A SYSTEMS APPROACH FOR IDENTIFYING POTENTIAL PROBLEMS IN AIRCRAFT AND AIRPORT COMPATIBILITY

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Abstract

A methodology has been developed for determining the effects of changes in aircraft dimensions or characteristics on the ability of these aircraft to operate at airports. The intent of the methodology is to identify and define, quantitatively whenever possible, the potential problem areas. It does not offer solutions, but can be very valuable to a designer by providing assistance in evaluating design changes. It can be used in real time in the design process.

The methodology is based on three interaction matrices: (1) aircraft/aircraft, which indicates other aircraft quantities which might be affected by the initial changes contemplated; (2) aircraft/airport, which indicates airport characteristics which might be affected by the aircraft changes; (3) airport/airport, which indicates additional airport quantities which may have to be altered if others are changed. By using these interaction matrices in conjunction with a set of data banks involving airport and aircraft data, OAG schedules, and published literature or regulations, the user can be presented with all available information on each potential point of incompatibility between a new aircraft design and specific airport operations.

The methodology is structured about two user-interactive computer programs which start with a definition of a candidate aircraft. The procedures are reversible so that the methodology can be applied to analyze the effects of changes in airport design on the ability of the airport to accommodate aircraft.

An illustration is provided by considering some prospective changes to a standard commercial jet transport.

Introduction

The matter of aircraft/airport compatibility is of great importance when considering possible new aircraft designs which might result from research and development programs. Although these new designs might lead to improvements in aircraft operating performance, and hence lower seat mile costs, they may require major changes to existing airports in order to realize these performance gains. Thus, the airports, if not altered, may impose constraints on the aircraft which may nullify part or all of the performance improvement; or, the cost of removing these airport constraints may equal or exceed the economic gain from the new aircraft. Since all economic gains and losses are ultimately reflected in the pricing of the system product, viz. an aircraft seat (or ton) mile, it is important that new aircraft designs reflect a maximum of economic gain and productivity increase when viewed from the entire air transportation system.

The overall system is very complex. When a change is made to one or more design parameters of an aircraft there are numerous points of interaction where the possible effect of these changes may require changes in other parts of the system. These interactions can be with other parts of the aircraft (a self-interaction), or with components or parameters of the airport (joint-interactions). Furthermore, the problems exist in both directions, i.e., as new airports are built or old ones modified, changes in the numerous design criteria associated with an airport may generate both self- and joint-interactions requiring either additional changes in the airport design or restricting certain aircraft from using parts or all of the airport. When addressing problems of such complexity it is essential to have available a methodology which will assure that, when entering a system at any point (i.e., making one or more design changes in either the aircraft or airport), a rigorous and systematic analysis will be made of all potential interactions throughout the system. This methodology should identify the interaction points, describe the nature of each interaction, classify the types of impacts which result, and guide the user to all available material which can be used in evaluating the extent of the effect of the interaciton on the system. The methodology does not provide solutions. This is the responsibility of the user (engineer or analyst). What the methodology does is provide these users with tools for identifying all the potential problems, outlining the perspectives from which they must be viewed, and assisting in assembling the information required to approach the problem solution phase. This paper outlines such a methodology which is under development at the University of Virginia and is supported by the NASA/Langley Research Center under Contract NAS1-16286, Task 1.

General Approach

The procedure has been divided into two separate routines. The objectives of the first routine are to provide the analyst with a list of all the information which is required to evaluate the total effect of any given system change, and to identify how much of this information is readily available and where it can be found. Additional steps can be added, if desired, to catalog the information and make it available for immediate access.

The second routine is designed to assist the analyst in making the evaluation, once the information has been gathered. It should be emphasized that this second routine does not generate solutions. Its role is to indicate the magnitude of the problems to be encountered by making a system change. However, some guidance toward possible solutions can be obtained by repeated applications of the process with varying values of the design parameters involved in the key interactions, and then comparing results.

The first routine is referred to as a "search" and the second as an "evaluation." Each will be discussed separately.

The Search Routine

This routine is based on the formation of two types of data banks, and the appropriate steps for accessing them. The first type of data bank involves interactions between system components. There are three types of interactions which must be considered when making a change in any system component. To illustrate the process it will be assumed that a change in some component of an aircraft is contemplated, e.g. wing span.

Step 1. Identify all other aircraft components or characteristics that might change due to the change in wing span; e.g. wing area, aircraft weight, take-off and landing field lengths, etc. are some of the things that should be examined.

Implementation of Step 1 requires the formation of what is called an "Aircraft/Aircraft Interaction Matrix." The role of this matrix is simply to identify all of the potential interactions which do exist. However, additional qualitative information can be presented to the analyst within the matrix format by classifying the interactions as strong (S), Medium (M), or weak (W).

