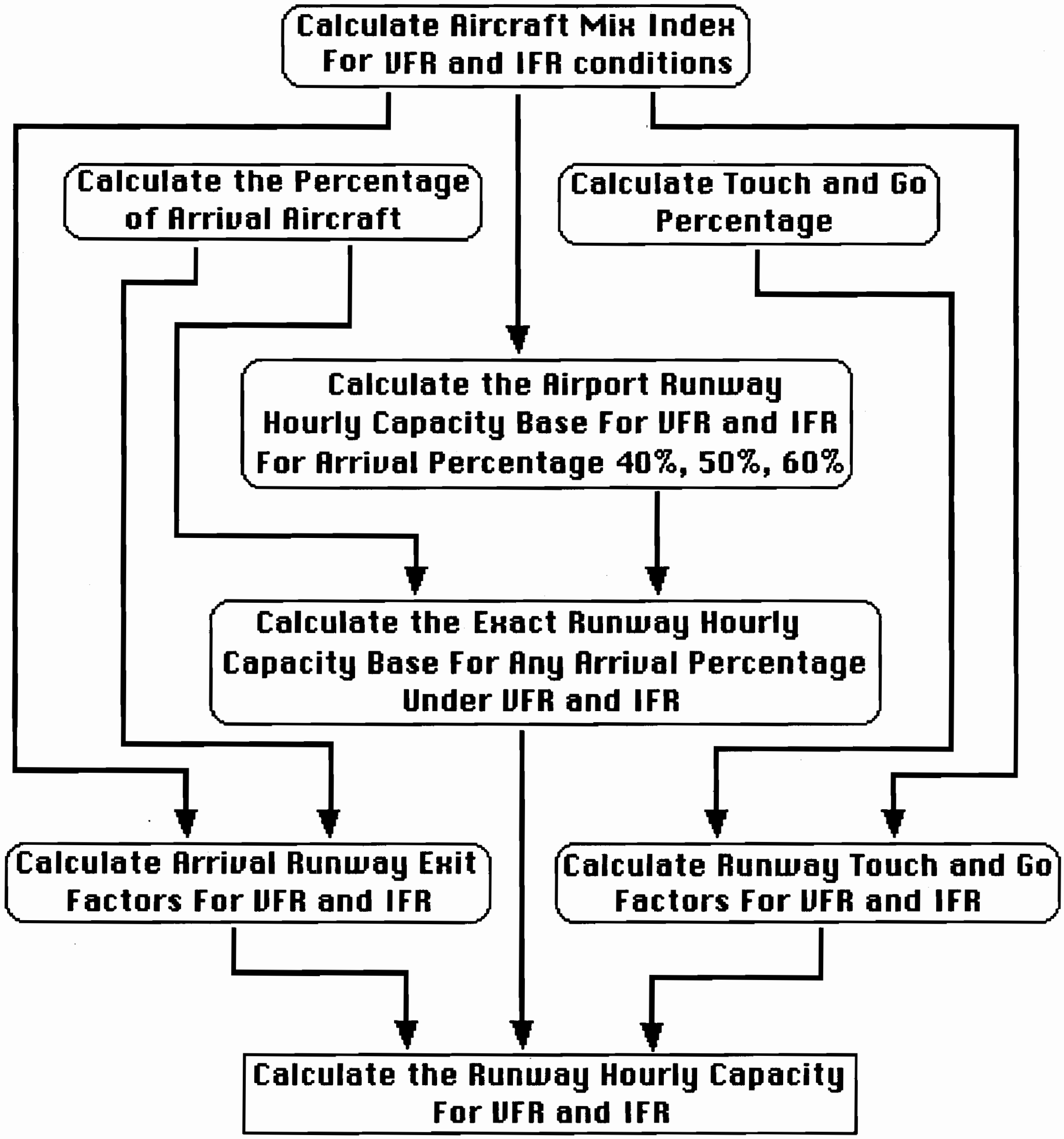


Fig. 4-2 Computational Flow Logic for Runway Hourly Capacity

VFRPA = Percent Arrival under VFR condition
IFRPA = Percent Arrival under IFR condition
VFRCap = Hourly Capacity under VFR condition
IFRCap = Hourly Capacity under IFR condition
VFRDem = Hourly Demand under VFR condition
IFRDem = Hourly Demand under IFR condition

All input and output blocks are fields which are named alphabetically columnwise, and numerically rowwise. The script structures to declare and carry out the calculations of Mix Index, Percent of Arrivals, Percent of Touch and Go for both VFR and IFR are identical to those below. To calculate the value of Mix Index as a global variable for VFR, the command is,

```
Put the value of (field A3+field B3+3*(field A4+field B4))*100/(field A1+field A2+field A3+field
A4+field B1+field B2+field B3+field B4) into VFRMI -- MI for VFR
```

Results of polynomial regressions to estimate the runway hourly capacity base are included in the scripts. All results at this stage are still local variables since the regression equations are derived from sets of data exactly for 40%, 50%, and 60% arrivals. Those local variables are from holder 1 to holder 6. The following is an example of Hourly Capacity Base for VFR with 40% Arrivals, the script structures for rest of them are the same,

```
Put -61.972*(field I1/100)^5+337.566*(field I1/100)^4-713.865*(field I1/100)^3+714.803*(field
I1/100)^2-414.693*(field I1/100)+218.260 into holder1--VFR 40% arrivals
```

Note that in previous calculations in the scripts, the only parameter needed to estimate Hourly Capacity Base is the Mix Index with Percent Arrivals at exactly 40%, 50%, and 60% respectively. In reality, percent arrivals are a continuos value that could vary from 0 to 100%. Thus, an interpolation mechanism is used in the script to find capacity values for Percent Arrivals of any value. A simple decision structure is used in ICAD scripting in order to implement the interpolation. It shows as follows,

```
If field I2>=40 and field I2<=50 then
Put the value of holder1+(40-field I2)*(holder1-holder2)/10 into field I4-- C* for VFR
Else if field I2>=50 and field I2<=60 then
Put the value of holder2+(50-field I2)*(holder2-holder3)/10 into field I4-- C* for VFR
End if
If field J2>=40 and field J2<=50 then
Put the value of holder4+(40-field J2)*(holder4-holder5)/10 into field J4-- C* for IFR
Else if field J2>=50 and field J2<=60 then
```

```
Put the value of holder5+(50-field J2)*(holder5-holder6)/10 into field J4-- C* for IFR
 End if
```

Touch and Go factors are classified by several ranges of Touch and Go percentages from 0% to 51%. A decision structure has been used to branch efficiently between Touch and Go factors. The following expression branches between seven Touch and Go ranges and then assign a numerical value to the output field,

```
If field I3=0 then Put 1.00 into field I5
Else if field I3>=1 and field I3<11 then Put 1.04 into field I5
Else if field I3>=11 and field I3<21 then Put 1.10 into field I5
Else if field I3>=21 and field I3<31 then Put 1.20 into field I5
Else if field I3>=31 and field I3<41 then Put 1.31 into field I5
Else if field I3>=41 and field I3<51 then Put 1.40 into field I5
 End if
 Put 1.00 into field J5 -- Tn'G factors
 Put the value of field I2 into temp5
 Put the value of field J2 into temp6
```

To find out runway exit factors, multipliers to decrease runway hourly capacity, regression equations containing two parameters--Percent Arrivals and number of runway exits are used. The first parameter has been found and placed in field I2 and J2 for VFR and IFR conditions respectively. As seen in the application input table at Fig. 4-1, there are twelve exits located along two arrival runways. With a certain range of Mix Indices, The locations of exits need to be verified six times for each runway. The number of exits counted from the exit location verification is then defined as a local variable. At this time, number in the local variable belongs to two runways, and do not need to be averaged since the scripts are already made to fit this situation. The following series of scripts illustrates the process.

```
If field I1>=0 and field I1<21 then
 Put 0 into var1
If field E1>=2000 and field E1<=4000 then add 1 to var1
If field E2>=2000 and field E2<=4000 then add 1 to var1
If field E3>=2000 and field E3<=4000 then add 1 to var1
If field E4>=2000 and field E4<=4000 then add 1 to var1
If field E5>=2000 and field E5<=4000 then add 1 to var1
If field E6>=2000 and field E6<=4000 then add 1 to var1
If field F1>=2000 and field F1<=4000 then add 1 to var1
If field F2>=2000 and field F2<=4000 then add 1 to var1
If field F3>=2000 and field F3<=4000 then add 1 to var1
If field F4>=2000 and field F4<=4000 then add 1 to var1
If field F5>=2000 and field F5<=4000 then add 1 to var1
If field F6>=2000 and field F6<=4000 then add 1 to var1
If var1=6 then put 1.03-0.00167*temp5 into field I6
If var1=5 then put 1.03-0.00167*temp5 into field I6
If var1=4 then put 1.03-0.00167*temp5 into field I6
```

```
   If var1<4 then put 0.794-0.00167*temp5+0.118*var1/2 into field I6
End if
   If field I1>=21 and field I1<51 then
    Put 0 into var2
   If field E1>=3000 and field E1<=5500 then add 1 to var2
   If field E2>=3000 and field E2<=5500 then add 1 to var2
   If field E3>=3000 and field E3<=5500 then add 1 to var2
   If field E4>=3000 and field E4<=5500 then add 1 to var2
   If field E5>=3000 and field E5<=5500 then add 1 to var2
   If field E6>=3000 and field E6<=5500 then add 1 to var2
   If field F1>=3000 and field F1<=5500 then add 1 to var2
   If field F2>=3000 and field F2<=5500 then add 1 to var2
   If field F3>=3000 and field F3<=5500 then add 1 to var2
   If field F4>=3000 and field F4<=5500 then add 1 to var2
   If field F5>=3000 and field F5<=5500 then add 1 to var2
   If field F6>=3000 and field F6<=5500 then add 1 to var2
   If var2=8 then put 1.00 into field I6
   If var2=7 then put (2.056-0.00267*temp5)/2 into field I6
   If var2=6 then put 1.056-0.00267*temp5 into field I6
   If var2=5 then put 1.056-0.00267*temp5 into field I6
   If var2=4 then put 1.056-0.00267*temp5 into field I6
   If var2<4 then put 0.889-0.00267*temp5+0.0833*var2/2 into field I6
End if
```

So far, every intermediate parameter (i.e., Runway Hourly Capacity Base, Touch and Go Factor, and Arrival Runway Exit Factor), has been estimated. The final result of runway hourly capacity is then,

```
 Put (field I4)*(field I5)*(field I6) into VFRCap
 Put (field I4)*(field I5)*(field I6) into field K1
 Put (field J4)*(field J5)*(field J6) into IFRCap
 Put (field J4)*(field J5)*(field J6) into field K2
 Put field A1+field A2+field A3+field A4+field A5+field B1+field B2+field B3+field B4 into VFRDem
 Put field C1+field C2+field C3+field C4+field C5+field D1+field D2+field D3+field D4 into IFRDem
end mouseUp
```

4.2 Taxiway Hourly Capacity

Taxiway hourly capacities are only with those taxiways that cross active runways. The computation of taxiway capacity is independent of that of the runway.

4.2.1 Input and Output Parameters of Taxiway Hourly Capacity

The input and output interface for taxiway capacity estimation is presented in Fig. 4-3. There are two possible types of aircraft operations on a single runway--Arrivals only and Mixed Operations as well as Departure and Touch and Go Operations. Input parameters here include the number of aircraft belonging to each classification group with two operations under VFR and IFR whether conditions, and the distance from the crossing taxiway to the departure end of runway. Five crossing taxiway capacities are allowed by this application at the same time as shown in Fig. 4-3, but they all share the same input area except for the distance from departure end of runway to the taxiway. In other words, when users press the calculating button labeled as X'g..., the number of aircraft on the input table refers the aircraft operations occurring along the runway crossed by the taxiway. If the capacity of another crossing taxiway is needed with different aircraft operations, the entire input data must be replaced with that belonging to the second crossing taxiway's.

4.1.2 Computational Flow Logic

The computational flow logic chart of taxiway hourly capacity is shown in Fig. 4-3.

4.2.3 Sample Script Information of Taxiway Hourly Capacity

Taxiway hourly capacities are presented as integer parameters. Define variables in this scripts as integer,

```
Set numberFormat to 0.
```

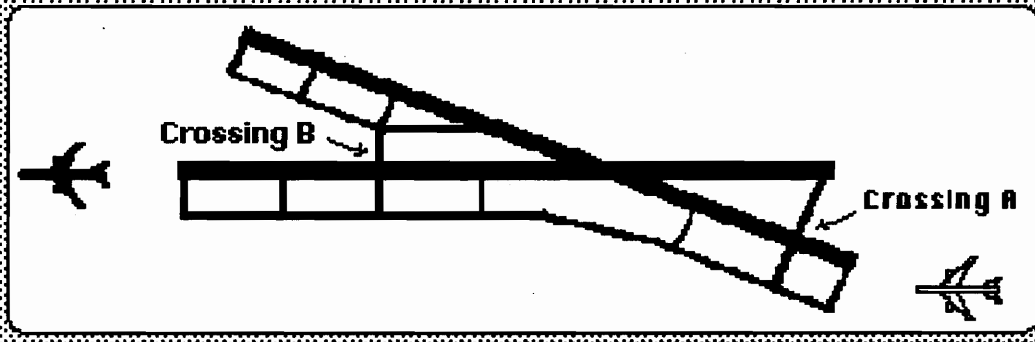
Several input and output parameters for crossing taxiway A are declared as global variables as follows,

```
Global VAMXADem, VDTXADem, IAMXADem, IDTXADem, VAMXACap,
VDTXACap, IAMXACap, IDTXACap
```

where,

VAMXADem = air operation demand over crossing taxiway A with arrival and mixed operations under VFR

Hourly Capacity of The Taxiways



Items / Temps	VFR AM	VFR DT	IFR AM	IFR DT	Items / X'gs	DFT (Ft)	VFRMI AM	VFRMI DT	IFRMI AM	IFRMI DT	VFRCap. AM	VFRCap. DT	IFRCap. AM	IFRCap. DT
A	0	0	0	0	A	2300	61	0	89	0	106	0	95	0
B	0	0	0	0	B	3000	0	63	0	93	0	119	0	105
C	0	0	0	0	C	1200	0	0	0	0	0	0	0	0
D	0	0	0	0	D	1500	0	0	0	0	0	0	0	0
TnG	0	0	0	0	E	1050	0	0	0	0	0	0	0	0

Main Menu | X'g A | X'g B | X'g C | X'g D | X'g E | Help

Fig. 4-3 Taxiway Hourly Capacity

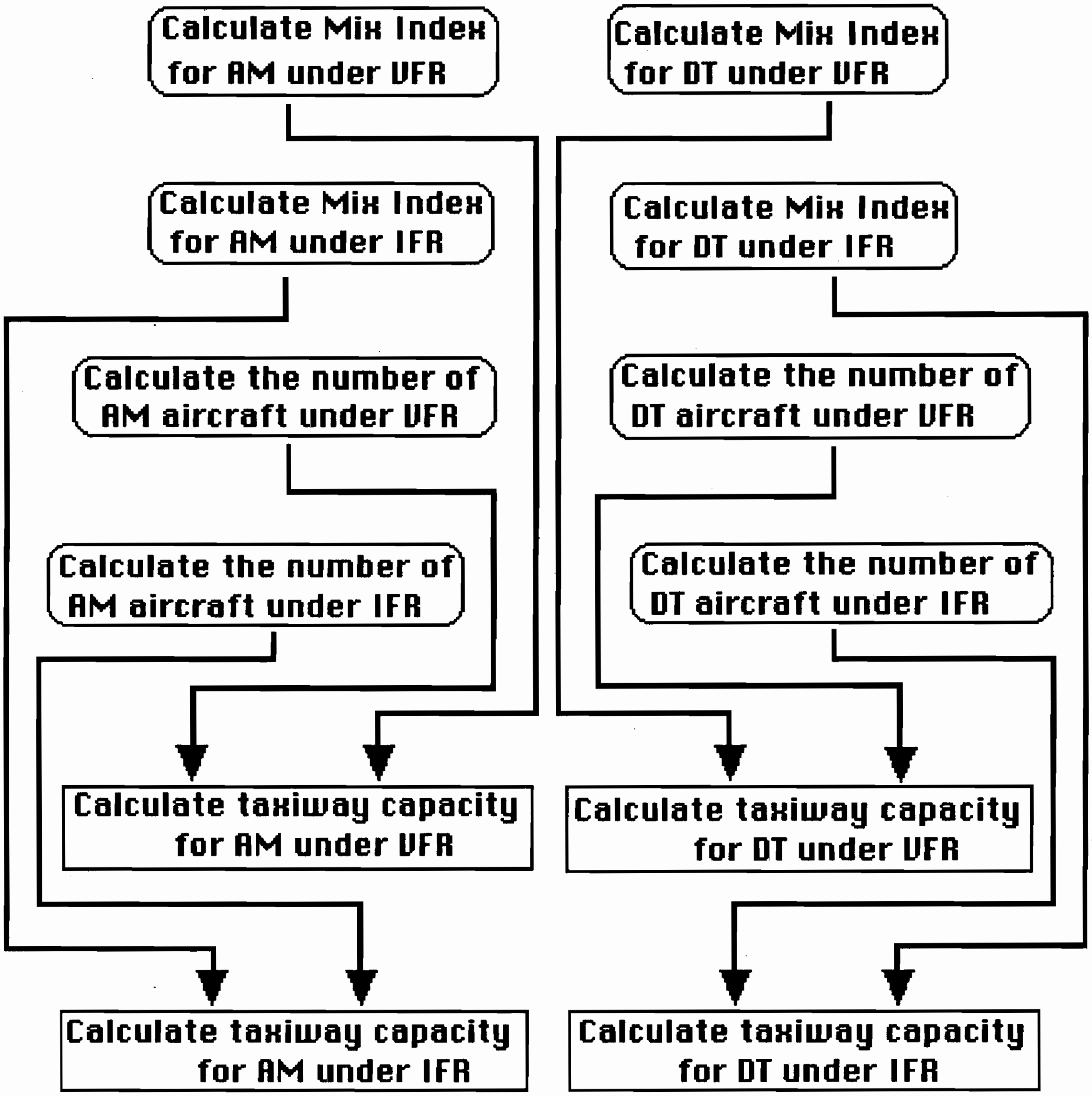


Fig. 4-4 Computational Flow Logic for Taxiway Hourly Capacity

VDTXADem = air operation demand over crossing taxiway A with departure and T'nG operations under VFR

IAMXADem = air operation demand over crossing taxiway A with arrival and mixed operations under IFR

IDTXADem = air operation demand over crossing taxiway A with departure and T'nG operations under IFR

VAMXACap = hourly capacity of crossing taxiway A with arrivals mixed operations under VFR

VDTXACap = hourly capacity of crossing taxiway A with departure and T'nG operations under VFR

IAMXACap = hourly capacity of crossing taxiway A with arrival mixed operations under IFR

IDTXACap = hourly capacity of crossing taxiway A with departure and T'nG operations under IFR

The following scripts are used to calculate the values for global variables and Mix Index,

```
Put field A1+field A2+field A3+field A4+field A5 into VAMXADem
Put field B1+field B2+field B3+field B4+field B5 into VDTXADem
Put field C1+field C2+field C3+field C4+field C5 into IAMXADem
Put field D1+field D2+field D3+field D4+field D5 into IDTXADem
Put (field A3+3*field A4)*100/(field A1+field A2+field A3+field A4+field A5) into field F1
Put (field B3+3*field B4)*100/(field B1+field B2+field B3+field B4+field B5) into field G1
Put (field C3+3*field C4)*100/(field C1+field C2+field C3+field C4+field C5) into field H1
Put (field D3+3*field D4)*100/(field D1+field D2+field D3+field D4+field D5) into field I1
Put the value of field A1+field A2+field A3+field A4+field A5 into holder1
If holder1>=56 then
  If field E1>2000 then ask "When the operation rate is greater than 56
  and distance of the exit from runway threshold is greater than 2000 Ft,
  the calculation can not be executed!"
  If holder1>95 then ask "When the operation rate is over 95, the
  calculation can not be executed!"
End if
Put the value of field B1+field B2+field B3+field B4+field B5 into holder2
Put the value of field C1+field C2+field C3+field C4+field C5 into holder3
Put the value of field D1+field D2+field D3+field D4+field D5 into holder4
```

With the increase of runway operation rate and the distance from the taxiway to the departure end of a runway, the curves for taxiway capacity in FAA AC 150/5060-5 become to be independent of Mix Indices. Interpolations are used between those regression equations to estimate taxiway hourly capacity.

The scripts of taxiway hourly capacity with arrivals only and mixed operations under VFR are shown as below. The similar script structure is used for the rest of cases.

```
Put 79.7-1.47*(field F1)+0.0393*(field F1)^2-0.000446*(field F1)^3 into temp1
Put 194-0.0437*(field E1)-2.41*(field F1)+0.0268*(field F1)^2 into temp2
 Put 128-0.013*(field E1)-0.856*(field F1) into temp3
Put 179-0.0618*(field E1)-2.07*(field F1)+0.0242*(field F1)^2 into temp4
 Put 95.5-0.0185*(field E1)-0.427*(field F1) into temp5
 If holder1=0 then
    Put 0 into field F1
    Put 0 into field J1
 End if
If holder1>0 and holder1<36 then put 195-0.00416*(field E1)-2.19*(field
F1)+0.0174*(field F1)^2-0.000048*(field F1)^3 into field J1-- VFRCap. AM
If holder1>=36 and holder1<56 then put 123-0.0068*(field E1)-1.23*(field
F1)+0.00957*(field F1)^2-0.000025*(field F1)^3 into field J1 -- VFRCap. AM
If holder1>=56 and holder1<76 then
   If field E1>=0 and field E1<1000 then put temp1-(temp1-35)*(field E1)/1000
    into field J1-- VFRCap. AM
   If field E1>=1000 and field E1<=2000 then put 35-30*(field E1-1000)/1000
    into field J1-- VFRCap. AM
If holder1>=76 and holder1<=95 then put 60-55*(field E1)/2000 into field J1-- VFRCap.AM
 End if
```

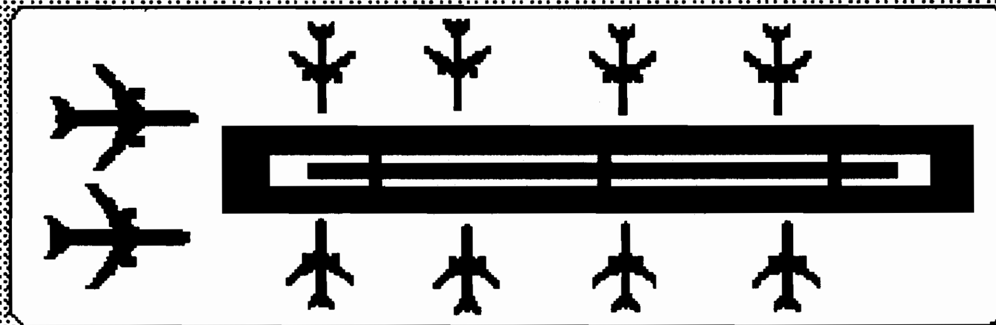
4.3 Gate Group Hourly Capacity

Pier, satellite, or combined types of airport terminal can be analyzed in ICAD. Total terminal capacity results from each individual gate group are explained in this section.

4.3.1 Input and Output Parameters of Gate Group Hourly Capacity

This application provides input / output table, shown in Fig. 4-5, to estimate gate group capacities at the same time. Parameters needed to enter into the capacity calculations are aircraft operation demands, number of gates, and gate service time. More specifically, gate times for processing aircraft are divided into two groups--non wide-bodied and wide-bodied aircraft. Some intermediate parameters are calculated in Table 4-6 such as gate occupancy ratio, hourly capacity base, gate size, and number of gates. The capacity for each gate group is finally reconciled to estimate the total airport terminal capacity.

Hourly Capacity of The Gate Group



Gate Group	Demand		No. Gates		Gate Mix		GateTime		Gate Occu Rat.	Hrly Cap. Base	Gate Size	No. Gate	Hrly Cap.	Total Cap.
	N	W	N	W	N	W	N	W						
A	13	2	4	1	86.	20.	45	55	.22	2.6	0.95	5.0	12.6	29.4
B	8	0	2	1	100	33.	40	0	.00	3.2	1.00	3.0	9.66	
C	4	0	2	0	100	0.0	35	0	.00	3.5	1.00	2.0	7.10	
D	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.0	0.00	0.0	0.00	
E	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.0	0.00	0.0	0.00	

Result Main Menu Help

Fig. 4-5 Gate Group Hourly Capacity

4.3.2 Computational Flow Logic

Computational flow logic of gate group hourly capacity is shown in Fig. 4-6.

4.3.3 Sample Script Information of Gate Group Hourly Capacity

As usual, a Result script is provided to demonstrate the execution of internal computation. Two global variables are defined by,

```
Global GaCap, GaDem
```

where,

GaCap = Gate Groups Hourly Capacity
GaDem = Gate Groups Hourly Demand

Note that several fields are defined as zero to avoid computer system errors. To calculate the gate group aircraft demand percentages for non wide-bodied aircraft, scripts below shows,

```
Put the value of field A1+field A2+field A3+field A4+field A5+field B1+field B2+field B3+field
 B4+field B5 into GaDem
If field A1=0 and field B1=0 then
   Put 0 into field C1
   Put 0 into field D1
   Put 0 into field E1
   Put 0 into field G1
   Put 0 into field H1
   Put 0 into field K1
   Put 0 into field L1
   Put 0 into field M1
Else put (field A1)*100/(field A1+field B1) into field E1
```

Script structures for gate percentages for wide-bodied aircraft and gate occupancy ratios are similar. Shown below is the calculation of gate percentages for wide-bodied aircraft.

```
If field C1=0 and field D1=0 then put 0 into field F1
Else put (field D1)*100/(field C1+field D1) into field F1
If field C2=0 and field D2=0 then put 0 into field F2
Else put (field D2)*100/(field C2+field D2) into field F2
If field C3=0 and field D3=0 then put 0 into field F3
```

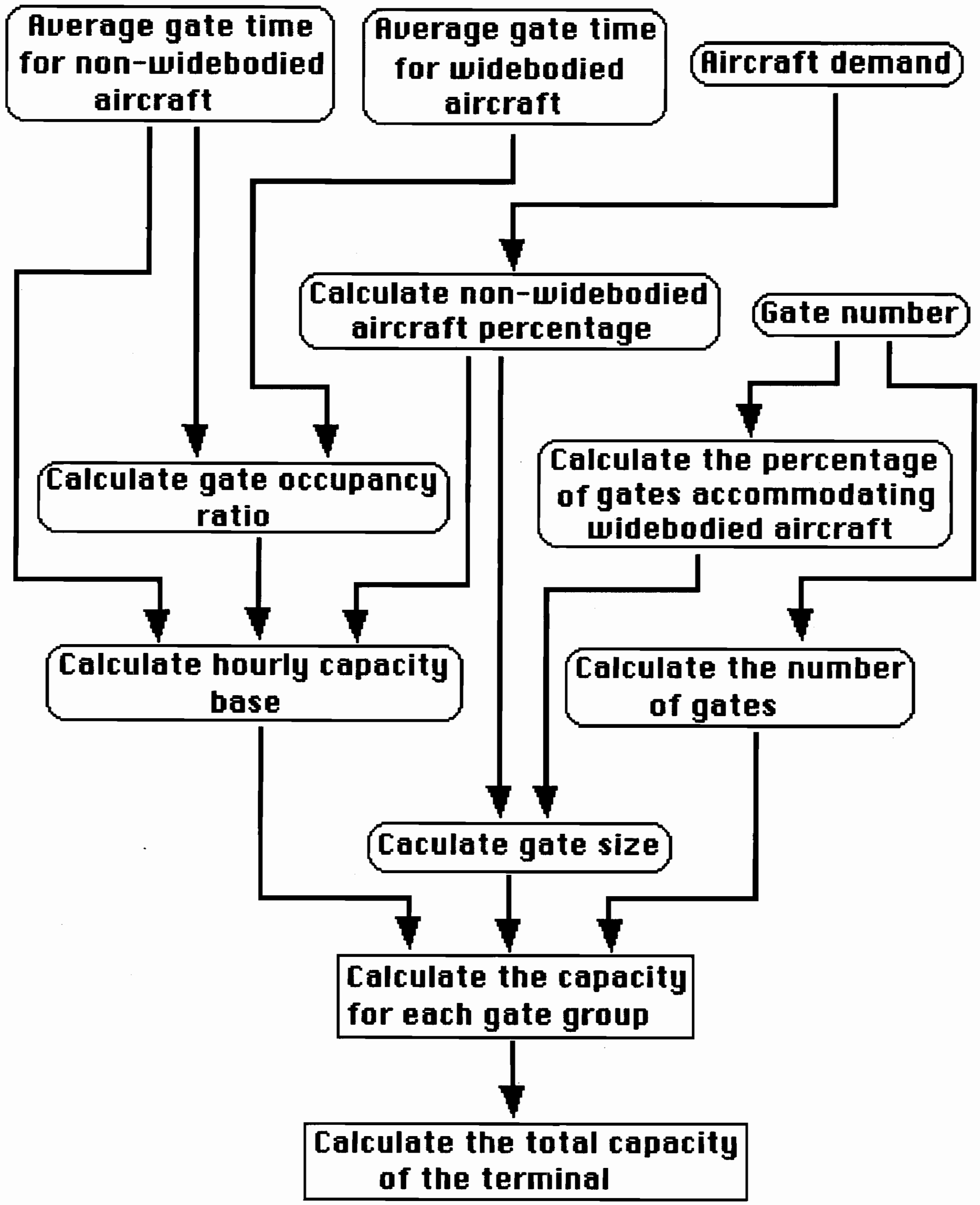


Fig. 4-6 Computational Flow Logic for Gate Group Hourly Capacity

```
Else put (field D3)*100/(field C3+field D3) into field F3
If field C4=0 and field D4=0 then put 0 into field F4
Else put (field D4)*100/(field C4+field D4) into field F4
If field C5=0 and field D5=0 then put 0 into field F5
Else put (field D5)*100/(field C5+field D5) into field F5
```

Since gate group hourly capacities vary according to gate occupancy ratios. Gate group hourly capacity bases (at R=1.0, 1.2, 1.4, 1.6) are calculated first, and then interpolation is used to estimate gate group hourly capacity for any R values. The complex script structure for their computations is shown as follows,

```
Put 7.43-0.15*(field G1)+0.001*(field G1)^2 into temp1
Put 7.43-0.15*(field G2)+0.001*(field G2)^2 into temp2
Put 7.43-0.15*(field G3)+0.001*(field G3)^2 into temp3
Put 7.43-0.15*(field G4)+0.001*(field G4)^2 into temp4
Put 7.43-0.15*(field G5)+0.001*(field G5)^2 into temp5
If field A1=0 and field B1=0 then put 0 into field I1
Put 7.33+0.00702*(field E1)-0.802*(field I1)-0.138*(field G1)+0.000942*(field G1)^2 into temp6
If field A2=0 and field B2=0 then put 0 into field I2
Put 7.33+0.00702*(field E2)-0.802*(field I2)-0.138*(field G2)+0.000942*(field G2)^2 into temp7
If field A3=0 and field B3=0 then put 0 into field I3
Put 7.33+0.00702*(field E3)-0.802*(field I3)-0.138*(field G3)+0.000942*(field G3)^2 into temp8
If field A4=0 and field B4=0 then put 0 into field I4
Put 7.33+0.00702*(field E4)-0.802*(field I4)-0.138*(field G4)+0.000942*(field G4)^2 into temp9
If field A5=0 and field B5=0 then put 0 into field I5
Put 7.33+0.00702*(field E5)-0.802*(field I5)-0.138*(field G5)+0.000942*(field G5)^2 into temp10
If temp1>=1.00 and temp1<1.20 then put temp1-(temp1-temp6)*(field I1-1.00)/0.2 into field J1
Else put 7.33+0.00702*(field E1)-0.802*(field I1)-0.138*(field G1)+0.000942*(field G1)^2 into
 field J1
If field A1=0 and field B1=0 then put 0 into field J1
If temp2>=1.00 and temp2<1.20 then put temp2-(temp2-temp7)*(field I2-1.00)/0.2 into field J2
Else put 7.33+0.00702*(field E2)-0.802*(field I2)-0.138*(field G2)+0.000942*(field G2)^2 into
 field J2
If field A2=0 and field B2=0 then put 0 into field J2
If temp3>=1.00 and temp3<1.20 then put temp3-(temp3-temp8)*(field I3-1.00)/0.2 into field J3
Else put 7.33+0.00702*(field E3)-0.802*(field I3)-0.138*(field G3)+0.000942*(field G3)^2 into
 field J3
If field A3=0 and field B3=0 then put 0 into field J3
If temp4>=1.00 and temp4<1.20 then put temp4-(temp4-temp9)*(field I4-1.00)/0.2 into field J4
Else put 7.33+0.00702*(field E4)-0.802*(field I4)-0.138*(field G4)+0.000942*(field G4)^2 into
 field J4
If field A4=0 and field B4=0 then put 0 into field J4
If temp5>=1.00 and temp5<1.20 then put temp5-(temp5-temp10)*(field I5-1.00)/0.2 into field J5
Else put 7.33+0.00702*(field E5)-0.802*(field I5)-0.138*(field G5)+0.000942*(field G5)^2 into
 field J5
If field A5=0 and field B5=0 then put 0 into field J5
```

The following are the scripts for gate size factors at gate percentages 10, 20, 40, 60, 80, and at any gate percentage for wide-bodied aircraft,

```
Put 1.344*(field E1/100)^4-0.217*(field E1/100)^3-0.407*(field E1/100)^2-0.223*(field
 E1/100)+0.098 into hold1
```

```
Put -17.574*(field E1/100)^5+36.952*(field E1/100)^4-25.105*(field E1/100)^3+6.958*(field
 E1/100)^2-0.444*(field E1/100)+0.2 into hold2
Put 0.024*(field E1/100)^4-1.88*(field E1/100)^3+2.566*(field E1/100)^2-0.122*(field
  E1/100)+0.403 into hold3
Put 3.253*(field E1/100)^4-6.858*(field E1/100)^3+3.909*(field E1/100)^2+0.102*(field
  E1/100)+0.599 into hold4
Put 0.729*(field E1/100)^3-1.516*(field E1/100)^2+0.988*(field E1/100)+0.802 into hold5
Put 1.344*(field E2/100)^4-0.217*(field E2/100)^3-0.407*(field E2/100)^2-0.223*(field
  E2/100)+0.098 into hold6
 Put -17.574*(field E2/100)^5+36.952*(field E2/100)^4-25.105*(field E2/100)^3+6.958*(field
 E2/100)^2-0.444*(field E2/100)+0.2 into hold7
Put 0.024*(field E2/100)^4-1.88*(field E2/100)^3+2.566*(field E2/100)^2-0.122*(field
  E2/100)+0.403 into hold8
Put 3.253*(field E2/100)^4-6.858*(field E2/100)^3+3.909*(field E2/100)^2+0.102*(field
  E2/100)+0.599 into hold9
Put 0.729*(field E2/100)^3-1.516*(field E2/100)^2+0.988*(field E2/100)+0.802 into hold10
Put 1.344*(field E3/100)^4-0.217*(field E3/100)^3-0.407*(field E3/100)^2-0.223*(field
  E3/100)+0.098 into hold11
Put -17.574*(field E3/100)^5+36.952*(field E3/100)^4-25.105*(field E3/100)^3+6.958*(field
 E3/100)^2-0.444*(field E3/100)+0.2 into hold12
Put 0.024*(field E3/100)^4-1.88*(field E3/100)^3+2.566*(field E3/100)^2-0.122*(field
  E3/100)+0.403 into hold13
Put 3.253*(field E3/100)^4-6.858*(field E3/100)^3+3.909*(field E3/100)^2+0.102*(field
  E3/100)+0.599 into hold14
Put 0.729*(field E3/100)^3-1.516*(field E3/100)^2+0.988*(field E3/100)+0.802 into hold15
Put 1.344*(field E4/100)^4-0.217*(field E4/100)^3-0.407*(field E4/100)^2-0.223*(field
  E4/100)+0.098 into hold15
Put -17.574*(field E4/100)^5+36.952*(field E4/100)^4-25.105*(field E4/100)^3+6.958*(field
 E4/100)^2-0.444*(field E4/100)+0.2 into hold17
Put 0.024*(field E4/100)^4-1.88*(field E4/100)^3+2.566*(field E4/100)^2-0.122*(field
  E4/100)+0.403 into hold18
Put 3.253*(field E4/100)^4-6.858*(field E4/100)^3+3.909*(field E4/100)^2+0.102*(field
  E4/100)+0.599 into hold19
Put 0.729*(field E4/100)^3-1.516*(field E4/100)^2+0.988*(field E4/100)+0.802 into hold20
Put 1.344*(field E5/100)^4-0.217*(field E5/100)^3-0.407*(field E5/100)^2-0.223*(field
  E5/100)+0.098 into hold21
Put -17.574*(field E5/100)^5+36.952*(field E5/100)^4-25.105*(field E5/100)^3+6.958*(field
 E5/100)^2-0.444*(field E5/100)+0.2 into hold22
Put 0.024*(field E5/100)^4-1.88*(field E5/100)^3+2.566*(field E5/100)^2-0.122*(field
  E5/100)+0.403 into hold23
Put 3.253*(field E5/100)^4-6.858*(field E5/100)^3+3.909*(field E5/100)^2+0.102*(field
  E5/100)+0.599 into hold24
Put 0.729*(field E5/100)^3-1.516*(field E5/100)^2+0.988*(field E5/100)+0.802 into hold25

If field F1>=10 and field F1<20 then put hold1+(hold2-hold1)*(field F1-10)/10 into field K1
Else if field F1>=20 and field F1<40 then put hold2+(hold3-hold2)*(field F1-20)/20 into field K1
Else if field F1>=40 and field F1<60 then put hold3+(hold4-hold3)*(field F1-20)/20 into field K1
Else if field F1>=60 and field F1<80 then put hold4+(hold5-hold4)*(field F1-20)/20 into field K1
  Else if field F1>=80 then put 1.00 into field K1
 If field E1=100 then put 1.00 into field K1
If field F2>=10 and field F2<20 then put hold6+(hold7-hold6)*(field F2-10)/10 into field K2
Else if field F2>=20 and field F2<40 then put hold7+(hold8-hold7)*(field F2-20)/20 into field K2
Else if field F2>=40 and field F2<60 then put hold8+(hold9-hold8)*(field F2-20)/20 into field K2
Else if field F2>=60 and field F2<80 then put hold9+(hold10-hold9)*(field F2-20)/20 into field K2
 Else if field F2>=80 then put 1.00 into field K2
```

```
If field E2=100 then put 1.00 into field K2
If field F3>=10 and field F3<20 then put hold11+(hold12-hold11)*(field F3-10)/10 into field K3
Else if field F3>=20 and field F3<40 then put hold12+(hold13-hold12)*(field F3-20)/20 into field K3
Else if field F3>=40 and field F3<60 then put hold13+(hold14-hold13)*(field F3-20)/20 into field K3
Else if field F3>=60 and field F3<80 then put hold14+(hold15-hold14)*(field F3-20)/20 into field K3
Else if field F3>=80 then put 1.00 into field K3
If field E3=100 then put 1.00 into field K3
If field F4>=10 and field F4<20 then put hold16+(hold17-hold16)*(field F4-10)/10 into field K4
Else if field F4>=20 and field F4<40 then put hold17+(hold18-hold17)*(field F4-20)/20 into field K4
Else if field F4>=40 and field F4<60 then put hold18+(hold19-hold18)*(field F4-20)/20 into field K4
Else if field F4>=60 and field F4<80 then put hold19+(hold20-hold19)*(field F4-20)/20 into field K4
Else if field F4>=80 then put 1.00 into field K4
If field E4=100 then put 1.00 into field K4
If field F5>=10 and field F5<20 then put hold21+(hold22-hold21)*(field F5-10)/10 into field K5
Else if field F5>=20 and field F5<40 then put hold22+(hold23-hold22)*(field F5-20)/20 into field K5
Else if field F5>=40 and field F5<60 then put hold23+(hold24-hold23)*(field F5-20)/20 into field K5
Else if field F5>=60 and field F5<80 then put hold24+(hold25-hold24)*(field F5-20)/20 into field K5
Else if field F5>=80 then put 1.00 into field K5
If field E5=100 then put 1.00 into field K5
```

The scripts for the calculations of number of gates, gate hourly capacity for each gate group, total capacity of the terminal are shown as follows,

```
Put field C1+field D1 into field L1
Put field C2+field D2 into field L2
Put field C3+field D3 into field L3
Put field C4+field D4 into field L4
Put field C5+field D5 into field L5
Put (field J1)*(field K1)*(field L1) into field M1
Put (field J2)*(field K2)*(field L2) into field M2
Put (field J3)*(field K3)*(field L3) into field M3
Put (field J4)*(field K4)*(field L4) into field M4
Put (field J5)*(field K5)*(field L5) into field M5
Put the value of field M1+field M2+field M3+field M4+field M5 into GaCap
Put the value of field M1+field M2+field M3+field M4+field M5 into field N1
```

4.4 Airport Overall Hourly Capacity

Airport overall hourly capacity virtually measures the capacity of the airport system which contains several components such as runways, taxiways, and terminals. The capacities of each component could be remarkably different without regard to their own aircraft operation demands. In general, the airport component which has the smallest capacity will become a constraint in deciding airport overall hourly capacity.

4.4.1 Input and Output Parameters of Airport Overall Hourly Capacity

In this application, it is not necessary for the users to type parameters into input fields since all input data are already prepared from previous runway, crossing taxiway, and gate group capacity calculations. The input parameters needed for this application are the hourly capacities for three types of airport components and the aircraft operation demand of each airport component under VFR and IFR weather conditions. The demand ratios and component quotients are the output results of this procedure (See Fig. 4-7).

4.4.2 Computational Flow Logic

Computational flow logic of airport overall hourly capacity is seen on Fig.4-8.

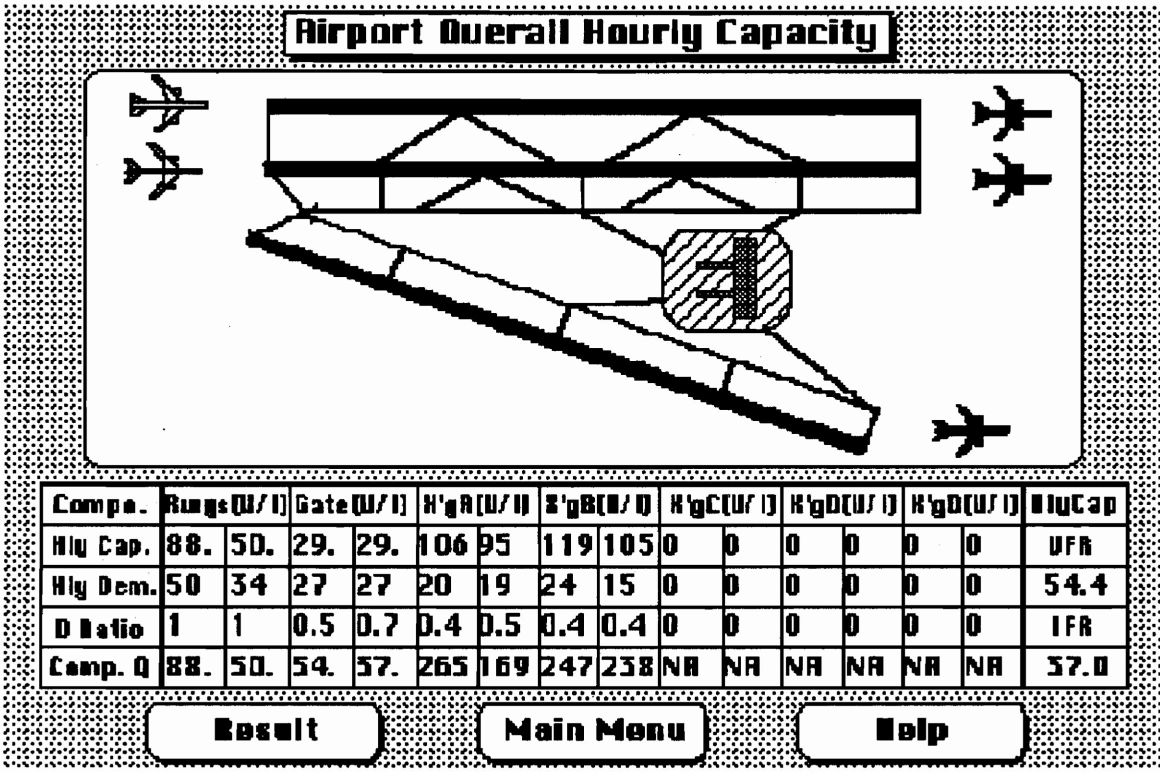
4.4.3 Sample Script Information of Airport Overall Hourly Capacity

All input data are global variables passed on from the capacity calculations of runways, crossing taxiways, and gate groups. They are declared previously, but need to be declared again as the first line of this application scripts.

```
Global VFRCap, IFRCap, VFRDem, IFRDem, GaCap, GaDem
Global VAMXACap, VDTXACap, VAMXBCap, VDTXBCap, VAMXCCap,
VDTXCCap, VAMXDCap, VDTXDCap, VAMXECap, VDTXECap
Global IAMXACap, IDTXACap, IAMXBCap, IDTXBCap, IAMXCCap, IDTXCCap,
IAMXDCap, IDTXDCap, IAMXECap, IDTXECap
Global VAMXADem, VDTXADem, VAMXBDem, VDTXBDem, VAMXCDem,
VDTXCDem, VAMXDDem, VDTXDDem, VAMXEDem, VDTXEDem
Global IAMXADem, IDTXADem, IAMXBDem, IDTXBDem, IAMXCDem,
IDTXCDem, IAMXDDem, IDTXDDem, IAMXEDem, IDTXEDem
```

To put the global variables into their corresponding fields, the scripts are,

```
Put the value of VFRCap into field A1
Put the value of IFRCap into field B1
Put the value of VFRDem into field A2
Put the value of IFRDem into field B2
Put the value of GaCap into field C1
```



Compo.	Rwys(V/I)		Gate(V/I)		H'gA(V/I)		H'gB(V/I)		H'gC(V/I)		H'gD(V/I)		H'gD(V/I)		HlyCap
Hly Cap.	88.	50.	29.	29.	106	95	119	105	0	0	0	0	0	0	VFR
Hly Dem.	50	34	27	27	20	19	24	15	0	0	0	0	0	0	54.4
D Ratio	1	1	0.5	0.7	0.4	0.5	0.4	0.4	0	0	0	0	0	0	IFR
Comp. Q	88.	50.	54.	57.	265	169	247	238	NA	NA	NA	NA	NA	NA	57.0

Fig. 4-7 Airport Overall Hourly Capacity

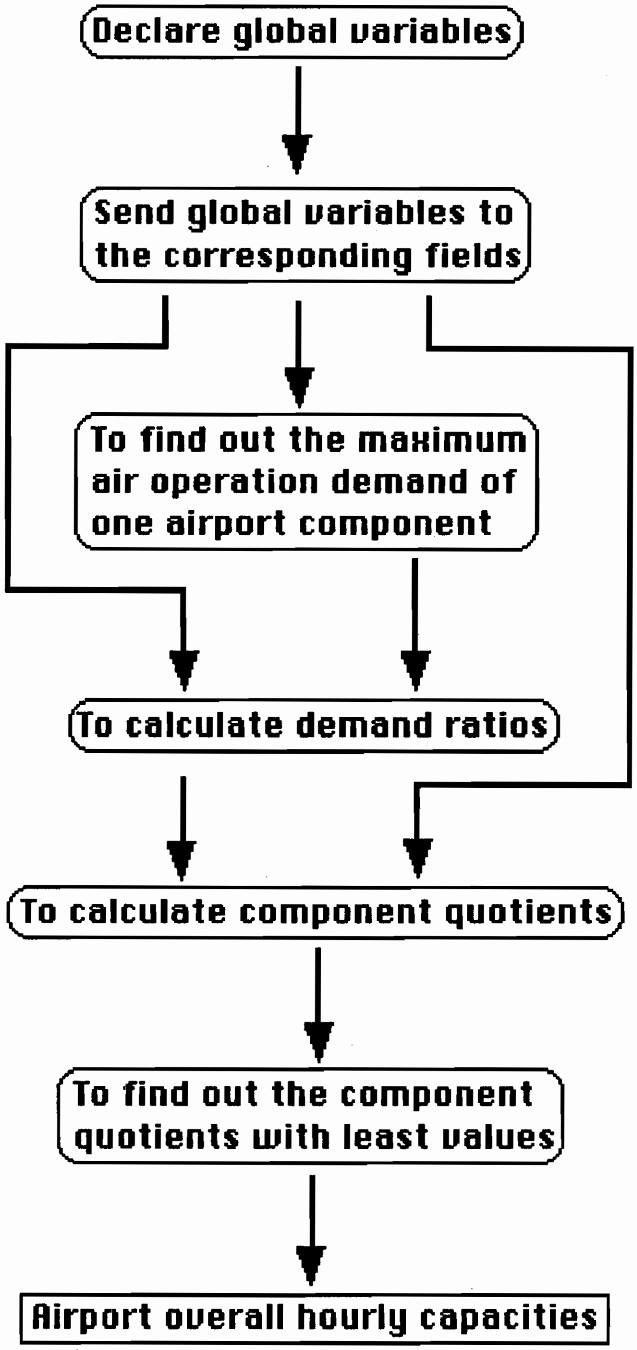


Fig. 4-8 Computational Flow Logic for Airport Overall Hourly Capacity

Put the value of GaCap into field Cc1
Put the value of GaDem into field C2
Put the value of GaDem into field Cc2
If the value of VAMXACap is 0 then put the value of VDTXACap into field D1
Else put the value of VAMXACap into field D1
If the value of IAMXACap is 0 then put the value of IDTXACap into field E1
Else put the value of IAMXACap into field E1
If the value of VAMXADem is 0 then put the value of VDTXADem into field D2

To find out the maximum hourly demand values from one or two of the airport components and each component demand ratio, the following scripts are used,

If field A2>=field C2 then put the value of field A2 into Denom1
Else put the value of field C2 into Denom1
If Denom1>=field D2 then put Denom1 into Denom1
Else put the value of field D2 into Denom1
If Denom1>=field F2 then put Denom1 into Denom1
Else put the value of field F2 into Denom1
If Denom1>=field H2 then put Denom1 into Denom1
Else put the value of field H2 into Denom1
If Denom1>=field J2 then put Denom1 into Denom1
Else put the value of field J2 into Denom1
If Denom1>=field L2 then put Denom1 into Denom1
Else put the value of field L2 into Denom1

Put the value of field A2/Denom1 into field A3
Put the value of field C2/Denom1 into field C3
Put the value of field D2/Denom1 into field D3
Put the value of field F2/Denom1 into field F3
Put the value of field H2/Denom1 into field H3
Put the value of field J2/Denom1 into field J3
Put the value of field L2/Denom1 into field L3

To calculate airport component quotients and find out the most critical components with lowest component quotient. The scripts are,

Put the value of field A1/field A3 into field A4
Put the value of field B1/field B3 into field B4
Put the value of field C1/field C3 into field C4
Put the value of field Cc1/field Cc3 into field Cc4
Put the value of field D1/field D3 into field D4
Put the value of field E1/field E3 into field E4
Put the value of field F1/field F3 into field F4
Put the value of field G1/field G3 into field G4
Put the value of field H1/field H3 into field H4
Put the value of field I1/field I3 into field I4
Put the value of field J1/field J3 into field J4
Put the value of field K1/field K3 into field K4
Put the value of field L1/field L3 into field L4
Put the value of field M1/field M3 into field M4

```
If field A4<=field C4 then put the value of field A4 into Medial
 Else put the value of field C4 into Medial
If Medial<=field D4 then put Medial into Medial
 Else put the value of field D4 into Medial
If Medial<=field F4 then put Medial into Medial
 Else put the value of field F4 into Medial
If Medial<=field H4 then put Medial into Medial
 Else put the value of field H4 into Medial
If Medial<=field J4 then put Medial into Medial
 Else put the value of field J4 into Medial
If Medial<=field L4 then put Medial into Medial
 Else put the value of field L4 into Medial
If field B4<=field Cc4 then put the value of field B4 into Media2
 Else put the value of field Cc4 into Media2
If Media2<=field E4 then put Media2 into Media2
 Else put field E4 into Media2
If Media2<=field G4 then put Media2 into Media2
 Else put field G4 into Media2
If Media2<=field I4 then put Media2 into Media2
 Else put field I4 into Media2
If Media2<=field K4 then put Media2 into Media2
 Else put field K4 into Media2
If Media2<=field M4 then put Media2 into Media2
 Else put field M4 into Media2

 Put the value of Medial into field N1
 Put the value of Media2 into field N2
```

4.5 Annual Service Volume

Considering wind effects year-round and the possible use of several runway configurations at the same airport, it is practicable to estimate all approximate annual service volume by combining several runway configurations and allocating percentages of use for each configuration.

4.5.1 Input and Output Parameters of Annual Service Volume

The script inside Result button will not be executed unless at least one set of global variables, runway hourly capacities, are defined. Other input parameters are the yearly percentages of each runway configuration, the annual aircraft operations, the average day operations per peak month, and the average peak hour operations per peak month (See Fig.4-9).

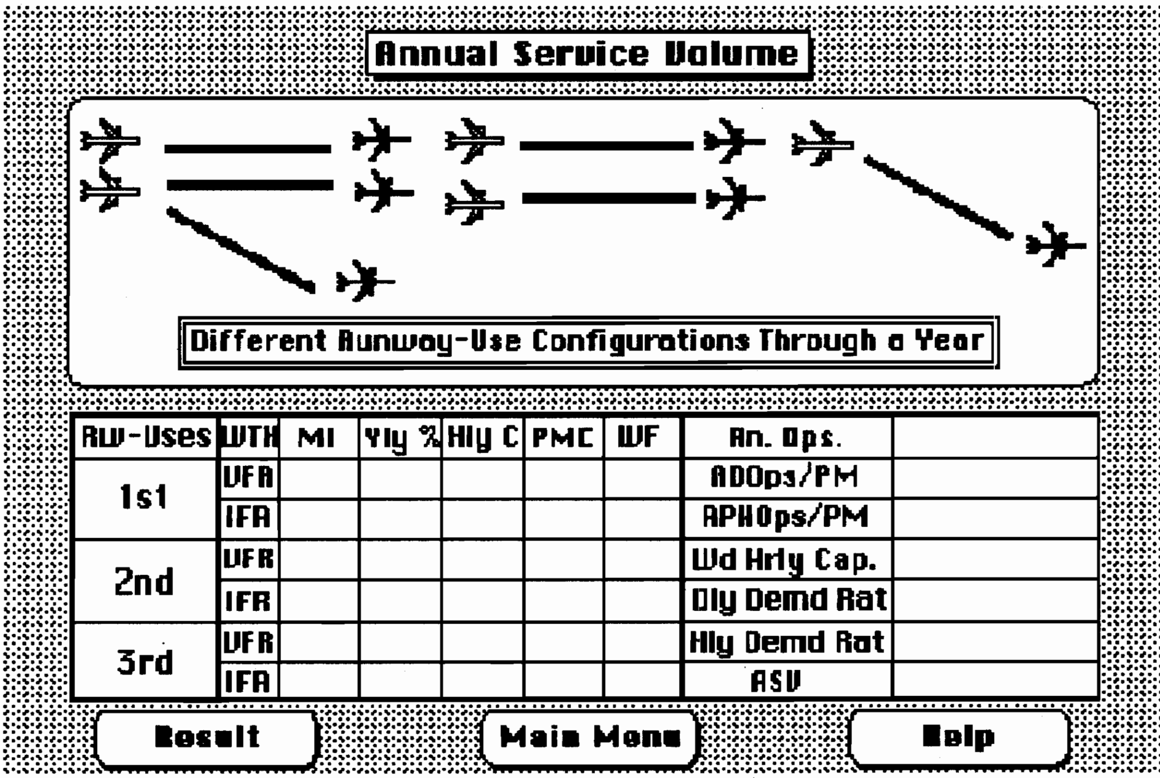


Fig. 4-9 Annual Service Volume

4.5.2 Computational Flow Logic

Computational flow logic of annual service volume is shown in Fig.4-10.

4.5.3 Sample Script Information of Annual Service Volume

Redeclare global variables at the beginning of the script,

```
Global VFRMI, IFRMI, VFRCap, IFRCap
```

The first line of script below is used to remind users to execute a runway hourly capacity calculation to have some input parameters before going through the scripts thereafter. To find out Mix Index, hourly capacities, the following shows,

```
If VFRMI is empty then ask "Please cancel this calculation, select the first runway-use type first and
 get the result!"
If field A1 is empty then put the value of VFRMI into field A1
Else if field A3 is empty then put the value of VFRMI into field A3
Else if field A5 is empty then put the value of VFRMI into field A5
If field A2 is empty then put the value of IFRMI into field A2
Else if field A4 is empty then put the value of IFRMI into field A4
Else if field A6 is empty then put the value of IFRMI into field A6
If field C1 is empty then put the value of VFRCap into field C1
Else if field C3 is empty then put the value of VFRCap into field C3
Else if field C5 is empty then put the value of VFRCap into field C5
If field C2 is empty then put the value of IFRCap into field C2
Else if field C4 is empty then put the value of IFRCap into field C4
Else if field C6 is empty then put the value of IFRCap into field C6
```

To find out the maximum capacity value of a runway use configuration and the percent of maximum capacity of each runway configuration. The scripts are,

```
If field C1>=field C2 then put the value of field C1 into Denom
Else put the value of field C2 into Denom
If Denom>=field C3 then put Denom into Denom
Else put the value of field C3 into Denom
If Denom>=field C4 then put Denom into Denom
Else put the value of field C4 into Denom
If Denom>=field C5 then put Denom into Denom
Else put the value of field C5 into Denom
If Denom>=field C6 then put Denom into Denom
Else put the value of field C6 into Denom
Put the value of (field C1)*100/Denom into field D1
Put the value of (field C2)*100/Denom into field D2
```

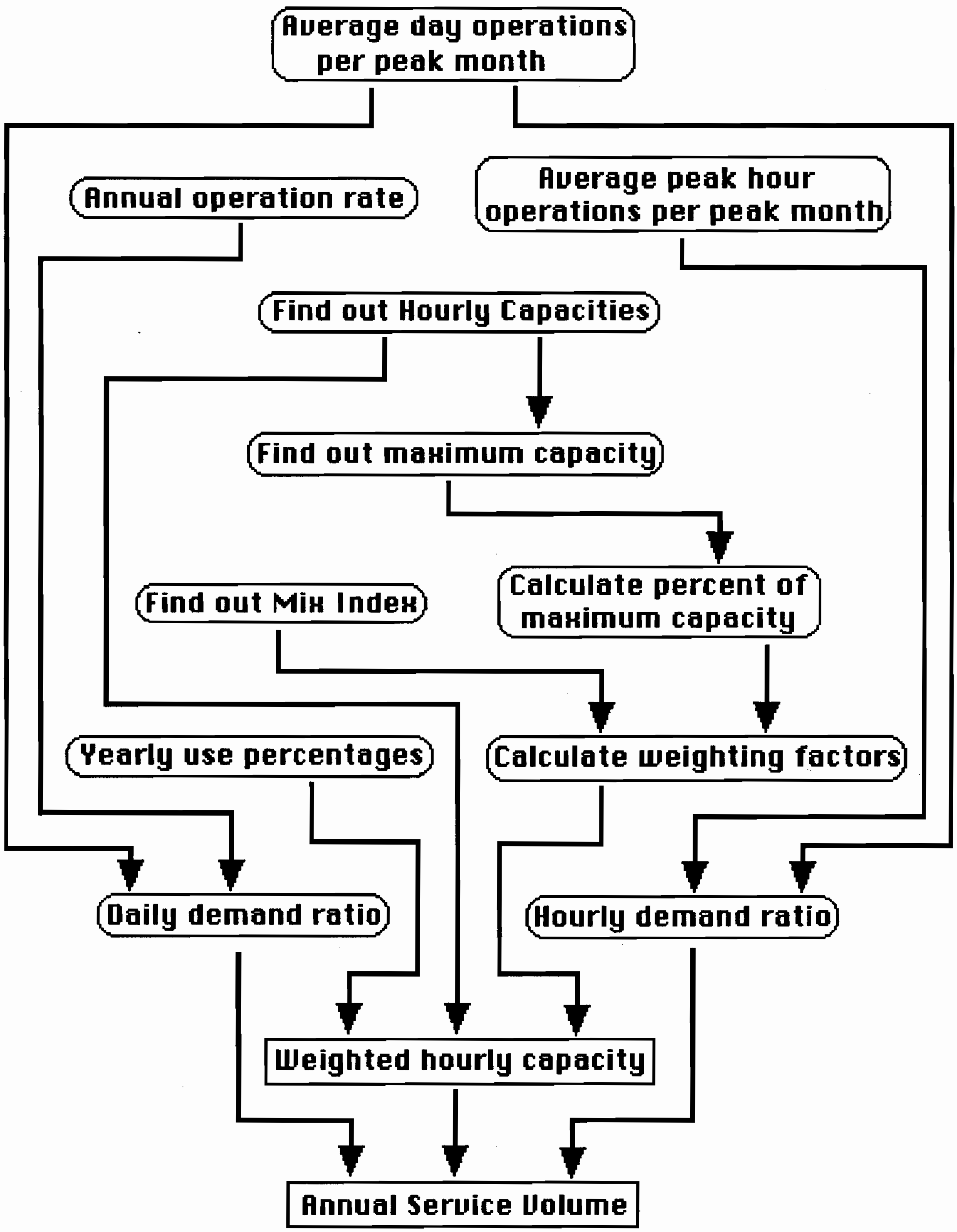


Fig. 4-10 Computational Flow Logic for Annaul Service Volume

```
If field C3 is empty then ask "Please cancel this calculation, select the second runway-use type first
 and get the result!"
Put the value of (field C3)*100/Denom into field D3
Put the value of (field C4)*100/Denom into field D4
If field C5 is empty then ask "Please cancel this calculation, select the third runway-use type first
 and get the result!"
Put the value of (field C5)*100/Denom into field D5
Put the value of (field C6)*100/Denom into field D6
```

The scripts below are for weighted factors,

```
If field D1>=91 then put 1 into field E1
Else if field D1>=81 and field D1<91 then put 5 into field E1
Else if field D1>=66 and field D1<81 then put 15 into field E1
Else if field D1>=51 and field D1<66 then put 20 into field E1
Else if field D1>=0 and field D1<51 then put 25 into field E1
If field D2>=91 then
  If field A2>=0 and field A2<=180 then put 1 into field E2
 End if
```

To calculate weighted capacity, daily demand ratio, and hourly demand ratio, the scripts are,

```
 Put (field B1)*(field C1)*(field E1)+(field B2)*(field C2)*(field E2)+(field B3)*(field C3)*(field E3)
into holder1
 Put (field B4)*(field C4)*(field E4)+(field B5)*(field C5)*(field E5)+(field B6)*(field C6)*(field E6)
into holder2
 Put (field B1)*(field E1)+(field B2)*(field E2)+(field B3)*(field E3)+(field B4)*(field E4)+(field
B5)*(field E5)+(field B6)*(field E6) into holder3
Put (holder1+holder2)/holder3 into field F4

Put field F1/field F2 into field F5
Put field F2/field F3 into field F6
```

Finally, the annual service volume is calculated as follows,

```
Put (field F4)*(field F5)*(field F6) into field F7
```

4.6 Hourly Delays to Aircraft on Runways

Hourly delays to aircraft on runways is another important application besides Runway Hourly Capacity in ICAD. Different applications can be identified by the number of runway in a configuration, separation distances between runways, and intersecting angles. One individual application interface contains an input / output table, runway use configuration picture, and a series of arrival and departure delay graphs invoked by the click of a button by users. An application executes after the calculations from Runway Hourly Capacity applications have been completed. For illustrative purpose, a close parallel runway configuration is chosen to represent some of the scripts in this application.

4.6.1 Input and Output Parameters of Hourly Delays to Aircraft on Runways

Input parameters like Mix Index, Hourly Capacity, Percent Arrivals, and Hourly Demand must be obtained before running through this application. There are significant numbers of intermediate parameters executed in the application so as to help users see the effect of the changes of Mix Index, Hourly Capacity, and Demand over Capacity Ratio on the final output--Hourly Delay (See Fig.4-11). One parameter that needs to be entered is the aircraft operation demand in the most critical minutes of the peak hour.

4.6.2 Computational Flow Logic

Computational flow logic of hourly delays to aircraft on runways is seen on Fig. 4-12.

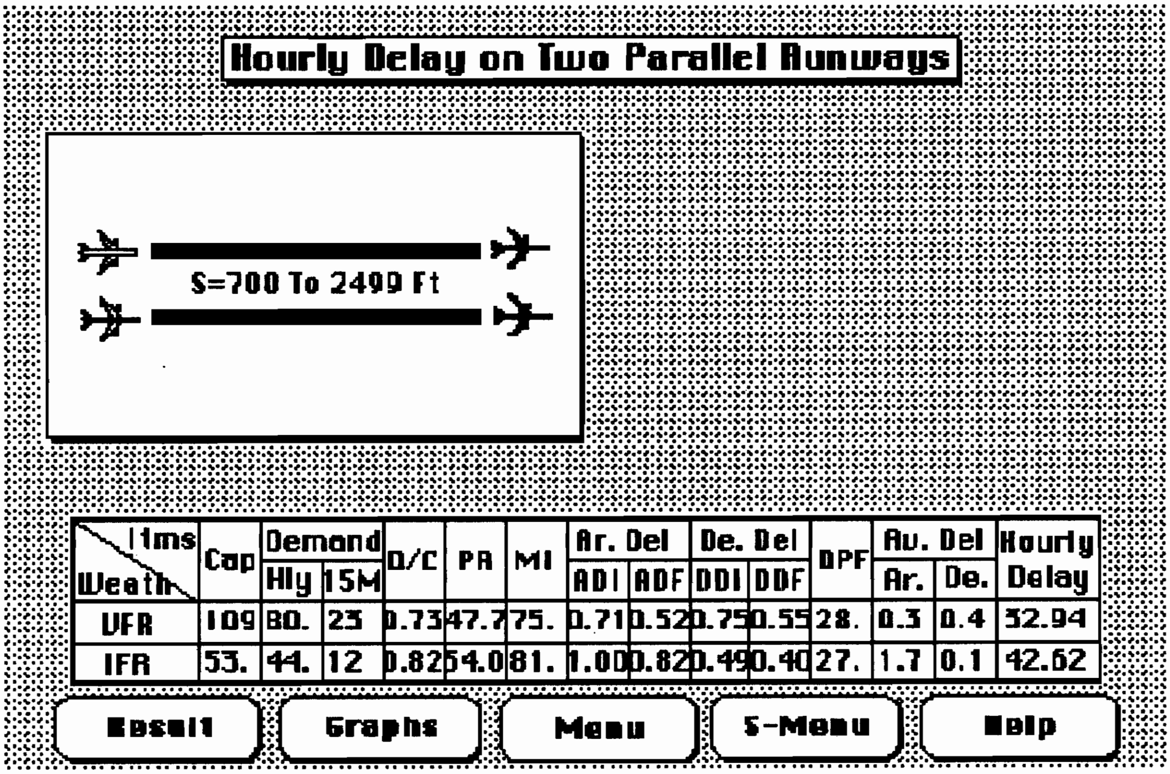
4.6.3 Sample Script Information of Hourly Delays to Aircraft on Runways

Mathematical precision is defined at first for all variables and declare global variables,

```
Set numberFormat to 0.00
Global VFRMI, IFRMI, VFRPA, IFRPA, VFRCap, IFRCap, VFRDem, IFRDem
```

To send global variables into the input fields,

```
Put the value of VFRCap into field A1
Put the value of IFRCap into field A2
Put the value of VFRDem into field B1
Put the value of IFRDem into field B2
Put the value of field B1/field A1 into field D1
Put the value of field B2/field A2 into field D2
Put the value of VFRPA into field E1
```



Itms / Weath	Cap	Demand		D/C	PR	MI	Ar. Del		De. Del		DPF	Av. Del		Hourly
		Hly	15M				ADI	ADF	DDI	DDF		Ar.	De.	Delay
VFR	109	80.	23	0.73	47.7	75.	0.71	0.52	0.75	0.55	28.	0.3	0.4	32.94
IFR	53.	44.	12	0.82	54.0	81.	1.00	0.82	0.49	0.40	27.	1.7	0.1	42.62

Fig. 4-11 Hourly Delays to Aircraft on Runways

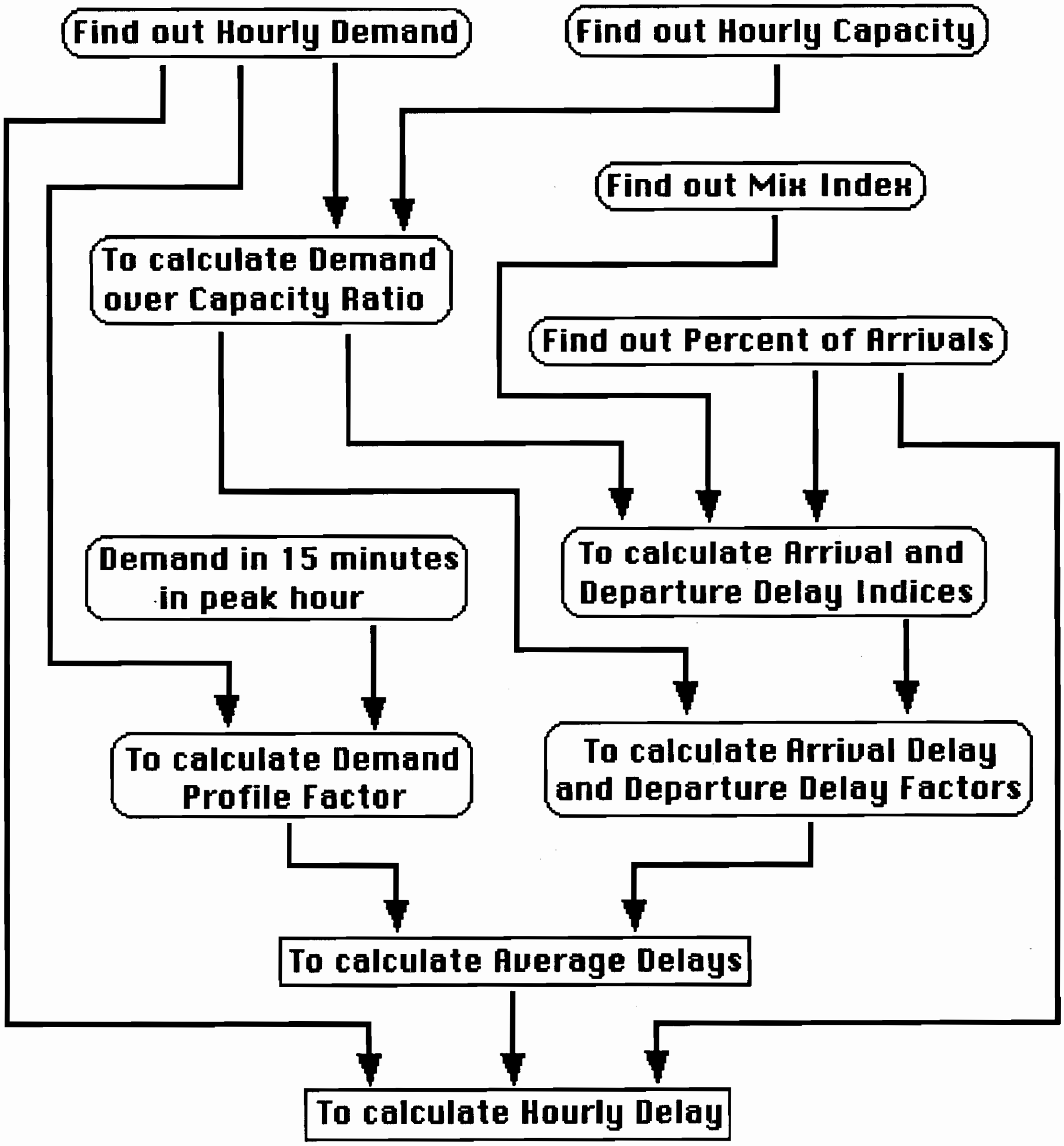


Fig. 4-12 Computational Flow Logic for Hourly Delays to Aircraft on Runways

```
Put the value of IFRPA into field E2
Put the value of VFRMI into field F1
Put the value of IFRMI into field F2
```

Regression equations are used to estimate arrival delay index and departure delay index as a function of mix indices at exact demand over capacity ratios, the scripts are,

```
Put 0.756+0.28*(field F1/100)-0.246*(field F1/100)^2+0.052*(field F1/100)^3 into temp1
Put -0.056+0.58*(field D1)+0.28*(field F1/100)-0.246*(field F1/100)^2+0.052*(field F1/100)^3
 into temp2
Put 0.524+0.28*(field F1/100)-0.246*(field F1/100)^2+0.052*(field F1/100)^3 into temp3
Put 0.89+0.354*(field F1/100)-0.333*(field F1/100)^2+0.0924*(field F1/100)^3 into temp4
Put -0.0453+0.668*(field D1)+0.354*(field F1/100)-0.333*(field F1/100)^2+0.0924*(field
 F1/100)^3 into temp5
Put 0.623+0.354*(field F1/100)-0.333*(field F1/100)^2+0.0924*(field F1/100)^3 into temp6
Put 0.86+0.407*(field F1/100)-0.363*(field F1/100)^2+0.101*(field F1/100)^3 into temp7
Put -0.0458+0.755*(field D1)+0.407*(field F1/100)-0.363*(field F1/100)^2+0.101*(field F1/100)^3
 into temp8
Put 0.709+0.407*(field F1/100)-0.363*(field F1/100)^2+0.101*(field F1/100)^3 into temp9
Put 0.798+0.0304*(field F1/100)+0.0628*(field F1/100)^2-0.0271*(field F1/100)^3 into temp10
Put 0.418+0.475*(field D1)+0.0304*(field F1/100)+0.0628*(field F1/100)^2-0.0271*(field
 F1/100)^3 into temp11
Put 0.608+0.0304*(field F1/100)+0.0628*(field F1/100)^2-0.0271*(field F1/100)^3 into temp12
Put 0.728+0.06*(field F1/100)-0.009*(field F1/100)^2+0.01*(field F1/100)^3 into temp13
Put 0.278+0.563*(field D1)+0.06*(field F1/100)-0.009*(field F1/100)^2+0.01*(field F1/100)^3 into
 temp14
Put 0.503+0.06*(field F1/100)-0.009*(field F1/100)^2+0.01*(field F1/100)^3 into temp15
Put 0.643+0.17*(field F1/100)-0.125*(field F1/100)^2+0.043*(field F1/100)^3 into temp16
Put 0.133+0.637*(field D1)+0.17*(field F1/100)-0.125*(field F1/100)^2+0.043*(field F1/100)^3
 into temp17
Put 0.388+0.17*(field F1/100)-0.125*(field F1/100)^2+0.043*(field F1/100)^3 into temp18
Put temp10+(1-temp10)*(field D1-0.8)/0.2 into temp19
Put temp13+(1-temp13)*(field D1-0.8)/0.2 into temp20
Put temp16+(1-temp16)*(field D1-0.8)/0.2 into temp21
Put 0.74+0.087*(field F2/100)+0.032*(field F2/100)^2 into temp22
Put 0.482+0.087*(field F2/100)+0.012*(field F2/100)^2 into temp23
Put 0.345+0.007*(field F2/100)+0.044*(field F2/100)^2 into temp24
```

To calculate Arrival and Departure Delay Indices at any demand over capacity ratios, the scripts are,

```
If field E1>=40 and field E1<50 then
  If field D1>=1.4 then put temp1+(temp4-temp1)*(field E1-40)/10 into field G1
  If field D1<1.4 and field D1>1.0 then put temp2+(temp5-temp2)*(field E1-40)/10 into field G1
  If field D1<=1.0 then put temp3+(temp6-temp3)*(field E1-40)/10 into field G1
End if
If field E1>50 and field E1<=60 then
  If field D1>=1.4 then put temp4+(temp7-temp4)*(field E1-50)/10 into field G1
  If field D1<1.4 and field D1>1.2 then put temp5+(temp7-temp5)*(field E1-50)/10 into field G1
  If field D1<=1.2 and field D1>1.0 then put temp5+(temp8-temp5)*(field E1-50)/10 into field G1
  If field D1<=1.0 then put temp6+(temp9-temp6)*(field E1-50) into field G1
```

```
 End if
 Put 1.00 into field G2
If field E1>=40 and field E1<=50 then
  If field D1>=1.0 then put 1.00 into field I1
 If field D1>=0.8 and field D1<1.0 then put temp19-(temp19-temp20)*(field E1-40)/10 into field I1
 If field D1>0.4 and field D1<0.8 then put temp11-(temp11-temp14)*(field E1-40)/10 into field I1
 If field D1<=0.4 then put temp12-(temp12-temp15)*(field E1-40)/10 into field I1
 End if
If field E1>50 and field E1<=60 then
  If field D1>=1.0 then put 1.00 into field I1
 If field D1>=0.8 and field D1<1.0 then put temp20-(temp20-temp21)*(field E1-50)/10 into field I1
 If field D1>0.4 and field D1<0.8 then put temp14-(temp14-temp17)*(field E1-50)/10 into field I1
 If field D1<=0.4 then put temp15-(temp15-temp18)*(field E1-50)/10 into field I1
 End if
If field E2>=40 and field E2<=50 then put temp22-(temp22-temp23)*(field E2-40)/10 into field I2
Else if field E2>50 and field E2<=60 then put temp23-(temp23-temp24)*(field E2-50)/10 field I2
```

The scripts for calculating Arrival and Departure Delay Factors, and Demand Profile Factors are,

```
Put (field D1)*(field G1) into field H1
Put (field D2)*(field G2) into field H2
Put (field D1)*(field I1) into field J1
Put (field D2)*(field I2) into field J2
Put (field C1)*100/field B1 into field K1
Put (field C2)*100/field B2 into field K2
```

Regression equations are used to calculate Average Delays at the exact Demand Profile Factors similar to the graphs shown on Fig.3-69 in FAA AC 150/5060-5, they are,

```
Put 10.88*(field H1)^3-4.98*(field H1)^2+4.11*(field H1)-0.025 into holvadf1
Put 8.796*(field H1)^3-2.927*(field H1)^2+2.638*(field H1)-0.018 into holvadf2
Put 8.333*(field H1)^3-2.679*(field H1)^2+1.56*(field H1)-0.014 into holvadf3
Put 7.523*(field H1)^3-2.758*(field H1)^2+0.953*(field H1)-0.006 into holvadf4
Put 6.771*(field H1)^3-3.08*(field H1)^2+0.613*(field H1) into holvadf5
Put 6.134*(field H1)^3-3.978*(field H1)^2+0.753*(field H1)-0.008 into holvadf6
Put 10.88*(field H2)^3-4.98*(field H2)^2+4.11*(field H2)-0.025 into holiadf1
Put 8.796*(field H2)^3-2.927*(field H2)^2+2.638*(field H2)-0.018 into holiadf2
Put 8.333*(field H2)^3-2.679*(field H2)^2+1.56*(field H2)-0.014 into holiadf3
Put 7.523*(field H2)^3-2.758*(field H2)^2+0.953*(field H2)-0.006 into holiadf4
Put 6.771*(field H2)^3-3.08*(field H2)^2+0.613*(field H2) into holiadf5
Put 6.134*(field H2)^3-3.978*(field H2)^2+0.753*(field H2)-0.008 into holiadf6
Put 10.88*(field J1)^3-4.98*(field J1)^2+4.11*(field J1)-0.025 into holvddf1
Put 8.796*(field J1)^3-2.927*(field J1)^2+2.638*(field J1)-0.018 into holvddf2
Put 8.333*(field J1)^3-2.679*(field J1)^2+1.56*(field J1)-0.014 into holvddf3
Put 7.523*(field J1)^3-2.758*(field J1)^2+0.953*(field J1)-0.006 into holvddf4
Put 6.771*(field J1)^3-3.08*(field J1)^2+0.613*(field J1) into holvddf5
Put 6.134*(field J1)^3-3.978*(field J1)^2+0.753*(field J1)-0.008 into holvddf6
Put 10.88*(field J2)^3-4.98*(field J2)^2+4.11*(field J2)-0.025 into holiddf1
Put 8.796*(field J2)^3-2.927*(field J2)^2+2.638*(field J2)-0.018 into holiddf2
Put 8.333*(field J2)^3-2.679*(field J2)^2+1.56*(field J2)-0.014 into holiddf3
```

```
Put 7.523*(field J2)^3-2.758*(field J2)^2+0.953*(field J2)-0.006 into holiddf4
Put 6.771*(field J2)^3-3.08*(field J2)^2+0.613*(field J2) into holiddf5
Put 6.134*(field J2)^3-3.978*(field J2)^2+0.753*(field J2)-0.008 into holiddf6
```

To calculate Average Delays at any Demand Profile Factors, the scripts are,

```
If field K1>=45 and field K1<=50 then put holvadf2+(holvadf1-holvadf2)*(field K1-45)/5 into field L1
Else if field K1>=40 and field K1<45 then put holvadf3+(holvadf2-holvadf3)*(field K1-40)/5 into field L1
Else if field K1>=35 and field K1<40 then put holvadf4+(holvadf3-holvadf4)*(field K1-35)/5 into field L1
Else if field K1>=30 and field K1<35 then put holvadf5+(holvadf4-holvadf5)*(field K1-30)/5 into field L1
Else if field K1>=25 and field K1<30 then put holvadf6+(holvadf5-holvadf6)*(field K1-25)/5 into field L1
If field K2>=45 and field K2<=50 then put holiadf2+(holiadf1-holiadf2)*(field K2-45)/5 into field L2
Else if field K2>=40 and field K2<45 then put holiadf3+(holiadf2-holiadf3)*(field K2-40)/5 into field L2
Else if field K2>=35 and field K2<40 then put holiadf4+(holiadf3-holiadf4)*(field K2-35)/5 into field L2
Else if field K2>=30 and field K2<35 then put holiadf5+(holiadf4-holiadf5)*(field K2-30)/5 into field L2
Else if field K2>=25 and field K2<30 then put holiadf6+(holiadf5-holiadf6)*(field K2-25)/5 into field L2
If field K1>=45 and field K1<=50 then put holvddf2+(holvddf1-holvddf2)*(field K1-45)/5 into field M1
Else if field K1>=40 and field K1<45 then put holvddf3+(holvddf2-holvddf3)*(field K1-40)/5 into field M1
Else if field K1>=35 and field K1<40 then put holvddf4+(holvddf3-holvddf4)*(field K1-35)/5 into field M1
Else if field K1>=30 and field K1<35 then put holvddf5+(holvddf4-holvddf5)*(field K1-30)/5 into field M1
Else if field K1>=25 and field K1<30 then put holvddf6+(holvddf5-holvddf6)*(field K1-25)/5 into field M1
If field K2>=45 and field K2<=50 then put holiddf2+(holiddf1-holiddf2)*(field K2-45)/5 into field M2
Else if field K2>=40 and field K2<45 then put holiddf3+(holiddf2- holiddf3)*(field K2-40)/5 into field M2
Else if field K2>=35 and field K2<40 then put holiddf4+(holiddf3-holiddf4)*(field K2-35)/5 into field M2
Else if field K2>=30 and field K2<35 then put holiddf5+(holiddf4-holiddf5)*(field K2-30)/5 into field M2
Else if field K2>=25 and field K2<30 then put holiddf6+(holiddf5-holiddf6)*(field K2-25)/5 into field M2
```

Finally, the Hourly Delays are presented as follows,

```
Put (field B1)*((field E1)*(field L1)/100+(100-field E1)*(field M1)/100) into field N1
Put (field B2)*((field E2)*(field L2)/100+(100-field E2)*(field M2)/100) into field N2
```

Chapter 5

ICAD Validation

ICAD has been designed intentionally to substitute the FAA AC 150/5060-5. The software replicates in a more concise pattern of presenting runway use configurations and parameter graphs as well as performing computations. But ICAD could not be justified as an effective and dependable method for estimating runway hourly capacity and hourly delay to aircraft unless is proved to be reliable as a replacement of FAA AC 150/5060-5 document.

In this chapter, validation of ICAD applications will be demonstrated by comparing the output results between ICAD's and the manual calculations'. Total thirty single applications were selected to represent various imaginary scenarios in this procedure.

5.1 Validations of Runway Hourly Capacities

Runway capacity calculations are the most frequently used elements of ICAD. Since their output parameters are also used as input data for the rest of ICAD applications like Hourly Delay, Airport Overall Hourly Capacity, and Annual Service Volume.

The idea in this validation was to consider to involve as many individual scenarios as possible. Thirteen of them were chosen randomly and tested. Each particular scenario is shown in Fig. 5-1 through Fig. 5-13. The results from both FAA AC and ICAD calculations and their discrepancies are listed in the Table 5-1 through Table 5-13. Output parameters compared in the tables are Hourly Capacity Base C*, Touch and Go factor T, Exit factor E, and the final output Hourly Capacity C.

Acceptable level of deviation between observed and computed results is a crucial indicative in assessing the value of ICAD. When manual calculations are made by different people, the reading difficulty and parallax errors can explain major part of the difference between the two methods. Similarly in ICAD, due to mathematical regressions in approximating hourly capacity bases, exit factors, and arrival and departure delay indices, the outputs can not be assumed to be exactly the same as those of FAA AC even for a perfect human. A certain level of deviation is permitted in planning since these computations are likely to be fine-tuned with more accurate simulation models. It is uncommon to find that calculation discrepancies in FAA AC handbook for either runway hourly capacity, or hourly delay on runway, or other facility capacities are of more than ±5%. Maximum allowable output deviation--±5% for ICAD from that of the FAA AC was considered satisfactory. Table 5-1 through Table 5-13 show that in most cases, the deviations between ICAD and the FAA AC are less than ±2%. This procedure was repeated for numerous runway use configurations as shown in the following pages.

5.1.1 Single Runway Hourly Capacity

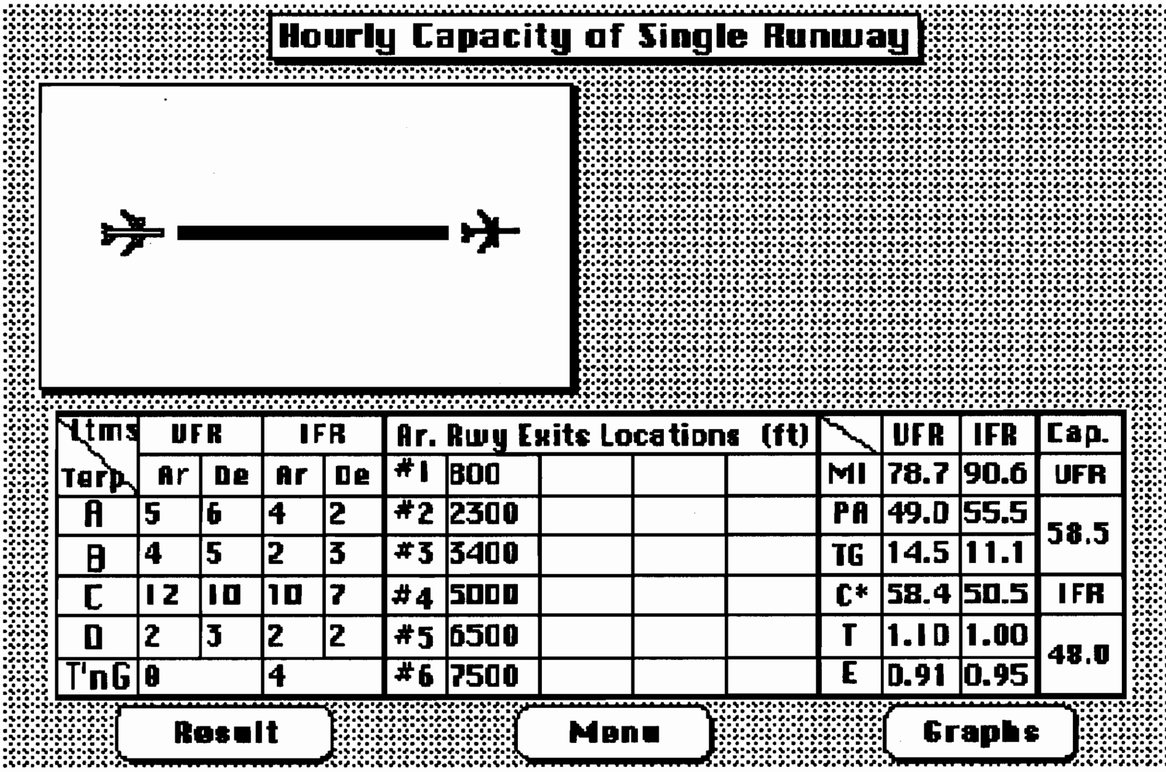


Fig.5-1 Single Runway Hourly Capacity.

Table 5-1 Single Runway Hourly Capacity.

Weather / Methods Prts Evaluations	UFR				IFR			
	C*	T	E	C	C*	T	E	C
FAA AC	58.0	1.10	0.91	58	51.0	1.00	0.95	49
ICAD	58.4	1.10	0.91	59	50.5	1.00	0.95	48
Deviation	+0.7%	0.0%	0.0%	+1.7%	-1.0%	0.0%	0.0%	-2.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: C*--Hourly Capacity Base; T--Touch and Go Factor; E--Exit Factor;
C--Hourly Capacity.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC 150/5060-5.

5.1.2 Two Parallel Runway Hourly Capacity

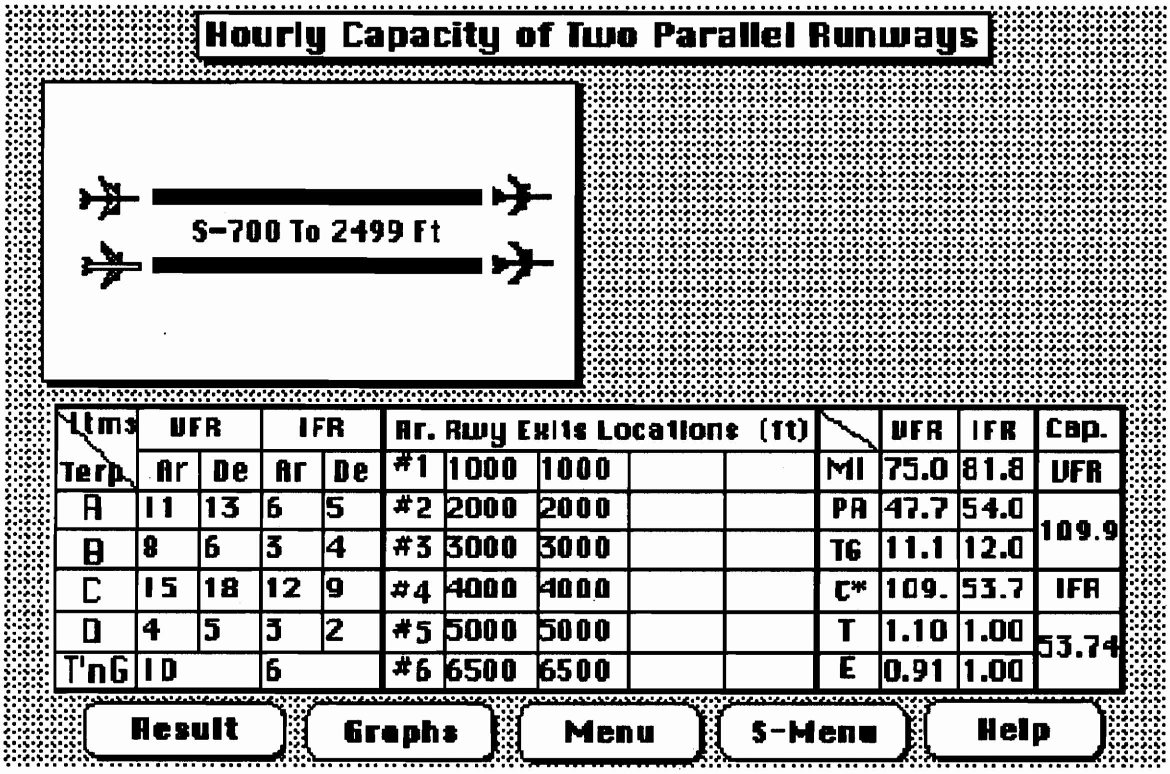


Fig. 5-2 Two Parallel Runway Hourly Capacity.

Table 5-2 Two Parallel Runway Hourly Capacity.

Weather / Methods Prts Evaluations	VFR				IFR			
	C*	T	E	C	C*	T	E	C
FAA AC	111	1.10	0.91	111	54	1.00	1.00	54
ICAD	109.9	1.10	0.91	110	53.74	1.00	1.00	54
Deviation	-1.0%	0.0%	0.0%	-0.9%	-0.5%	0.0%	0.0%	0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: C*--Hourly Capacity Base; T--Touch and Go Factor; E--Exit Factor; C--Hourly Capacity.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.1.3 Three Parallel Runway Hourly Capacity

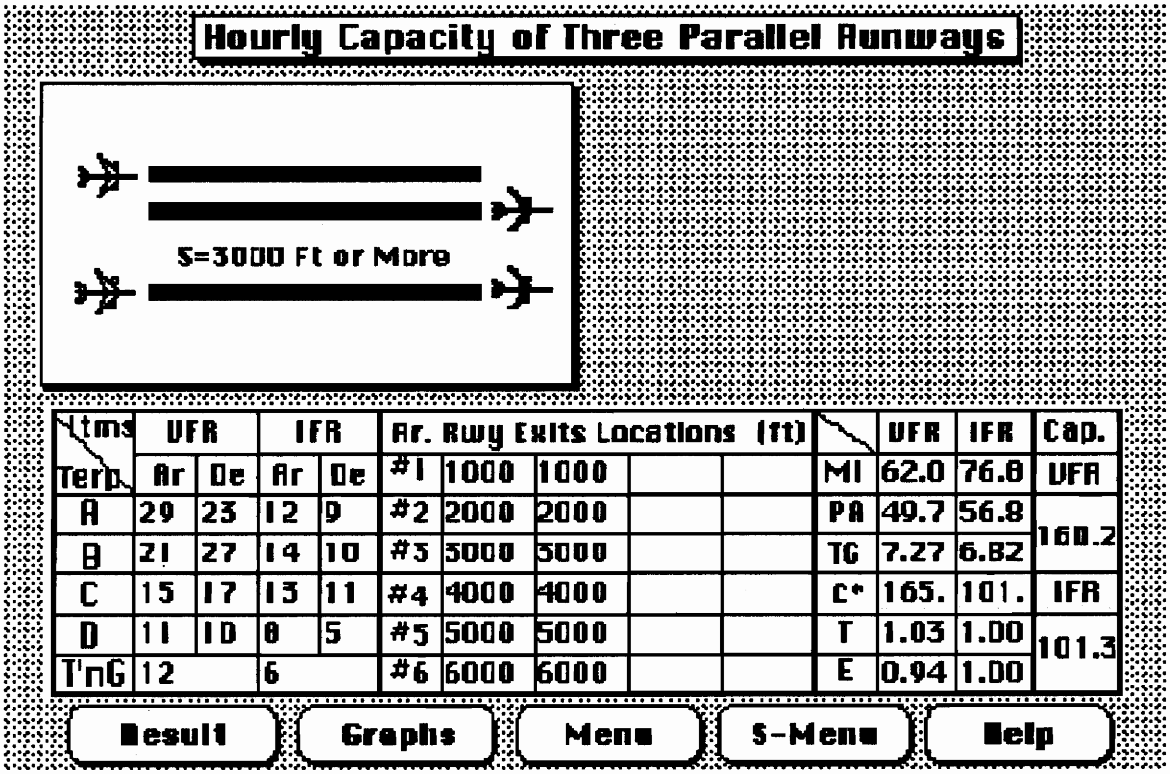


Fig. 5-3 Three Parallel Runway Hourly Capacity.

Table 5-3 Three Parallel Runway Hourly Capacity.

Weather / Prts / Methods Evaluations	VFR				IFR			
	C*	T	E	C	C*	T	E	C
FAA AC	165	1.03	0.92	156	102	1.00	1.00	102
ICAD	165.5	1.03	0.94	160	101.4	1.00	1.00	101
Deviation	+0.3%	0.0%	0.0%	+2.6%	-0.6%	0.0%	0.0%	-1.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: C*--Hourly Capacity Base; T--Touch and Go Factor; E--Exit Factor;
C--Hourly Capacity.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.1.4 Four Parallel Runway Hourly Capacity

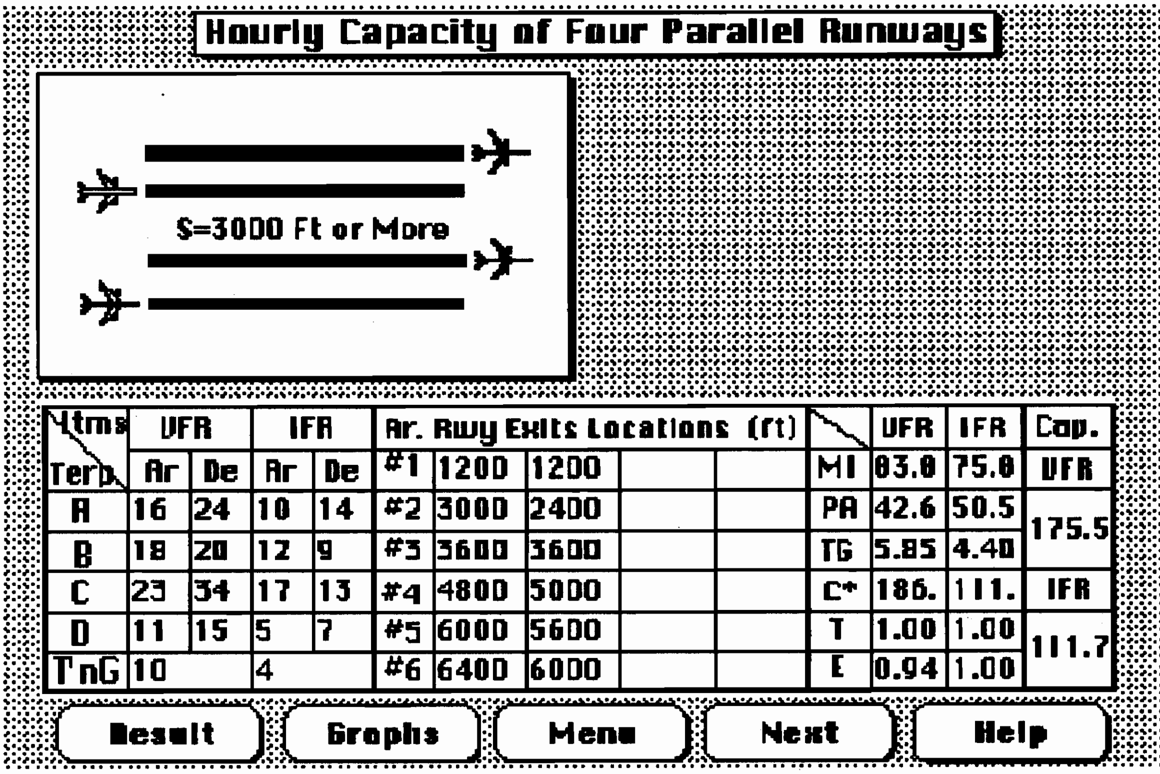


Fig. 5-4 Four Parallel Runway Hourly Capacity.

Table 5-4 Four Parallel Runway Hourly Capacity.

Weather / Methods Prts Evaluations	UFR				IFR			
	C*	T	E	C	C*	T	E	C
FAA AC	185	1.00	0.94	174	111	1.00	1.00	111
ICAD	186.8	1.00	0.94	176	111.8	1.00	1.00	112
Deviation	+1.0%	0.0%	0.0%	+1.1%	+0.7%	0.0%	0.0%	+0.9%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: C*--Hourly Capacity Base; T--Touch and Go Factor; E--Exit Factor; C--Hourly Capacity.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.1.5 Two Intersecting Runway Hourly Capacity

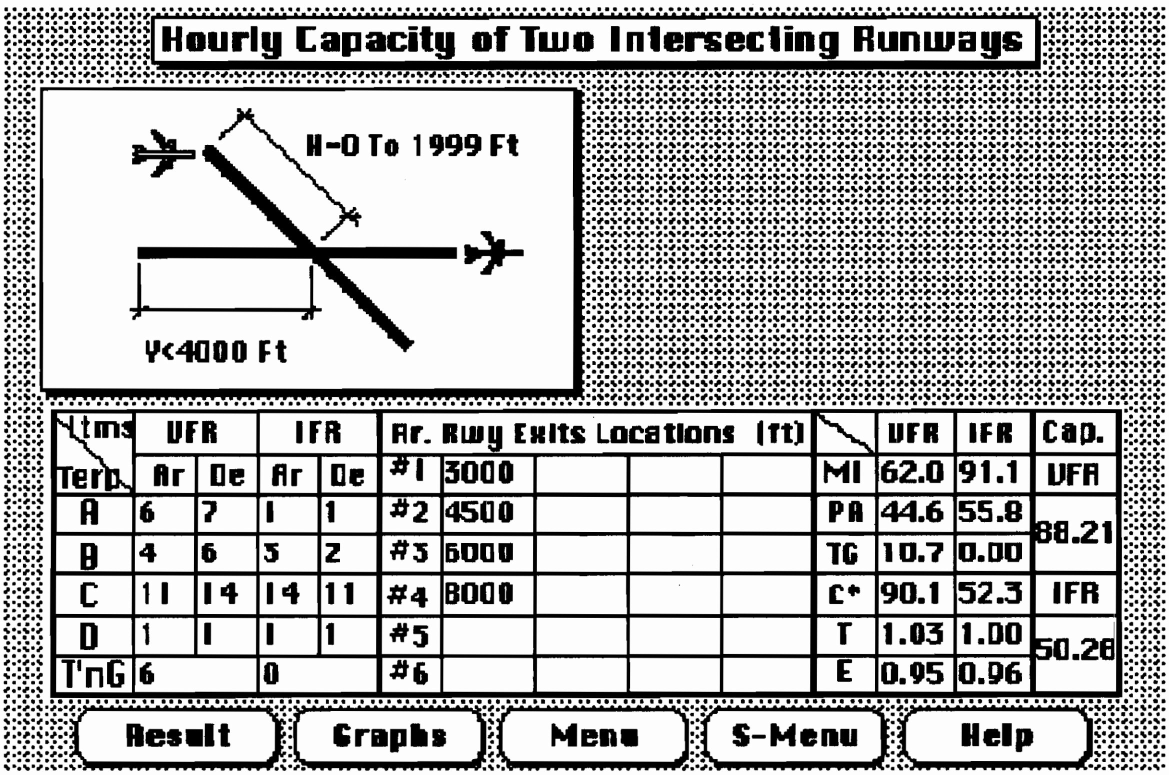


Fig. 5-5 Two Intersecting Runway Hourly Capacity.

Table 5-5 Two Intersecting Runway Hourly Capacity.

Weather / Method Prts Evaluation	VFR				IFR			
	C*	T	E	C	C*	T	E	C
FAA AC	90	1.03	0.94	87	53	1.00	0.97	51
ICAD	90.2	1.03	0.95	88	52.4	1.00	0.96	50
Deviation	+0.2%	0.0%	+1.1%	+1.1%	-1.5%	0.0%	-1.0%	-2.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: C*--Hourly Capacity Base; T--Touch and Go Factor; E--Exit Factor; C--Hourly Capacity.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.1.6 Three Intersecting Runway Hourly Capacity

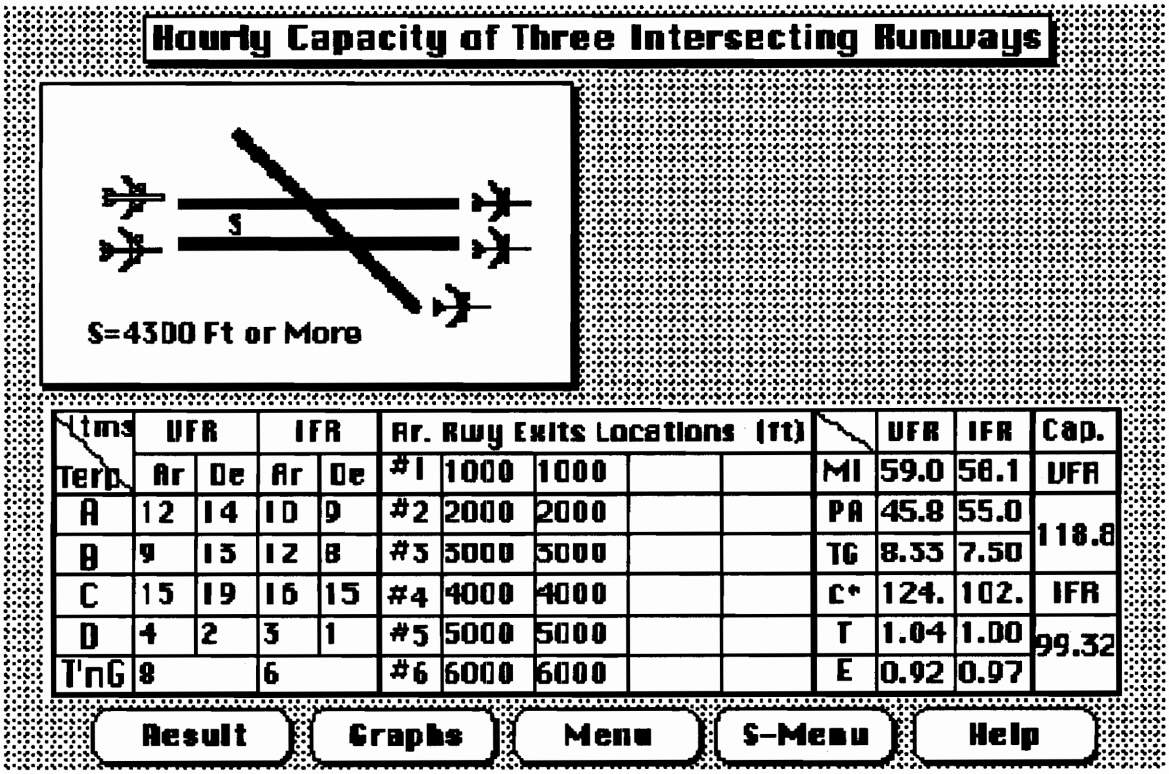


Fig. 5-6 Three Intersecting Runway Hourly Capacity.

Table 5-6 Three Intersecting Runway Hourly Capacity.

Weather / Methods Prts Evaluations	VFR				IFR			
	C*	T	E	C	C*	T	E	C
FAA AC	130	1.04	0.92	124	102	1.00	0.96	98
ICAD	124.3	1.04	0.92	119	102.4	1.00	0.97	99
Deviation	-4.4%	0.0%	0.0%	-4.0%	+0.4%	0.0%	+1.0%	+1.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: C*--Hourly Capacity Base; T--Touch and Go Factor; E--Exit Factor;
C--Hourly Capacity.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.1.7 Four Intersecting Runway Hourly Capacity

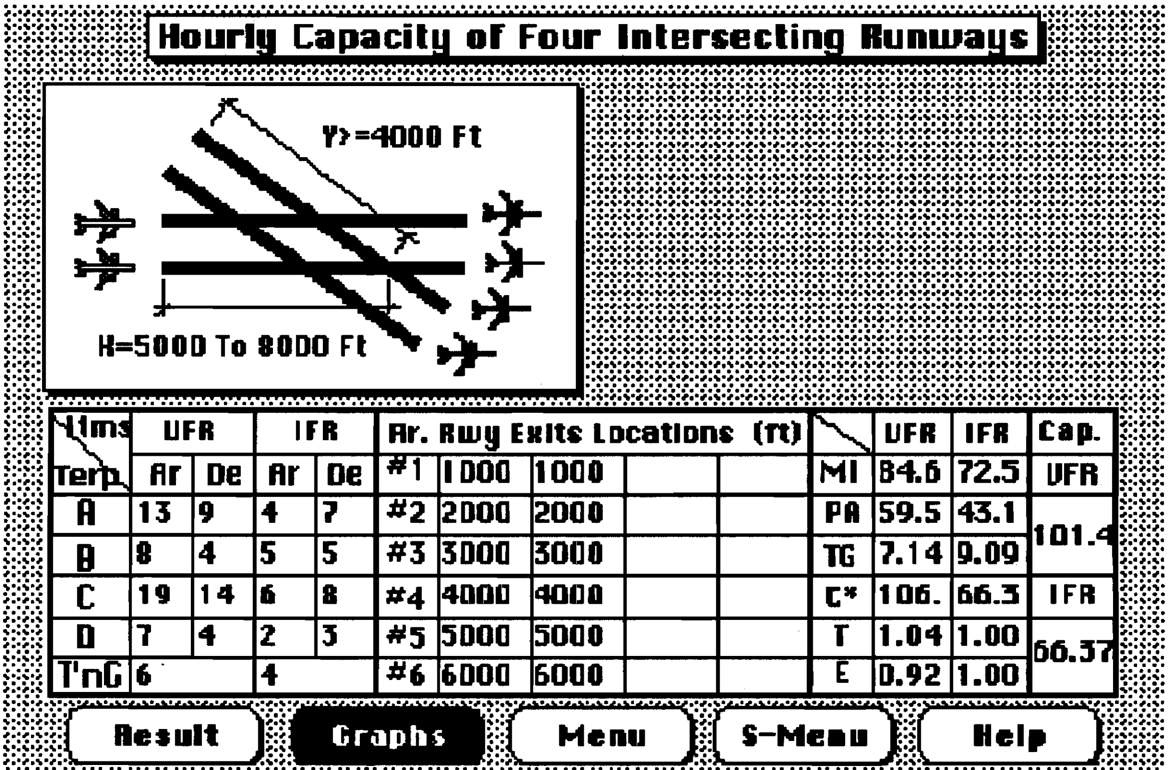


Fig. 5-7 Four Intersecting Runway Hourly Capacity.

Table 5-7 Four Intersecting Runway Hourly Capacity.

Weather / Methods Prts Evaluations	UFR				IFR			
	C*	T	E	C	C*	T	E	C
FAA AC	106	1.04	0.93	103	66	1.00	1.00	66
ICAD	106	1.04	0.92	101	66.4	1.00	1.00	66
Deviation	0.0%	0.0%	-1.1%	-1.9%	+0.6%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: C*--Hourly Capacity Base; T--Touch and Go Factor; E--Exit Factor;
C--Hourly Capacity.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.1.8 Two Converging Open V Runway Hourly Capacity

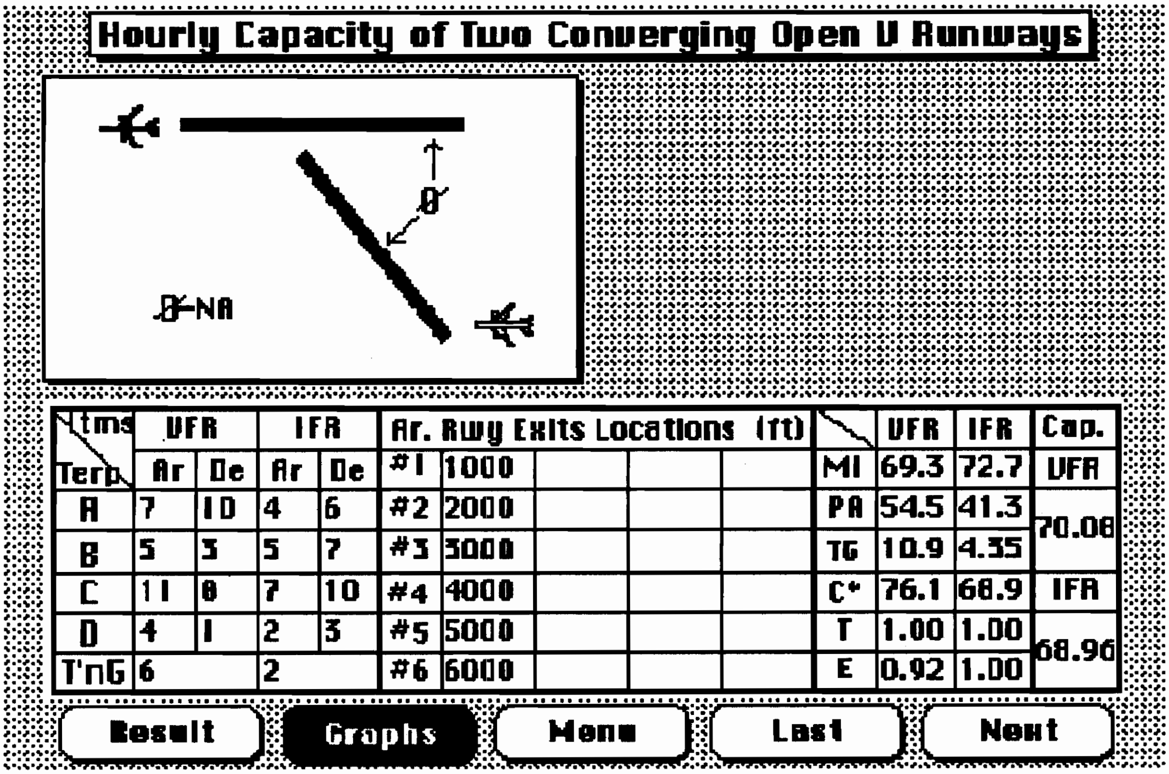


Fig. 5-8 Two Converging Open V Runway Hourly Capacity.

Table 5-8 Two Converging Open V Runway Hourly Capacity.

Weather / Methods Prts / Evaluations	VFR				IFR			
	C*	T	E	C	C*	T	E	C
FAA AC	76	1.00	0.92	70	69	1.00	1.00	69
ICAD	76.2	1.00	0.92	70	69	1.00	1.00	69
Deviation	+0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: C*--Hourly Capacity Base; T--Touch and Go Factor; E--Exit Factor; C--Hourly Capacity.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.1.9 Three Converging Open V Runway Hourly Capacity

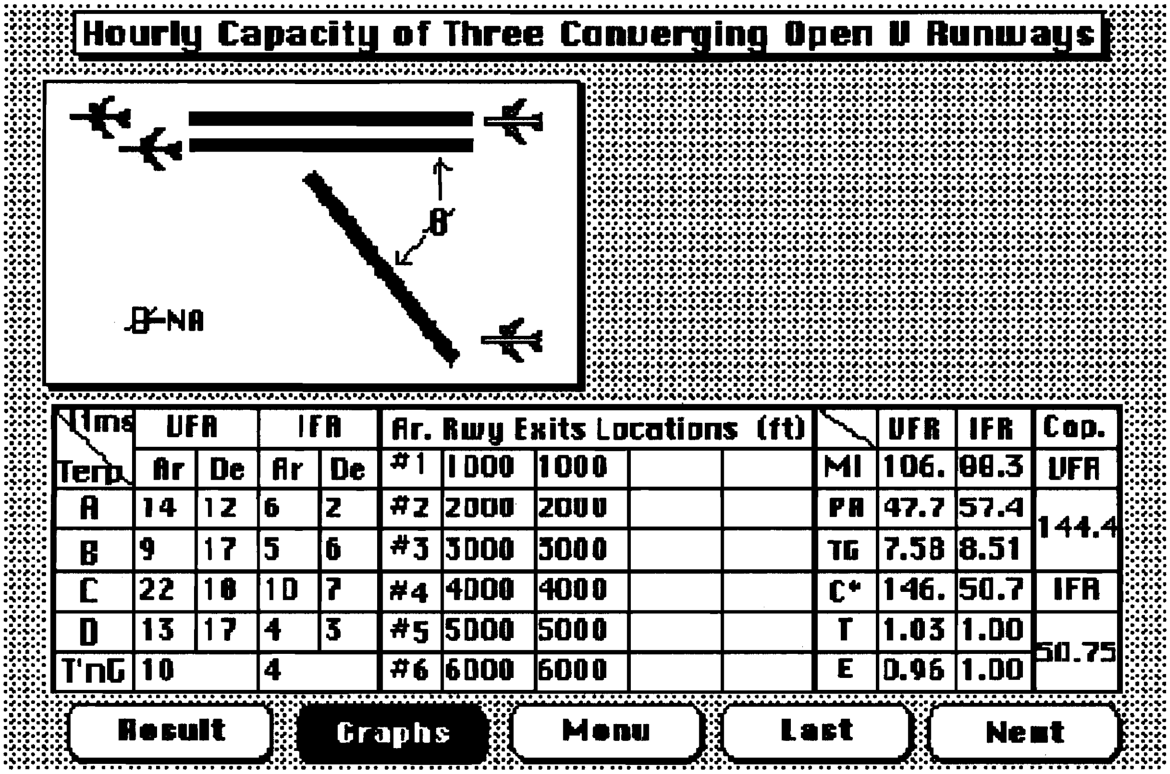


Fig. 5-9 Three Converging Open V Runway Hourly Capacity.

Table 5-9 Three Converging Open V Runway Hourly Capacity.

Weather / Methods Prts / Evaluations	VFR				IFR			
	C*	T	E	C	C*	T	E	C
FAA AC	148	1.03	0.96	146	51	1.00	1.00	51
ICAD	146.1	1.03	0.96	144	50.8	1.00	1.00	51
Deviation	-1.3%	0.0%	0.0%	-1.4%	-0.4%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: C*--Hourly Capacity Base; T--Touch and Go Factor; E--Exit Factor;
C--Hourly Capacity.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.1.10 Four Converging Open V Runway Hourly Capacity

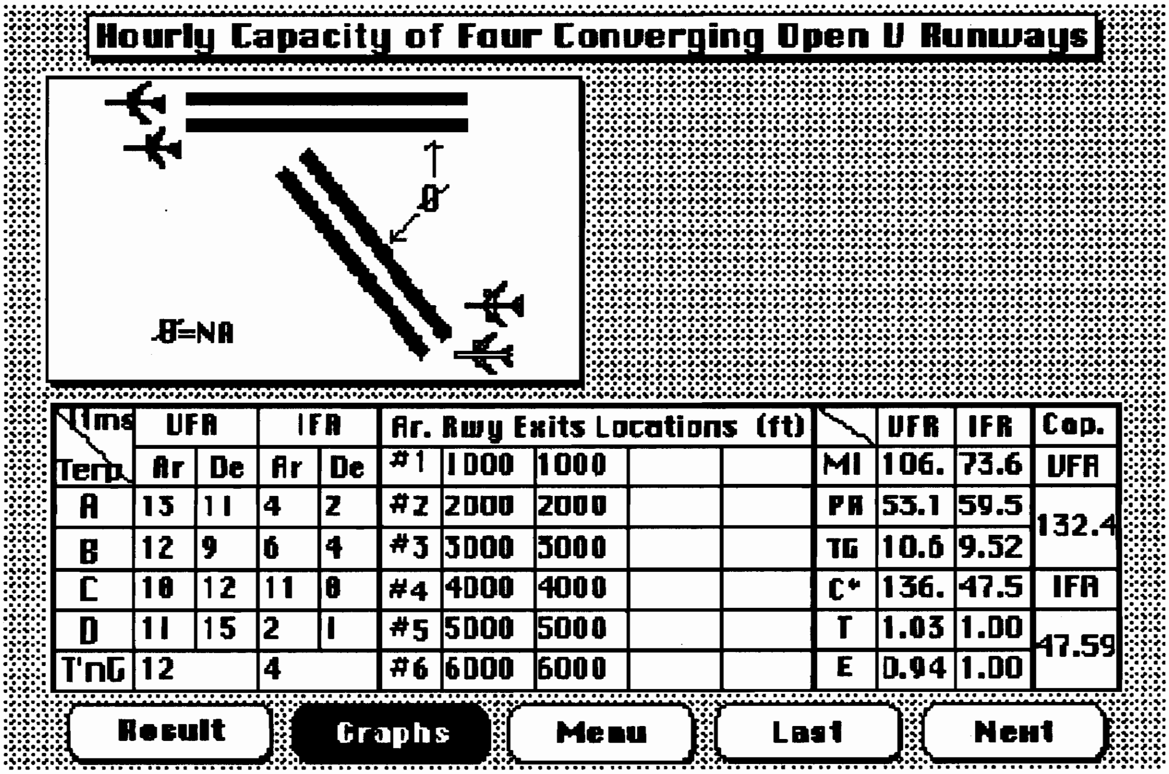


Fig. 5-10 Four Converging Open V Runway Hourly Capacity.

Table 5-10 Four Converging Open V Runway Hourly Capacity.

Weather / Methods Prts Evaluations	VFR				IFR			
	C*	T	E	C	C*	T	E	C
FAA AC	137	1.03	0.94	133	48	1.00	1.00	48
ICAD	136.8	1.03	0.94	132	47.6	1.00	1.00	48
Deviation	-0.1%	0.0%	0.0%	-0.8%	-0.8%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: C*--Hourly Capacity Base; T--Touch and Go Factor; E--Exit Factor; C--Hourly Capacity.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.1.11 Two Open V Runway Hourly Capacity

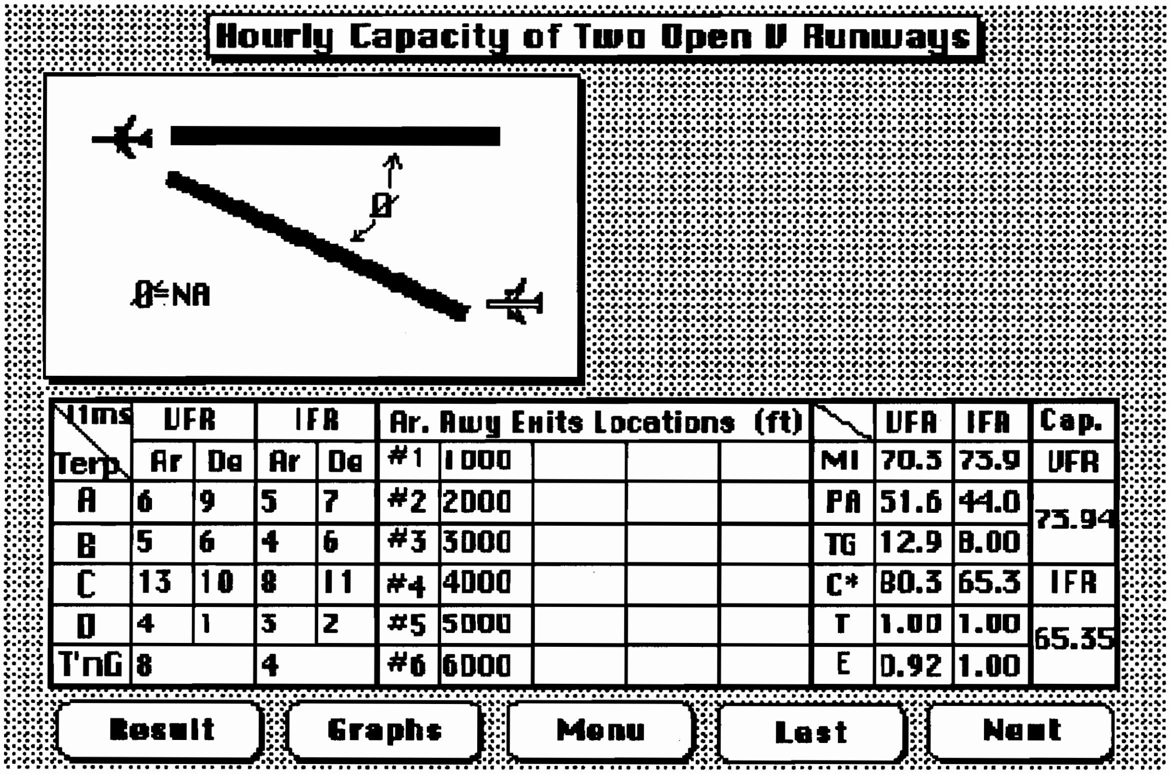


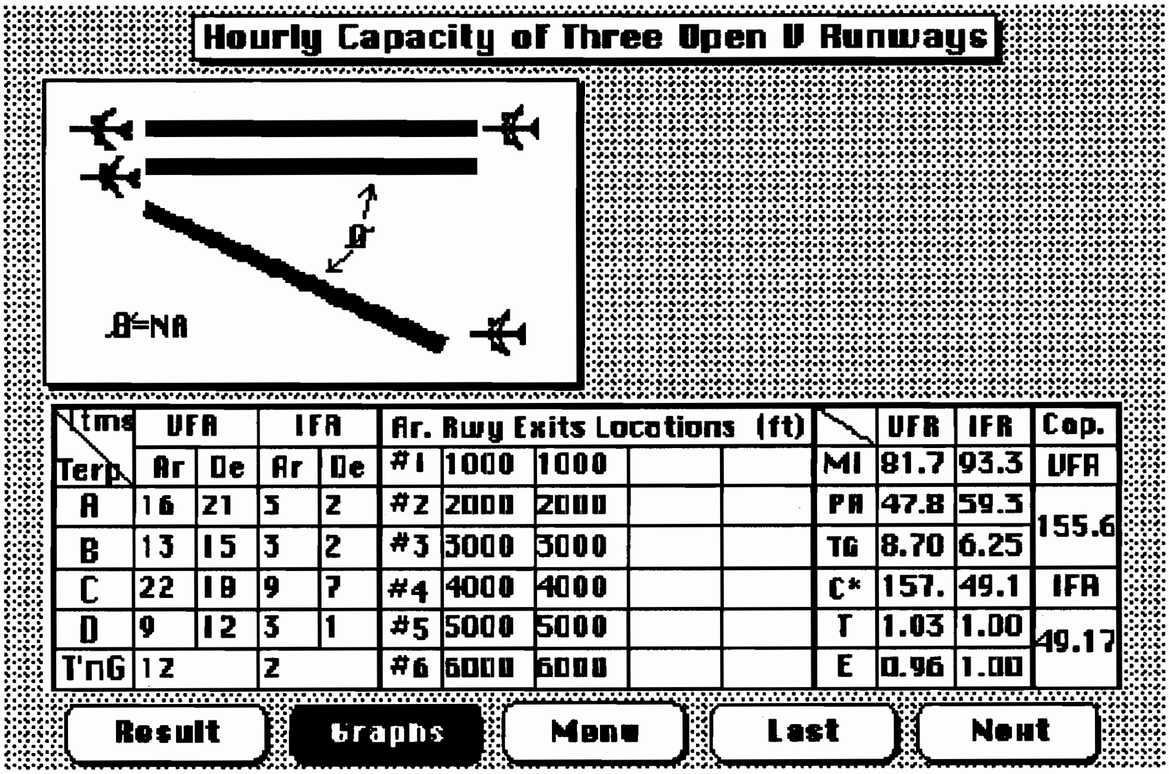
Fig. 5-11 Two Open V Runway Hourly Capacity.

Table 5-11 Two Open V Runway Hourly Capacity.

Weather / Methods Prts Evaluations	VFR				IFR			
	C*	T	E	C	C*	T	E	C
FAA AC	80	1.00	0.92	74	65	1.00	1.00	65
ICAD	80.4	1.00	0.92	74	65.4	1.00	1.00	65
Deviation	+0.5%	0.0%	0.0%	0.0%	+0.6%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: C*--Hourly Capacity Base; T--Touch and Go Factor; E--Exit Factor; C--Hourly Capacity.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.1.12 Three Open V Runway Hourly Capacity



Itms / Terp	VFR Ar	VFR De	IFR Ar	IFR De	Ar. Rwy Exits Locations (ft)				
A	16	21	3	2	#1	1000	1000		
B	13	15	3	2	#2	2000	2000		
C	22	18	9	7	#3	3000	3000		
D	9	12	3	1	#4	4000	4000		
T'nG	12		2		#5	5000	5000		
					#6	6000	6000		

	VFR	IFR	Cap.
MI	81.7	93.3	VFR
PA	47.8	59.3	155.6
TG	8.70	6.25	
C*	157.	49.1	IFR
T	1.03	1.00	49.17
E	0.96	1.00	

Fig. 5-12 Three Open V Runway Hourly Capacity.

Table 5-12 Three Open V Runway Hourly Capacity.

Weather / Methods Prts Evaluations	VFR				IFR			
	C*	T	E	C	C*	T	E	C
FAA AC	158	1.03	0.96	156	49	1.00	1.00	49
ICAD	157.4	1.03	0.96	156	49.2	1.00	1.00	49
Deviation	-0.4%	0.0%	0.0%	0.0%	-1.6%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: C*--Hourly Capacity Base; T--Touch and Go Factor; E--Exit Factor;
C--Hourly Capacity.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.1.13 Four Open V Runway Hourly Capacity

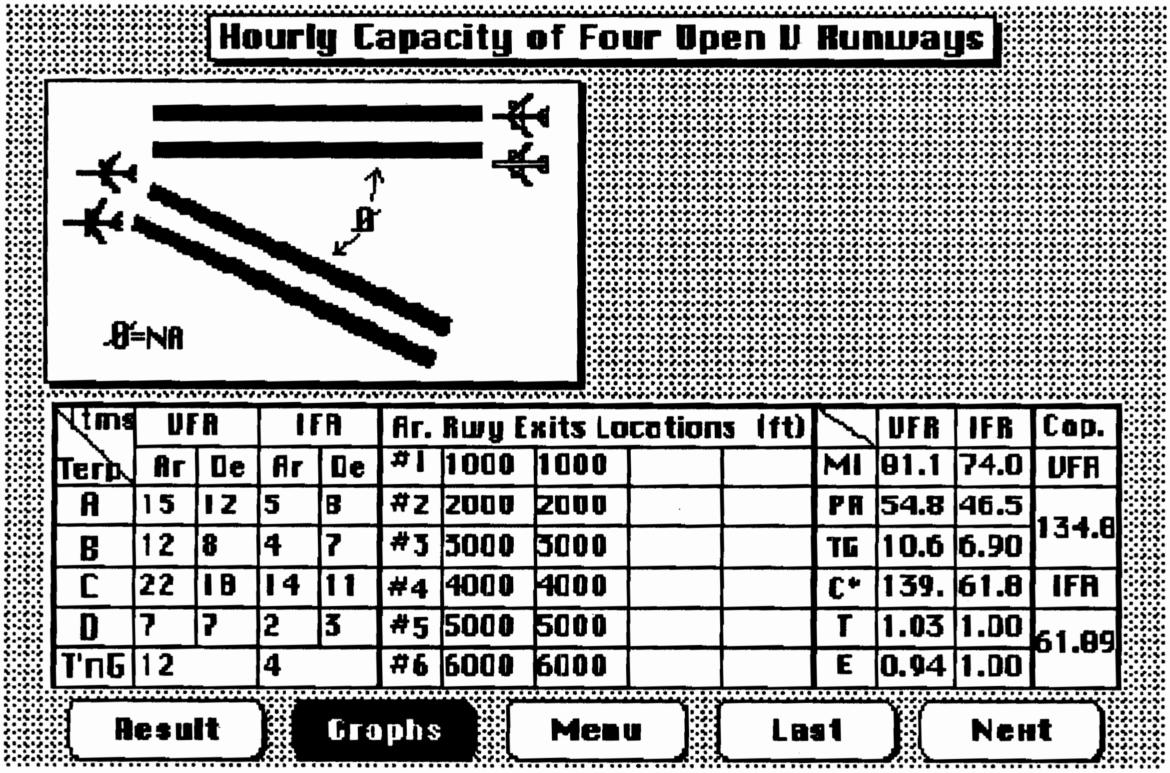


Fig. 5-13 Four Open V Runway Hourly Capacity.

Table 5-13 Four Open V Runway Hourly Capacity.

Weather / Methods Prts Evaluations	UFR				IFR			
	C*	T	E	C	C*	T	E	C
FAA AC	140	1.03	0.94	136	62	1.00	1.00	62
ICAD	139.2	1.03	0.94	135	61.9	1.00	1.00	62
Deviation	-0.6%	0.0%	0.0%	-0.7%	-0.2%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: C*--Hourly Capacity Base; T--Touch and Go Factor; E--Exit Factor; C--Hourly Capacity.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.2 Validations of Hourly Delays on Runways

A separate validation was made for runway hourly delays since the scripting structure in these applications is usually more complicated than those of hourly capacity. The output results from executing calculations are prone to have higher deviations than the rest of applications as there are more intermediate results calculated in this procedure, thus possibly resulting in larger errors. Considering the precision requirement for planning purposes, it is assumed that a ±5% discrepancy from FAA AC results is tolerable.

Tables 14 through 26 show numerical results for thirteen runway scenarios involving single, parallel, and converging and open V runway configurations. Most intermediate and final parameters are surprisingly the same as those in FAA AC except for the application shown in Fig.5-16 whose departure delay deviation in IFR is large because the absolute value of the departure delay is very small. the ultimate outcome of Table 5-16 shows that hourly delays are within ±2% of each other.

5.2.1 Hourly Delay on Single Runway

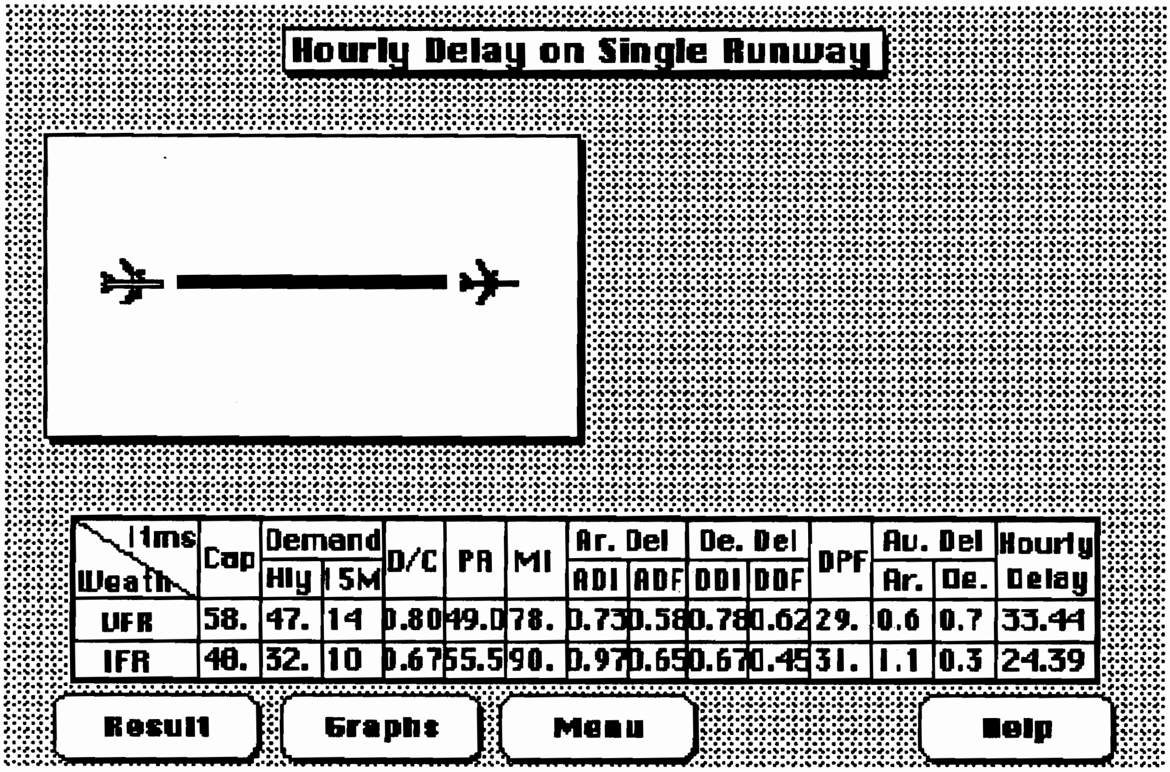


Fig. 5-14 Hourly Delay on Single Runway.

Table 5-14 Hourly Delay on Single Runway.

Weather / Methods Prts Evaluations	UFR					IFR				
	ADI	DDI	AD	DD	HD	ADI	DDI	AD	DD	HD
FAA AC	0.73	0.78	0.6	0.7	33.4	0.97	0.67	1.1	0.3	24.4
ICAD	0.73	0.78	0.6	0.7	33.4	0.97	0.67	1.1	0.3	24.4
Deviation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: ADI--Arrival Delay Index; DDI--Departure Delay Index; AD--Arrival Delay; DD--Departure Delay; HD--Hourly Delay.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.2.2 Hourly Delay on Two Parallel Runways

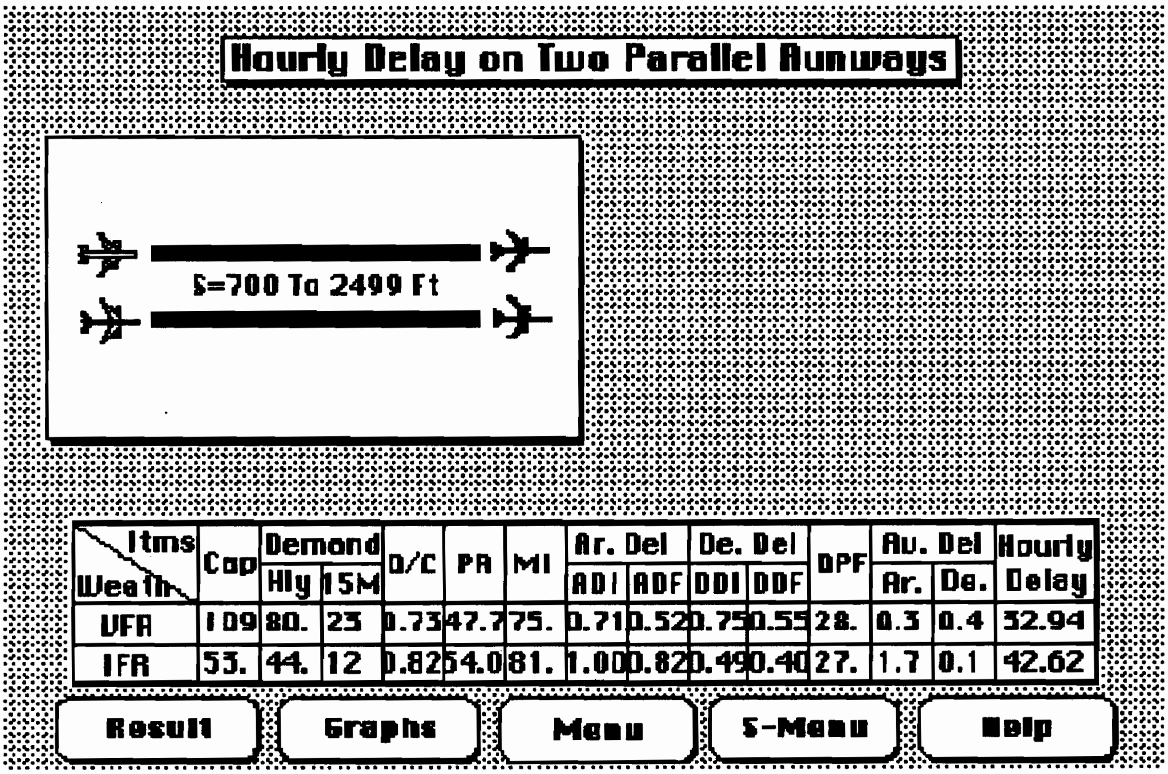


Fig. 5-15 Hourly Delay on Two Parallel Runways.

Table 5-15 Hourly Delay on Two Parallel Runways.

Weather / Methods Prts / Evaluations	VFR					IFR				
	ADI	DDI	AD	DD	HD	ADI	DDI	AD	DD	HD
FAA AC	0.71	0.75	0.3	0.4	32.9	1.00	0.48	1.7	1.1	42.4
ICAD	0.71	0.75	0.3	0.4	32.9	1.00	0.49	1.7	1.1	42.6
Deviation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	+2.1%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: ADI--Arrival Delay Index; DDI--Departure Delay Index; AD--Arrival Delay; DD--Departure Delay; HD--Hourly Delay.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.2.3 Hourly Delay on Three Parallel Runways

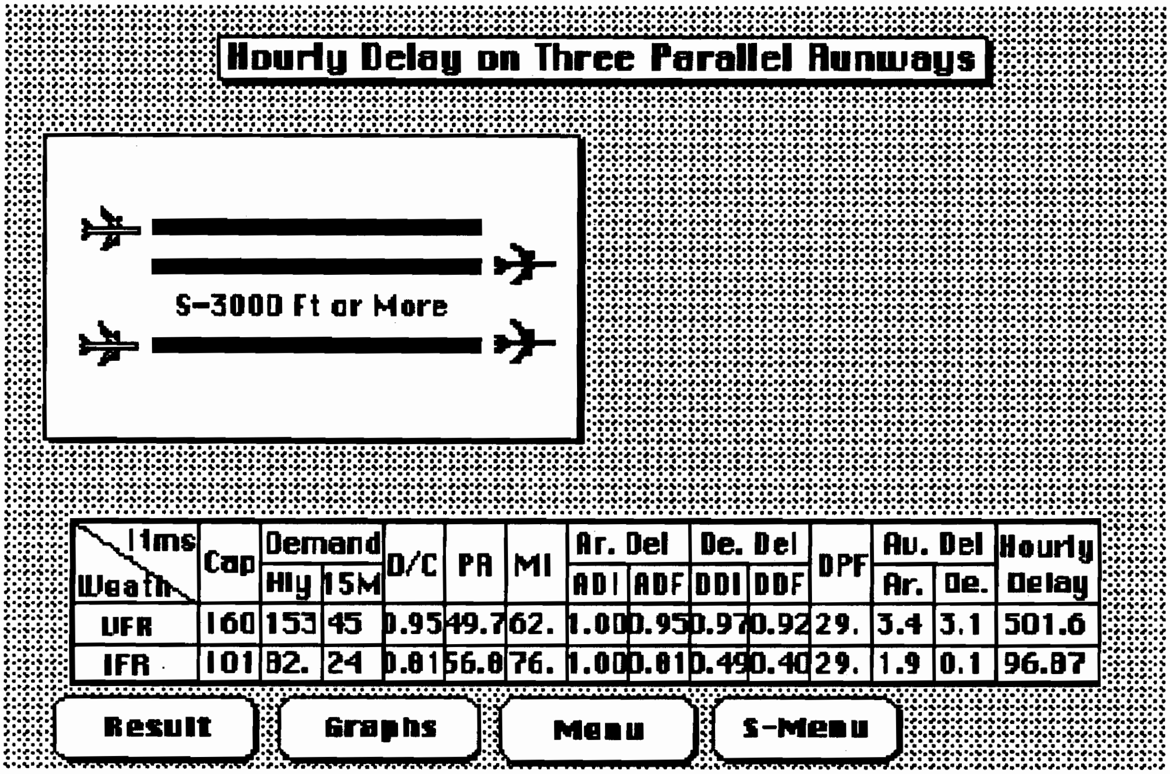


Fig. 5-16 Hourly Delay on Three Parallel Runways.

Table 5-16 Hourly Delay on Three Parallel Runways.

Weather / Methods / Prts Evaluations	VFR					IFR				
	ADI	DDI	AD	DD	HD	ADI	DDI	AD	DD	HD
FAA AC	1.00	0.97	3.4	3.1	502	1.00	0.51	1.9	0.2	95.6
ICAD	1.00	0.97	3.4	3.1	502	1.00	0.49	1.9	0.1	96.9
Deviation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-2.0%	0.0%	NA	+1.4%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: ADI--Arrival Delay Index; DDI--Departure Delay Index; AD--Arrival Delay; DD--Departure Delay; HD--Hourly Delay.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.2.4 Hourly Delay on Four Parallel Runways

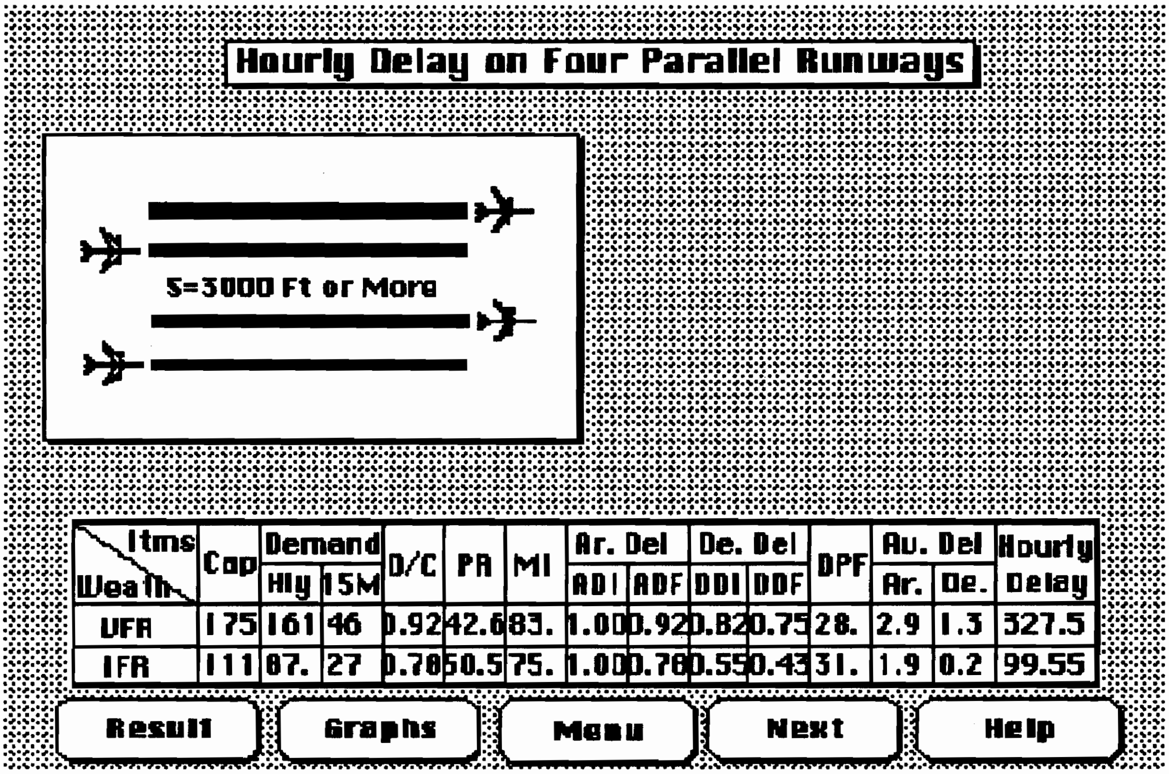


Fig. 5-17 Hourly Delay on Four Parallel Runways.

Table 5-17 Hourly Delay on Four Parallel Runways.

Weather / Methods Prts Evaluations	VFR					IFR				
	ADI	DDI	AD	DD	HD	ADI	DDI	AD	DD	HD
FAA AC	1.00	0.82	2.9	1.3	327.5	1.00	0.55	1.9	0.2	99.6
ICAD	1.00	0.82	2.9	1.3	327.5	1.00	0.55	1.9	0.2	99.6
Deviation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: ADI--Arrival Delay Index; DDI--Departure Delay Index; AD--Arrival Delay; DD--Departure Delay; HD--Hourly Delay.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.2.5 Hourly Delay on Two Intersecting Runways

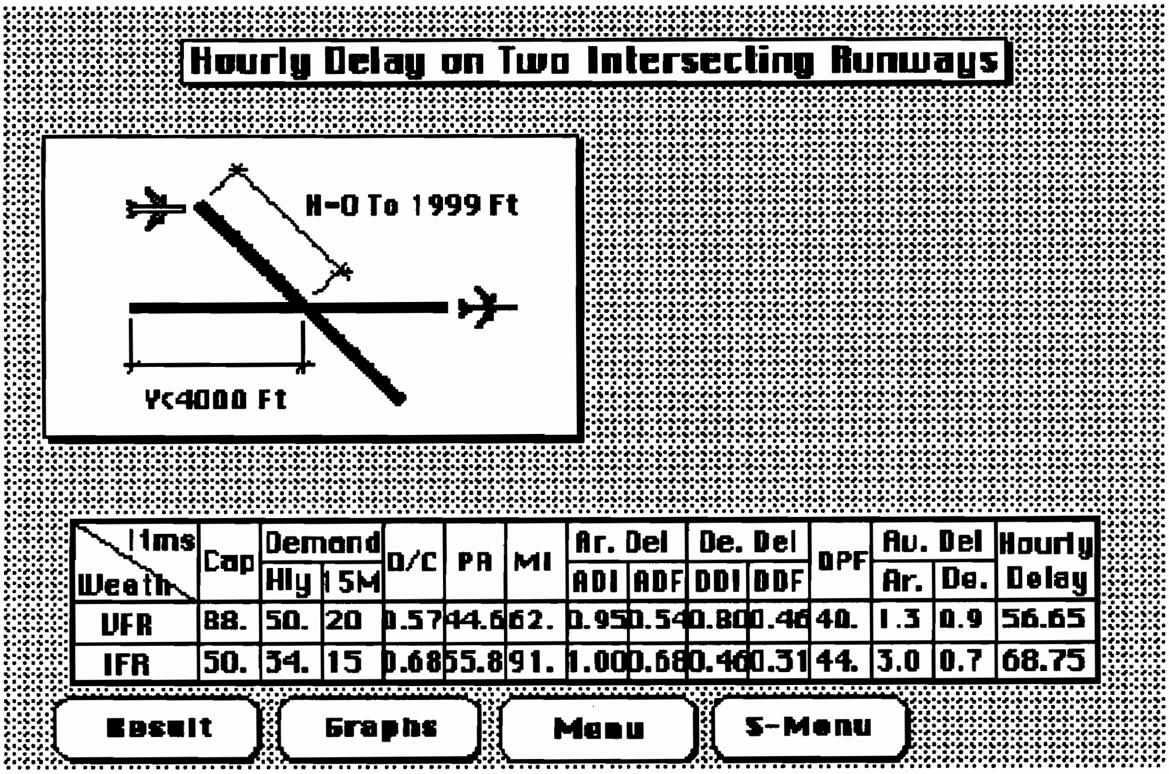


Fig. 5-18 Hourly Delay on Two Intersecting Runways.

Table 5-18 Hourly Delay on Two Intersecting Runways.

Weather / Methods Prts Evaluations	VFR					IFR				
	ADI	DDI	AD	DD	HD	ADI	DDI	AD	DD	HD
FAA AC	0.95	0.81	1.3	0.9	56.7	1.00	0.47	3.0	0.7	68.8
ICAD	0.95	0.80	1.3	0.9	56.7	1.00	0.46	3.0	0.7	68.8
Deviation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: ADI--Arrival Delay Index; DDI--Departure Delay Index; AD--Arrival Delay; DD--Departure Delay; HD--Hourly Delay.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.2.6 Hourly Delay on Three Intersecting Runways

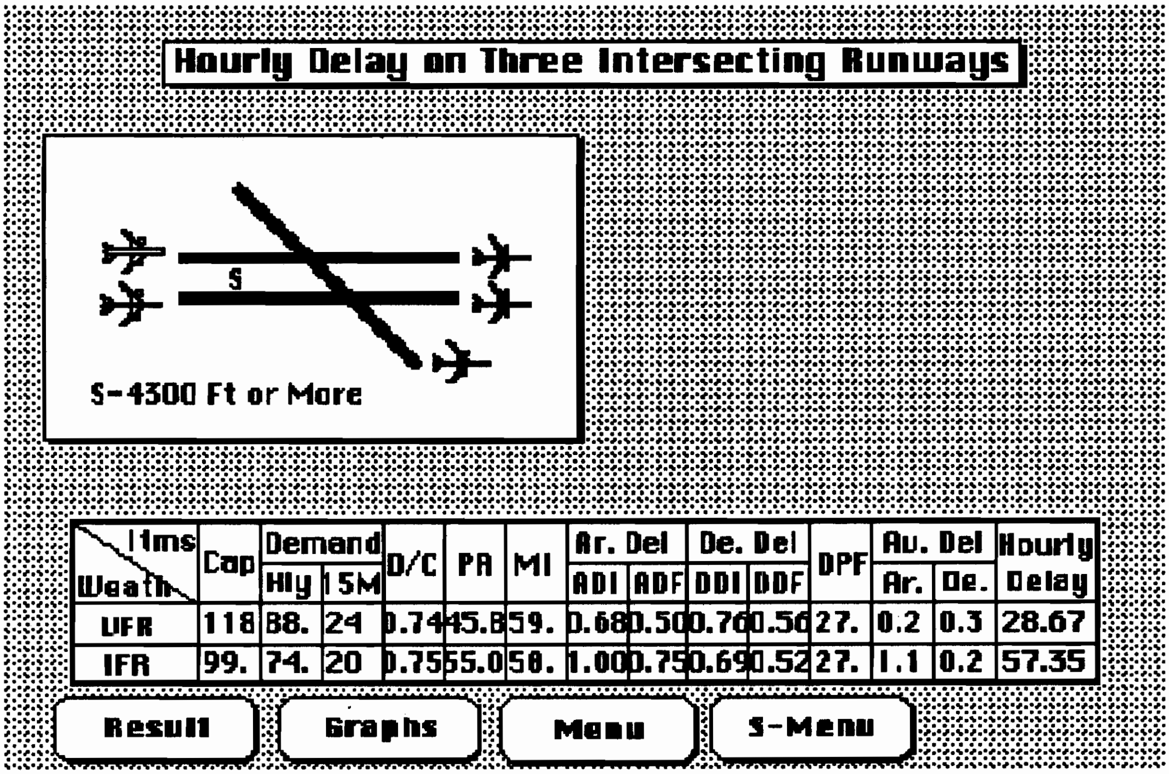


Fig. 5-19 Hourly Delay on Three Intersecting Runways.

Table 5-19 Hourly Delay on Three Intersecting Runways.

Weather / Methods Prts Evaluations	UFR					IFR				
	ADI	DDI	AD	DD	HD	ADI	DDI	AD	DD	HD
FAA AC	0.68	0.76	0.2	0.3	28.7	1.00	0.69	1.1	0.2	57.4
ICAD	0.68	0.76	0.2	0.3	28.7	1.00	0.69	1.1	0.2	57.4
Deviation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: ADI--Arrival Delay Index; DDI--Departure Delay Index; AD--Arrival Delay; DD--Departure Delay; HD--Hourly Delay.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.2.7 Hourly Delay on Four Intersecting Runways

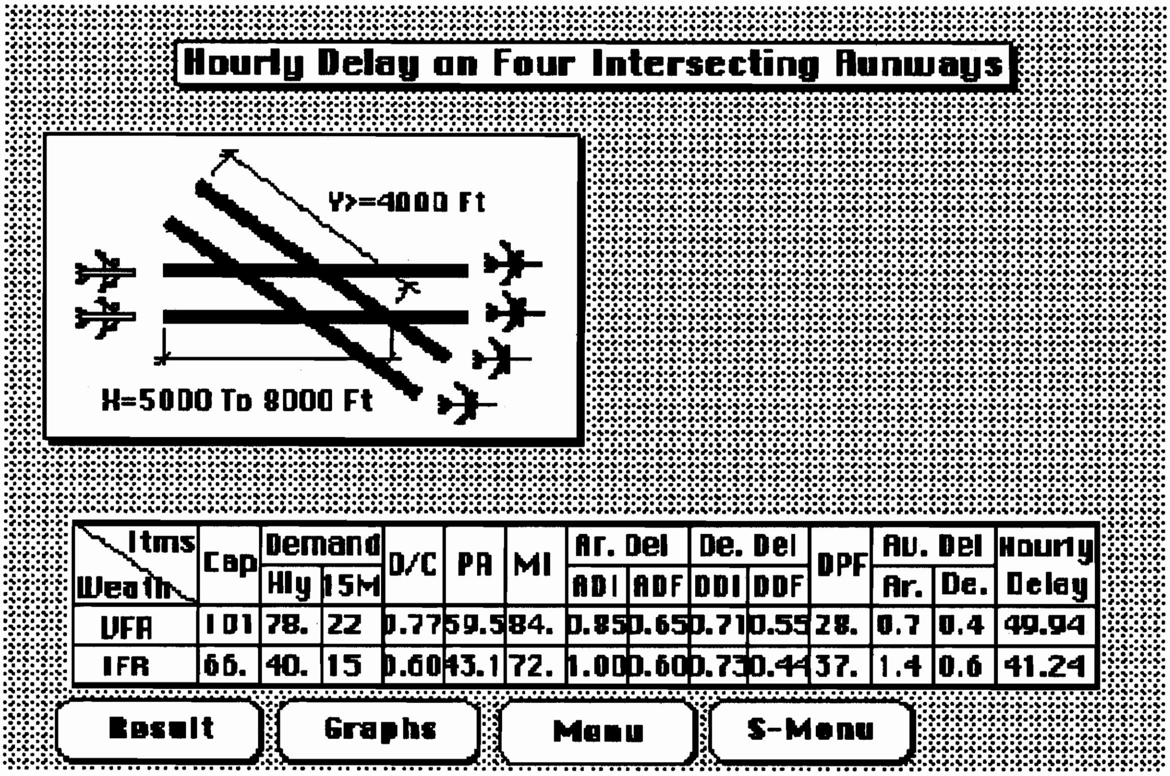


Fig. 5-20 Hourly Delay on Four Intersecting Runways.

Table 5-20 Hourly Delay on Four Intersecting Runways.

Weather / Methods Prts Evaluations	VFR					IFR				
	ADI	DDI	AD	DD	HD	ADI	DDI	AD	DD	HD
FAA AC	0.85	0.71	0.7	0.4	49.9	1.00	0.73	1.4	0.6	41.2
ICAD	0.85	0.71	0.7	0.4	49.9	1.00	0.73	1.4	0.6	41.2
Deviation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: ADI--Arrival Delay Index; DDI--Departure Delay Index; AD--Arrival Delay; DD--Departure Delay; HD--Hourly Delay.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.2.8 Hourly Delay on Two Converging Open V Runways

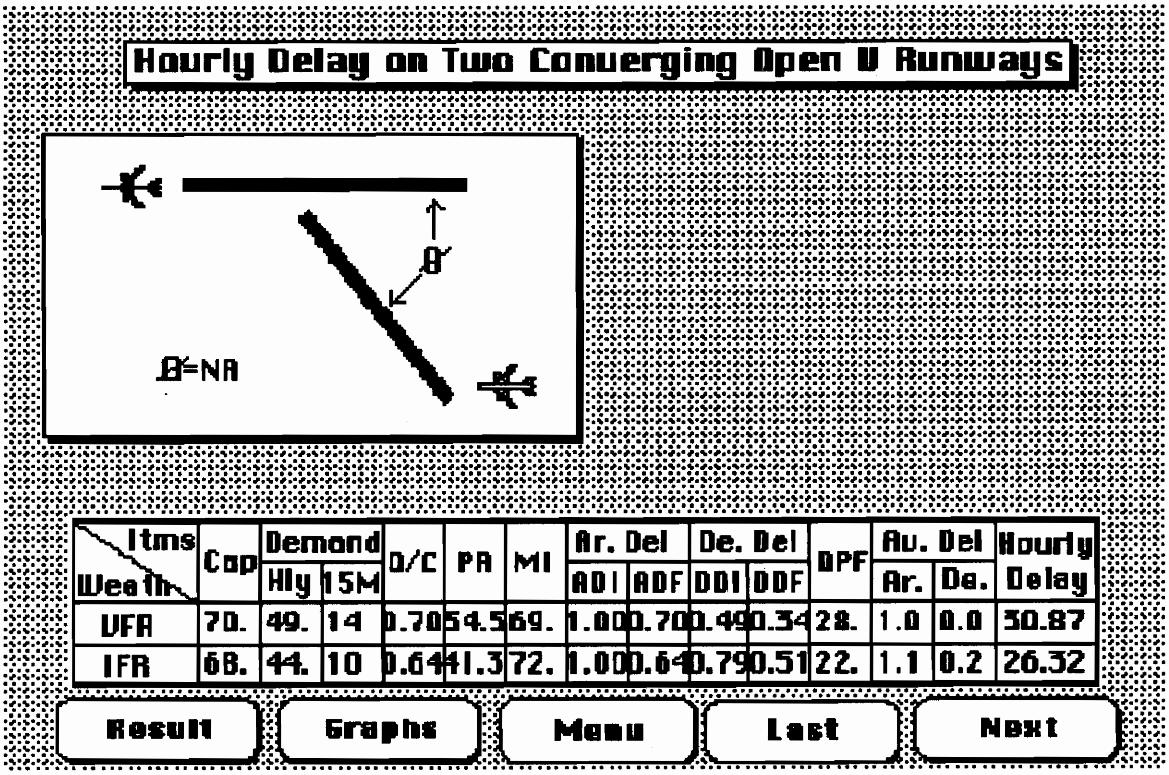


Fig. 5-21 Hourly Delay on Two Converging Open V Runways.

Table 5-21 Hourly Delay on Two Converging Open V Runways.

Weather / Methods, Prts / Evaluations	VFR					IFR				
	ADI	DDI	AD	DD	HD	ADI	DDI	AD	DD	HD
FAA AC	1.00	0.49	1.0	0.0	30.9	1.00	0.79	1.1	0.2	26.3
ICAD	1.00	0.49	1.0	0.0	30.9	1.00	0.79	1.1	0.2	26.3
Deviation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: ADI--Arrival Delay Index; DDI--Departure Delay Index; AD--Arrival Delay; DD--Departure Delay; HD--Hourly Delay.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.2.9 Hourly Delay on Three Converging Open V Runways

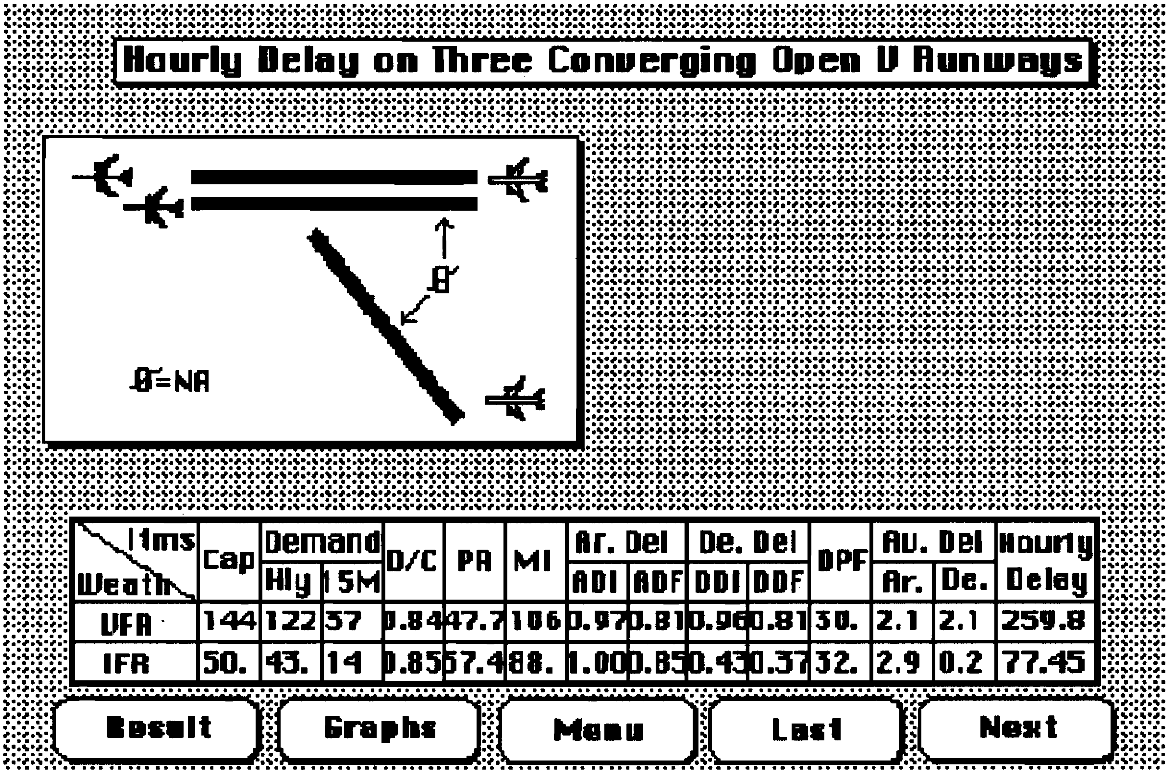


Fig. 5-22 Hourly Delay on Three Converging Open V Runways.

Table 5-22 Hourly Delay on Three Converging Open V Runways.

Weather / Methods Prts Evaluations	VFR					IFR				
	ADI	DDI	AD	DD	HD	ADI	DDI	AD	DD	HD
FAA AC	0.97	0.95	2.1	2.1	259.8	1.00	0.43	2.9	0.2	77.5
ICAD	0.97	0.96	2.1	2.1	259.8	1.00	0.43	2.9	0.2	77.5
Deviation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: ADI--Arrival Delay Index; DDI--Departure Delay Index; AD--Arrival Delay; DD--Departure Delay; HD--Hourly Delay.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.2.10 Hourly Delay on Four Converging Open V Runways

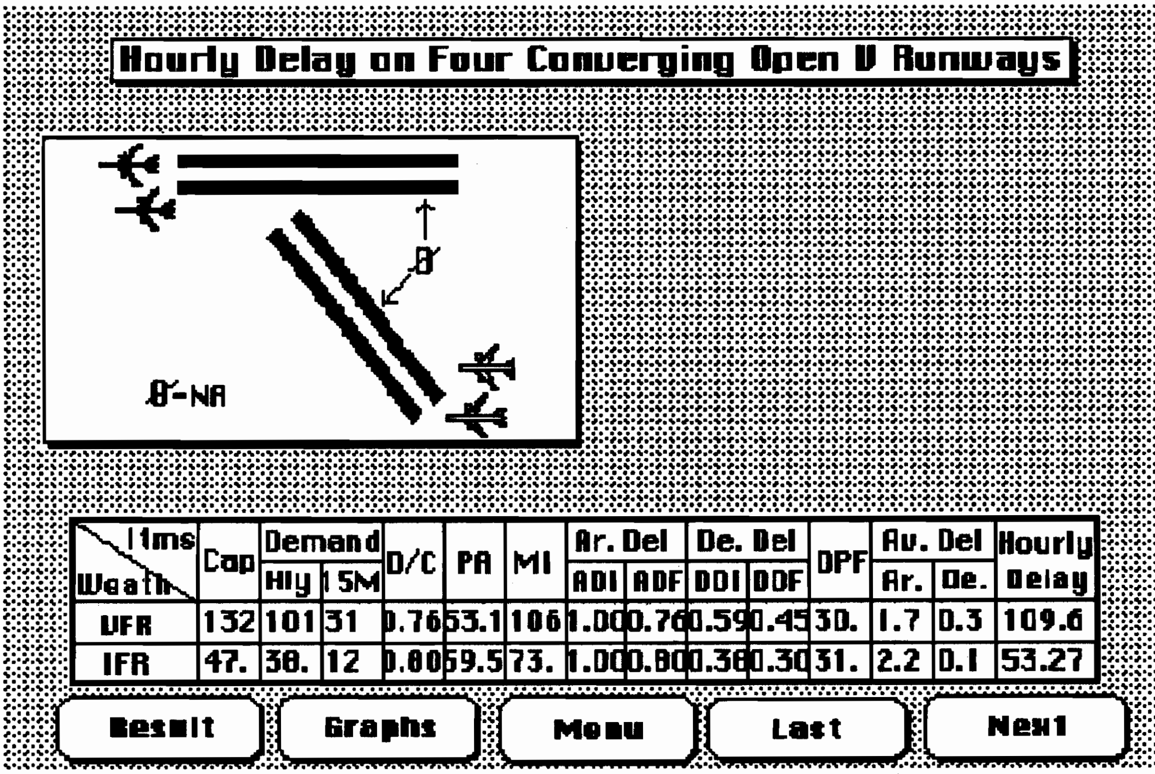


Fig. 5-23 Hourly Delay on Four Converging Open V Runways.

Table 5-23 Hourly Delay on Four Converging Open V Runways.

Weather / Methods Prts Evaluations	VFR					IFR				
	ADI	DDI	AD	DD	HD	ADI	DDI	AD	DD	HD
FAA AC	1.00	0.59	1.7	0.3	109.6	1.00	0.38	2.2	0.1	53.3
ICAD	1.00	0.59	1.7	0.3	109.6	1.00	0.38	2.2	0.1	53.3
Deviation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: ADI--Arrival Delay Index; DDI--Departure Delay Index; AD--Arrival Delay; DD--Departure Delay; HD--Hourly Delay.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.2.11 Hourly Delay on Two Open V Runways

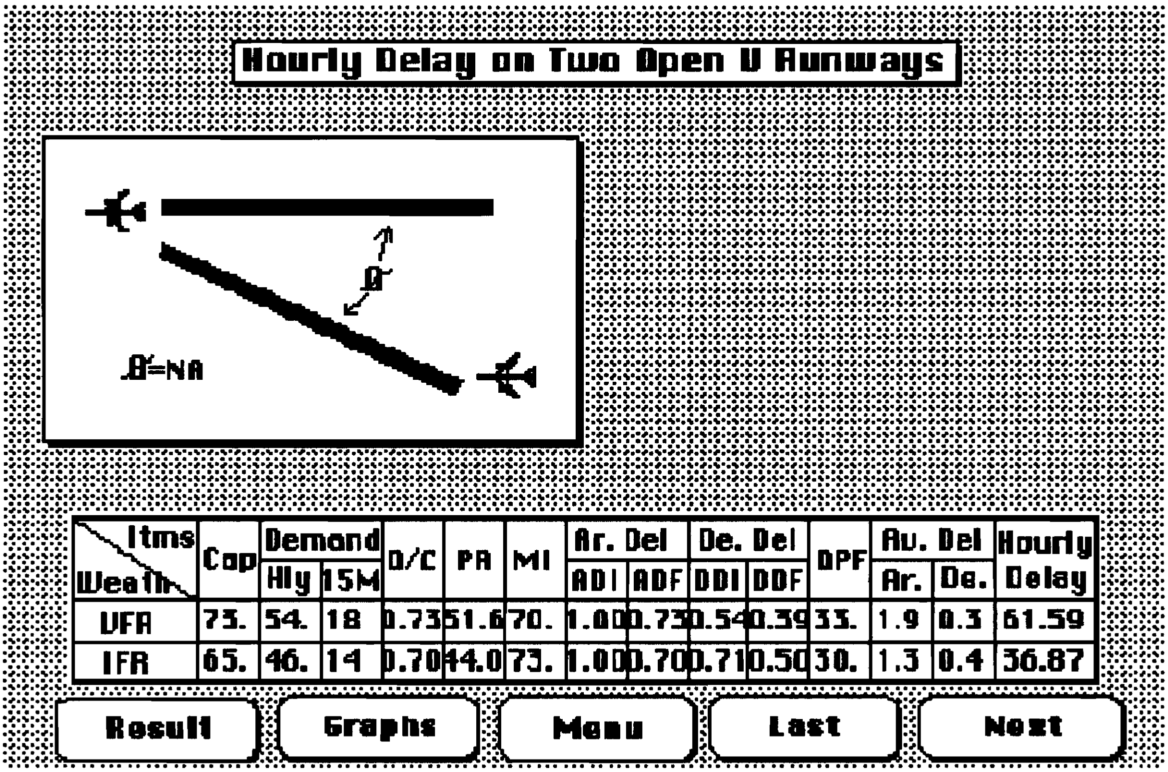


Fig. 5-24 Hourly Delay on Two Open V Runways.

Table 5-24 Hourly Delay on Two Open V Runways.

Weather / Methods Prts Evaluations	VFR					IFR				
	ADI	DDI	AD	DD	HD	ADI	DDI	AD	DD	HD
FAA AC	1.00	0.53	1.9	0.3	61.6	1.00	0.72	1.3	0.4	36.9
ICAD	1.00	0.54	1.9	0.3	61.6	1.00	0.71	1.3	0.4	36.9
Deviation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: ADI--Arrival Delay Index; DDI--Departure Delay Index; AD--Arrival Delay; DD--Departure Delay; HD--Hourly Delay.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.2.12 Hourly Delay on Three Open V Runways

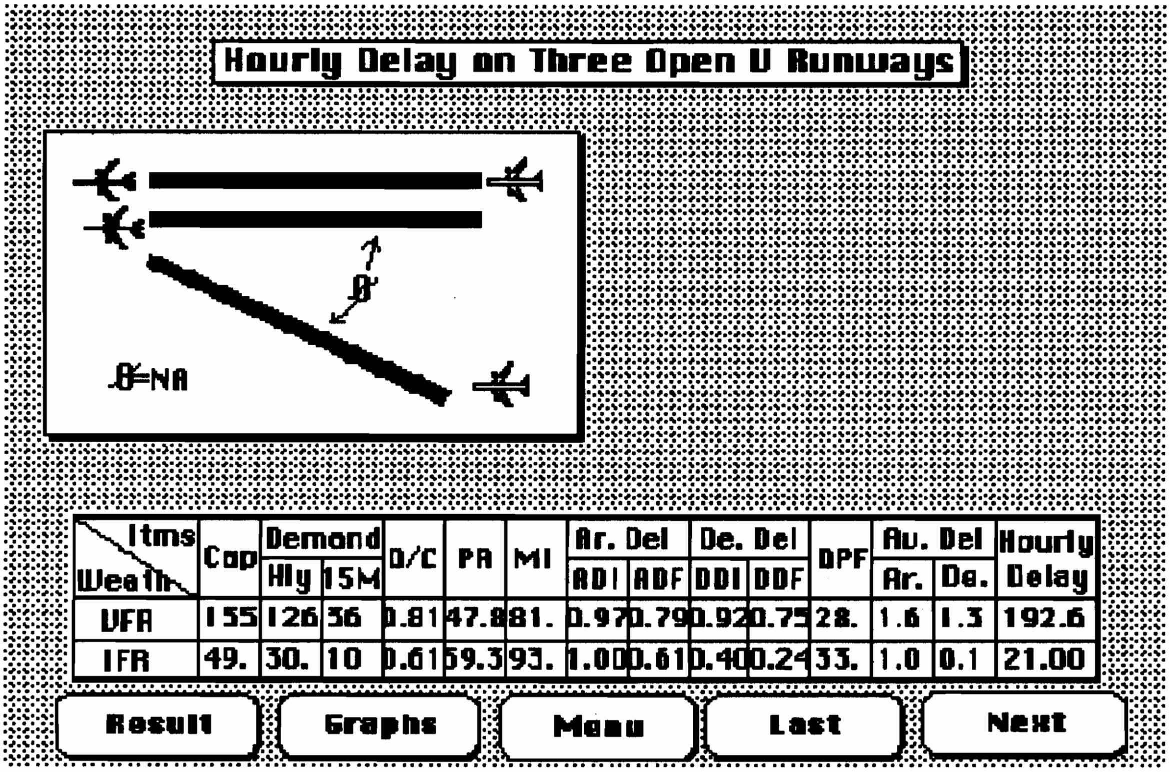


Fig. 5-25 Hourly Delay on Three Open V Runways.

Table 5-25 Hourly Delay on Three Open V Runways.

Weather / Methods Prts Evaluations	VFR					IFR				
	ADI	DDI	AD	DD	HD	ADI	DDI	AD	DD	HD
FAA AC	0.97	0.92	1.6	1.3	192.6	1.00	0.40	1.0	0.1	21.0
ICAD	0.97	0.92	1.6	1.3	192.6	1.00	0.40	1.0	0.1	21.0
Deviation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: ADI--Arrival Delay Index; DDI--Departure Delay Index; AD--Arrival Delay; DD--Departure Delay; HD--Hourly Delay.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.2.13 Hourly Delay on Four Open V Runways

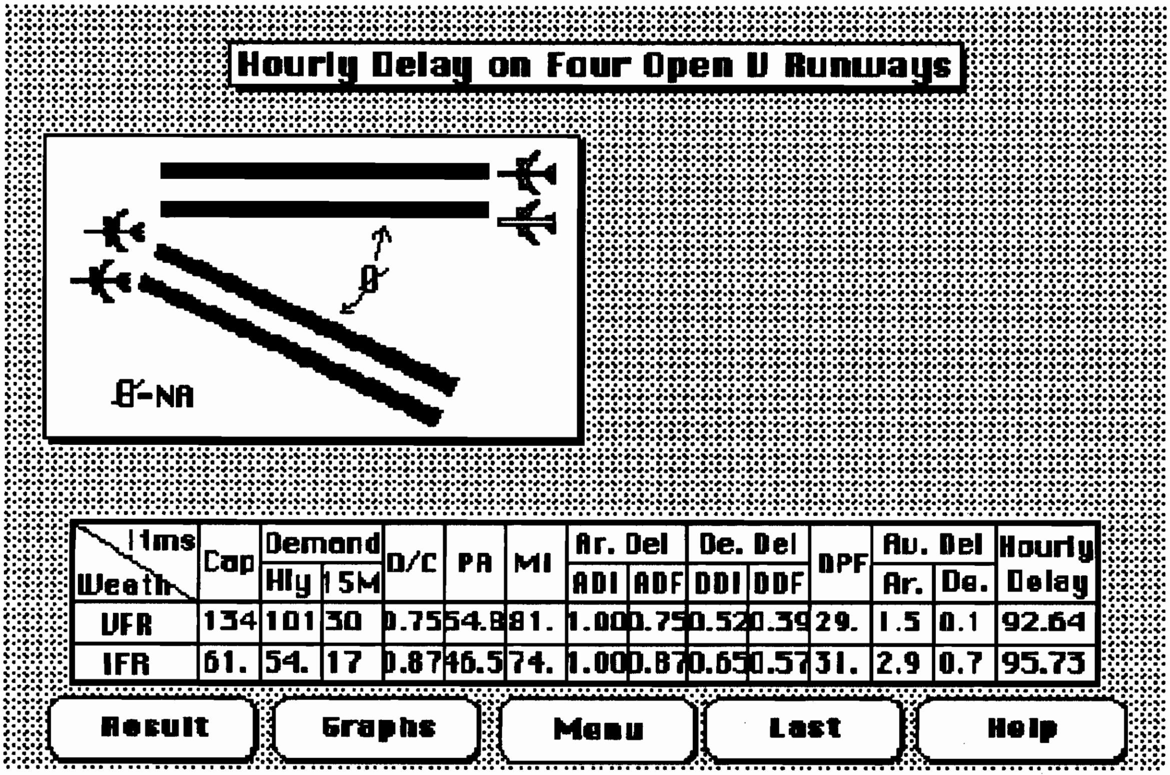


Fig. 5-26 Hourly Delay on Four Open V Runways.

Table 5-26 Hourly Delay on Four Open V Runways.

Weather / Methods Prts Evaluations	VFR					IFR				
	ADI	DDI	AD	DD	HD	ADI	DDI	AD	DD	HD
FAA AC	1.00	0.52	1.5	0.1	92.6	1.00	0.65	2.9	0.7	95.7
ICAD	1.00	0.52	1.5	0.1	92.6	1.00	0.65	2.9	0.7	95.7
Deviation	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: ADI--Arrival Delay Index; DDI--Departure Delay Index; AD--Arrival Delay; DD--Departure Delay; HD--Hourly Delay.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.3 Validations of Taxiway Hourly Capacity, Gate Group Hourly Capacity, Airport Overall Hourly Capacity and Annual Service Volume

Graphical interfaces for these special applications are shown in Figs.5-27 through 5-30. Validation results are shown in Tables 5-27 through 5-30 for various runway use configurations. It can be seen that ICAD provides satisfactory results for most scenarios. In some special applications, deviations are more than ±5% where FAA AC advocates a method without interpolation between capacity curves. Rather, ICAD uses an interpolation technique which, in the author's point view, is more reasonable.

Because some input parameters of these special applications depend entirely on those from previous runway hourly capacity calculations, inevitably cumulative errors tend to become bigger at the end. Especially when computational or printing mistakes in FAA AC are adverse of ICAD validation, the deviations are most likely to exceed the maximum acceptable ±5%. Nonetheless, this kind of cases arisen in only two parameter computations during the validation procedure.

5.3.1 Taxiway Hourly Capacity

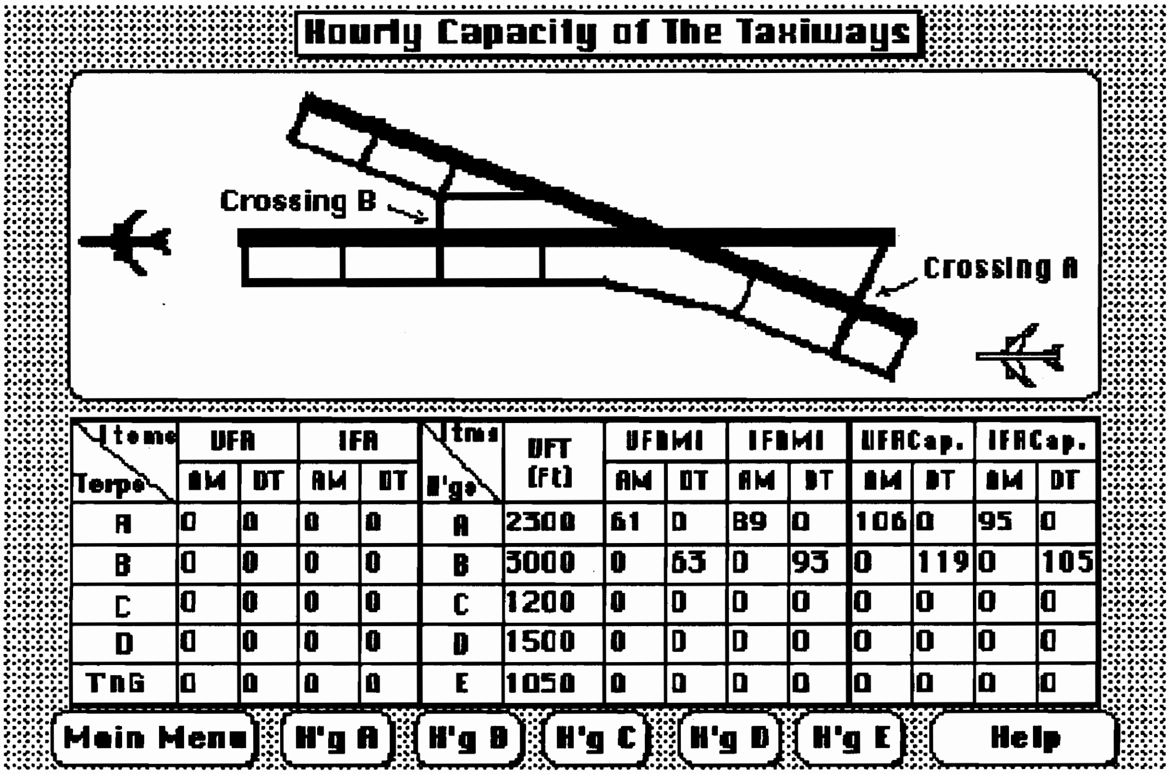


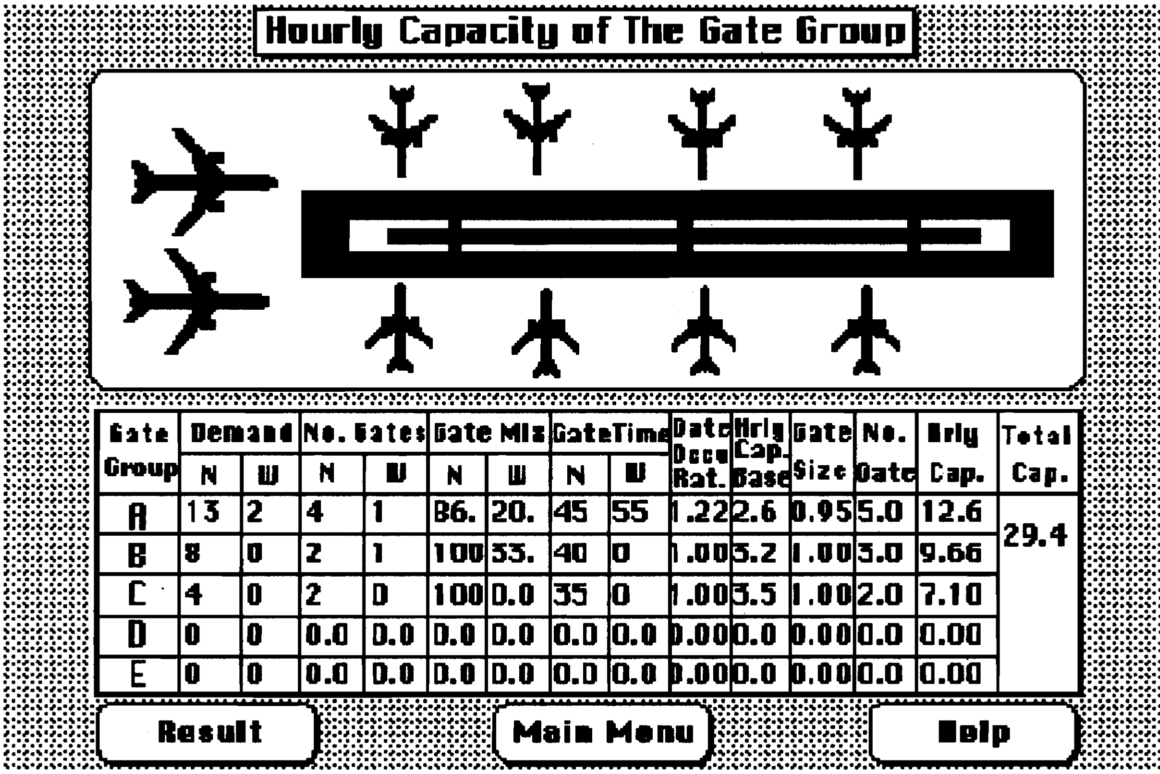
Fig. 5-27 Taxiway Hourly Capacity.

Table 5-27 Taxiway Hourly Capacity.

Weather / Methods Prts Evaluations	Crossing Runway A				Crossing Runway B			
	VMI	VC	IMI	IC	VMI	VC	IMI	IC
FAA AC	62	107	91	92	62	125	91	112
ICAD	61	106	89	95	63	119	93	105
Deviation	-1.6%	-0.9%	-2.2%	+3.3%	+1.6%	-4.8%	+2.2%	-6.3%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No

Note: VMI--Mix Index in VFR; IMI--Mix Index in IFR; VC--Hourly Capacity in VFR; IC--Hourly Capacity in IFR.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.3.2 Gate Group Hourly Capacity



Gate Group	Demand N	Demand W	No. Gates N	No. Gates W	Gate Mix N	Gate Mix W	GateTime N	GateTime W	Gate Occu Rat.	Hrly Cap. Base	Gate Size	No. Gate	Hrly Cap.	Total Cap.
A	13	2	4	1	86.	20.	45	55	1.22	2.6	0.95	5.0	12.6	29.4
B	8	0	2	1	100	33.	40	0	1.00	3.2	1.00	3.0	9.66	
C	4	0	2	0	100	0.0	35	0	1.00	3.5	1.00	2.0	7.10	
D	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.00	0.0	0.00	
E	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.00	0.0	0.00	

Fig. 5-28 Gate Group Hourly Capacity.

Table 5-28 Gate Group Hourly Capacity.

Weather / Methods Prts Evaluations	Group A			Group B			Group C			A+B+C
	G*	S	C	G*	S	C	G*	S	C	C
FAA AC	2.6	0.97	13	3.0	1.00	9	3.4	1.00	7	29
ICAD	2.6	0.95	12.6	3.2	1.00	9.7	3.5	1.00	7.1	29.4
Deviation	0.0%	-2.1%	-3.1%	+6.7%	0.0%	+7.8%	+2.9%	0.0%	+1.4%	+1.4%
Comment	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes

Note: G*--Gate Hourly Capacity Base; S--Gate Size Factor; C--Hourly Capacity for one gate group; C--Terminal Overall Hourly Capacity.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.3.3 Airport Overall Hourly Capacity

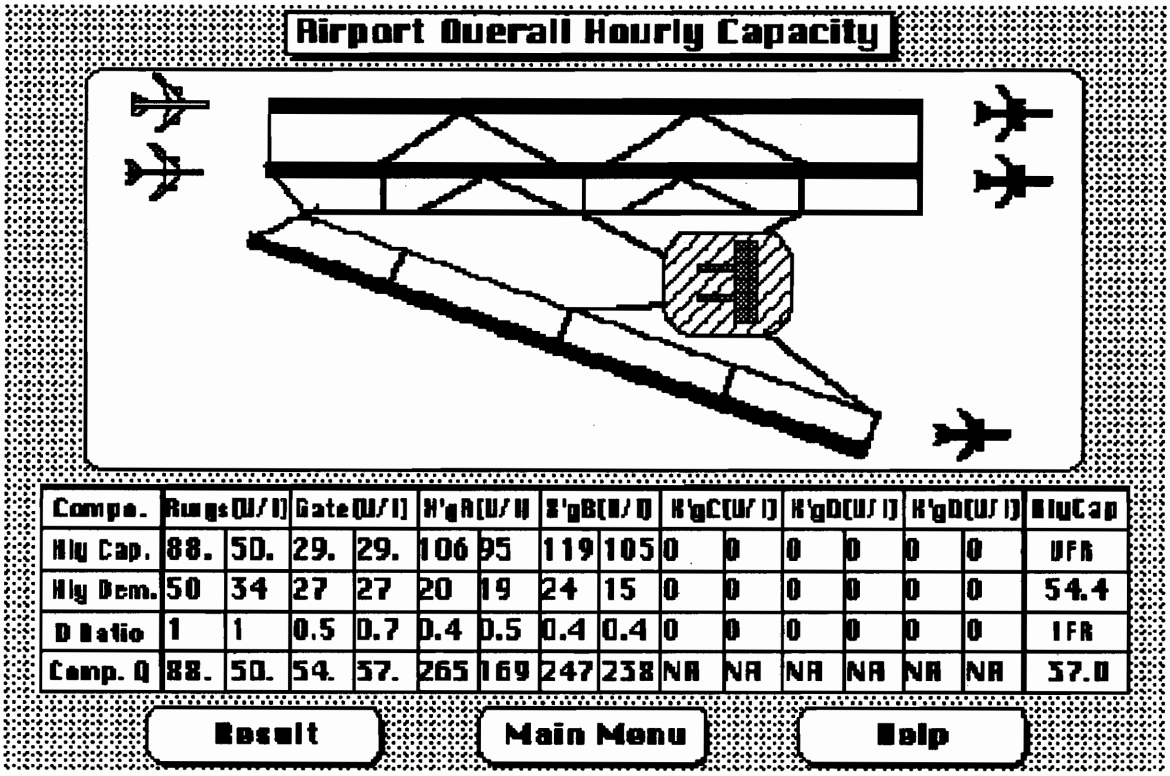


Fig. 5-29 Airport Overall Hourly Capacity.

Table 5-29 Airport Overall Hourly Capacity.

Weather / Methods Prts / Evaluations	Runway		Gate Groups		Taxiway A		Taxiway B	
	VFR CQ	IFR CQ	VFR CQ	IFR CQ	VFR CQ	IFR CQ	VFR CQ	IFRCQ
FAA AC	89	NA	54	NA	267	NA	260	NA
ICAD	89	50	54	37	265	169	247	238
Deviation	0.0%	NA	0.0%	NA	-0.7%	NA	-5.0%	NA
Comment	YES	NA	YES	NA	YES	NA	YES	NA

Note: VFR CQ--Component Quotient in VFR; IFR CQ--Component Quotient in IFR.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

5.3.4 Annual Service Volume

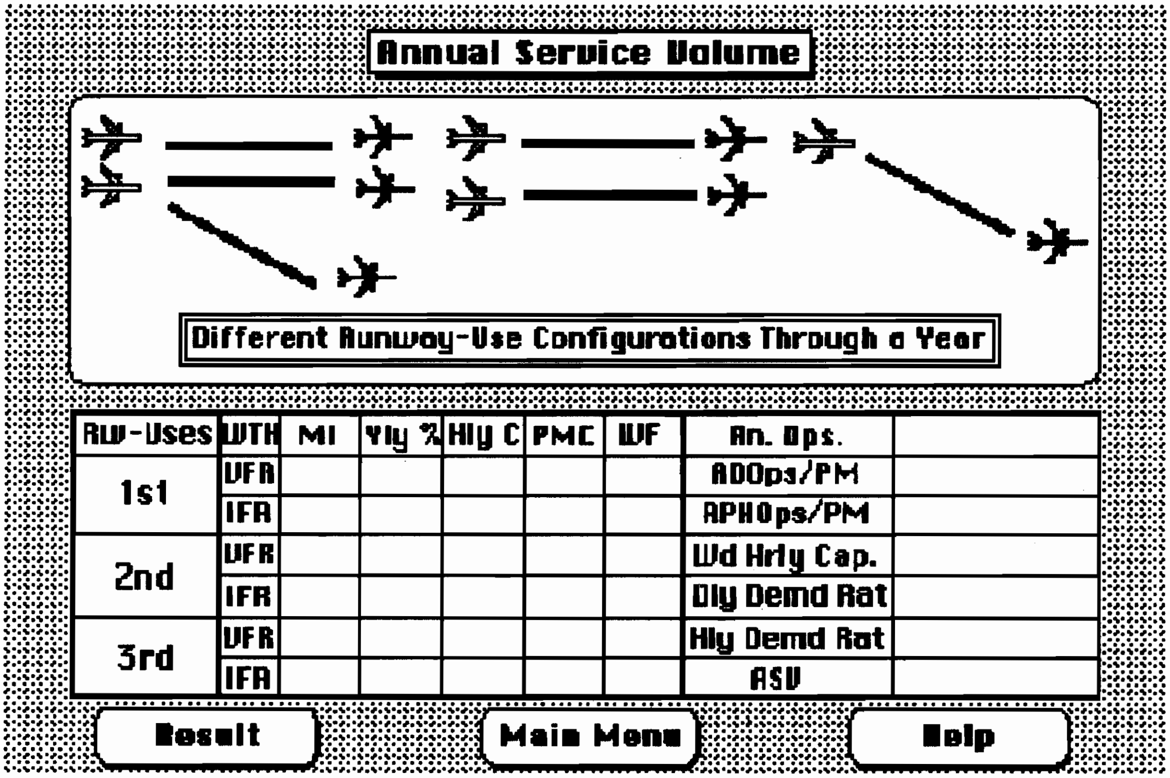


Fig. 5-30 Annual Service Volume.

Table 5-30 Annual Service Volume.

Weather / Methods Prts / Evaluations	Runway Use 1		Runway Use 2		Runway Use 3		ASV
	VFRC	IFRC	VFRC	IFRC	VFRC	IFRC	VFR & IFR
FAA AC	89	51	62	52	59	46	227052
ICAD	88.2	50.2	61.4	49.2	62.4	46.3	222402
Deviation	-0.9%	-1.6%	-1.0%	-5.4%	+5.8%	+0.7%	-2.0%
Comment	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: VFRC--Hourly Capacity in VFR; IFRC--Hourly Capacity in IFR;
ASV--Annual Service Volume.
Deviation--Percent difference between ICAD and FAA AC 150/5060-5.
Comment--Yes accounts for less than ±5% deviation from FAA AC.

Chapter 6

Conclusions and Recommendations

In Chapter 5, ICAD Validation, thirty different applications were randomly selected to perform computations and to compare output results with those of manual calculations. All validation efforts taken in this thesis show that deviations are within ±5% of those obtained from FAA AC 150/5060-5, thus implying good potential for ICAD in preliminary planning.

6.1 Conclusions

Overall ICAD software package has been evaluated and proven to be positive. Several advantages offered by ICAD to future users are listed as follows,

1) Users are virtually free from scrutinizing into details of FAA AC graphs, sample applications and calculations. This entitles the users to concentrate on exploring solutions rather than becoming involved in massive routine computation.

2) The advantages of a "friendly user interface" are factual in ICAD. All windows or interfaces have been created and designed purposely to include as many functioning components as possible. Users can easily recognize a particular application they desire to have by looking at the runway use configuration on the upper left corner of the window. If they want to see the trend of some dependent parameters with the changes of other relevant parameters, they can evoke actual graphs of Hourly Capacity Base, Arrival and Departure Delay Indices at the touch of a button. In the lower part of the interfaces lie input and output data tables which give users obvious and direct accesses to execute calculations.

3) Maneuvering between the current 108 individual applications in ICAD could look like wandering in a maze. But with the help of HyperCard's concatenation ability, navigating among more than 108 cards becomes so rational and organized that switching from one application to the remotest one will take about 10 seconds. Meanwhile, without closing the

HyperCard application file, users can also perform any calculations of different ICAD applications, thus making the procedure coherent and logical.

4) Results accuracy and quick problem solving capabilities are important elements in ICAD. As discussed in the last chapter and demonstrated above of their merits, ICAD guarantees its dependability and shows its speed to accomplish calculations. In general, it could be argued that ICAD yields output parameters more closely to the mean values than an average user. An average user needs 10 minutes to complete manually on an airport scenario calculation. The time consumed on problem solving may be even longer if the user is not familiarized with FAA AC procedure. In contrast, computations on ICAD only take about 1 minute for an experienced user including data entry and program execution. Compared with FAA AC 150/5060-5, ICAD can help save users' a great amount of time that could be employed in analyzing more feasible runway configurations.

5) The complete ICAD software requires 5 megabytes of hard disk space and runs on any standard Macintosh computers ranging from the entry level Classic II to the most sophisticated Quadra. ICAD offers users a great deal of flexibility by being able to print out results and diagrams of analysis on the spot. These output can be pasted into reports if desired.

6.2 Recommendations

It should be understood that the software presented constitutes a first iteration of ICAD. The goal of this project was to develop a proof-of-concept that can be further refined to include new runway separation criteria and other advances in ATC rules. Considering the time and resource constraints when the author started to undertake the development of ICAD, script structure shortcomings, interface design deficiencies, even typos can be found possibly in ICAD. The following recommendations, in the author's view, suggest the ways by which ICAD can be upgraded in the future.

1) Create the application interface on a computer with a less restricted screen. In this fashion, some of the screen congestion problems could be avoided. Another choice is some intermediate output area in the tables may be omitted to make more rooms for others.

2) Increase more "intranavigation" capability within ICAD by adding more buttons in Runway Hourly Capacity application interfaces so as to switch rapidly to Hourly Delay on Runways and other special applications. For the convenience of users, print functions can be transferred to the buttons on every application interface in ICAD.

3) Standardize button and picture designs on all application interfaces. A tentative method will be to create an archetypal card with several blank buttons of same size, and depending upon the need, one or two picture frames on it. Every time the user creates a new application window, the original card is cloned and pasted into the new one. Afterwards the user can fill in the information contents for the application. This standardized design will ensure more consistency and expedite the development process of ICAD.

4) Comply with more strict output precision requirements, it is crucial to alter the basic concept of making decision structures in ICAD scripts and regression equations obtained from FAA AC graphs. Script files will have to expand in terms of exacerbating structure complexity and sacrificing more memory in a disk. The regression equations, used for some applications in the first edition of ICAD in which errors above ±5% are found, should be disregarded. The point here is, not to maintain parameters involved into each regression equations unless they have been approved by statistical P value test.

5) Combine together the two decision structures used for calculating runway exit factors under VFR and IFR conditions. In a recent experiment on the number of exits counting structure in ICAD, it was found that one local variable can be used to indicate the number of exits within the same range of aircraft mix indices for VFR and IFR weather conditions. Consequently this adjustment will reduce considerable hard disk space taken by ICAD and shorten script execution time.

6) Allow to modify in the scripts in order to enhance the runway hourly capacity if new traffic control guidelines and new separation criteria for runways spaced between 4300 ft. and 3400 ft. with PRM radar are adopted.

Bibliography

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Appendix
ICAD Application Software

No.	File Name	File Description	File Size (Kb)
1	ICAD	Integrated Airport Capacity and Delay Model	76
2	Paca1	Single Runway Capacity	20
3	Paca2	Two Parallel Runway Capacity	88
4	Paca3	Three Parallel Runway Capacity	82
5	Paca4	Four Parallel Runway Capacity	39
6	Inca2	Two Intersecting Runway Capacity	142
7	Inca3	Three Intersecting Runway Capacity	76
8	Inca4	Four Intersecting Runway Capacity	184
9	Covca2	Two Converging Open V Runway Capacity	31
10	Covca3	Three Converging Open V Runway Capacity	56
11	Covca4	Four Converging Open V Runway Capacity	40
12	Ovca2	Two Open V Runway Capacity	31
13	Ovca3	Three Open V Runway Capacity	55
14	Ovca4	Four Open V Runway Capacity	40
15	Padela1	Delay on Single Runway	23
16	Padela2	Delay on Two Parallel Runways	71
17	Padela3	Delay on Three Parallel Runways	69
18	Padela4	Delay on Four Parallel Runways	27
19	Indela2	Delay on Two Intersecting Runway s	170
20	Indela3	Delay on Three Intersecting Runways	70
21	Indela4	Delay on Four Intersecting Runways	168
22	Codela	Delay on Converging Open V Runways	80
23	Odela	Delay on Open V Runways	80
24	Taca	Taxiway Exit Capacity	40
25	Gaca	Gate Group Capacity	40
26	Toca	Airport Overall Capacity	20
27	Anca	Annual Service Volume	32
28	Graphs	C*, ADI, DDI	2,700

Vita

The author was born in April 19, 1962 in Nanjing, China. He had his undergraduate education in Civil Engineering Department in Nanjing City College with an emphasis on Roadway and Bridge Design, and obtained Bachelor of Science degree in 1986. He came to Virginia Polytechnic Institute and State University in the Fall, Semester 1991 to pursue graduate study in Transportation System Planning. He earned his Master of Science degree in Civil Engineering in August, 1994. In order to gain some work experience, he expects to have a temporary training or a job on transportation system planning and infrastructure design, especially on airport transportation activities in the United States.