Step 2. For each aircraft component or property for which an interaction has been determined in Step 1, identify all airport components or characteristics which might be affected by the aircraft change; e.g. increased wing span might require changes in gate spacing, or taxiway separation, and an increase in aircraft weight due to the increased wing span might require additional runway pavement thickness, etc.

Implementation of Step 2 requires the formation of what is called an "Aircraft/Airport Interaction Matrix." The mission is similar to that of the first matrix except that now the emphasis is on the effect of aircraft on airport, and in this case it is desirable to be able to read the matrix in both directions, i.e. enter it either by means of an aircraft change or an airport change. As before, the interaction can be identified as to the level of severity.

Step 3. For each airport component identified in Step 2, determine other airport components or characteristics which might be affected by a change in the original items, e.g. the increased gate spacing, if required by the increase in wing span, could reduce the number of gates and affect airport capacity; or it could require additional gates encroaching on taxiways or on space for operation of ground service vehicles, etc.

Implementation of Step 3 required the formation of what is called an "Airport/Airport Interaction Matrix." It is similar in structure to the matrix in Step 1.

Step 4. Iterate. The new airport categories identified in Step 3 are now run through Step 2 to see if any additional aircraft categories are involved; if so, they go through Step 1, and the result through Steps 2 and 3, etc. until no new interactions are generated in Step 2.

Step 5. Provide specific information as requested for those aircraft/airport interactions selected from the list obtained in Step 4.

This step requires the formation of several types of informational data banks providing specific details concerning the nature of the interaction identified. These are true data banks rather than matrices, and so they can be constructed and arranged to be most useful to the initial process of problem identification. The number and type of data banks to be constructed is arbitrary, as is the size of each. Our experience to date has indicated that the following data might be particularly useful.

(1) Definitions: A definition of terms used in listing the interaction as identified in each interaction matrix, and a brief qualitative statement describing the nature of the interaction.
(2) Bibliography: This would contain citations of all literature pertaining to each particular interaction identified in the three interaction matrices. Abstracts could be included if so desired.
(3) Constraints: Short statements concerning current guidelines or restructions placed on any of the quantities involved in each interaction by regulatory bodies such as FAA or ICAO.
(4) Data and Formulas: Quantitative relationships which would provide a capability for estimating the magnitude of the interaction. Actually, several versions of this type of bank might be useful. Each could be oriented toward a specific evaluation measure, such as:
   - effect on the environment
   - productivity
   - user acceptance
   - technological requirements
   - capital costs
   - operating costs
   - etc.

At the present time the aircraft/airport mutual interaction matrix and the aircraft/aircraft self interaction matrix have been developed in detail. The general categories of components used in each of these are shown in Tables 1 and 2. (1)

To date, the interaction matrices have been developed only for the airside and terminal interface portions of the airport complex. The terminal itnerface is arbitrarily defined to stop at the areas within the terminal building to which the passengers are introduced as they enter the terminal building from the deplaning mechanism, or the area at which baggage or cargo is first deposited after unloading. These restrictions were imposed because they were the areas of prime interest to the sponsor, and seemed adequate to demonstrate the principles of the methodology. This is not intended to imply that there are no aircraft interactions with landside or curbside functions of the airport terminal.

With regard to the informational data banks, these are essentially openended, and their complete assembly was beyond the scope of the present work. Thus, they have been constructed only to the extent required to illustrate their applications in the methodology. It should be noted, however, that once they are developed they are universal in nature and can be used by all groups concerned with the general problem of aircraft/airport compatibility.

The Evaluation Routine

The objective of this routine is to guide the user through the process of determining the overall effect on airports or operations at airports resulting from a change in aircraft components or

Table 1. Major aircraft elements of aircraft/airport interaction matrix.

AC0100	Aerodynamic Design And Functions
AC0200	Aircraft Velocity
AC0300	Aircraft Control And Stability
AC0400	Aircraft Geometry
AC0500	Aircraft Structures
AC0600	Aircraft Weights
AC0700	Landing Gear System
AC0800	Propulsion System
AC0900	Fuel System
AC1000	Passenger System
AC1100	Baggage And/Or Cargo System
AC1200	Auxiliary Power Requirements
AC1300	Misc Gate Service Requirements
AC1400	Lighting System
AC1500	Radio/Navigation Systems
AC1600	Instrumentation Capability
AC1700	Operating Scenarios
AC1800	Aircraft Departure/Arrival Mix
AC1900	Aircraft Separation
AC2000	Flight Crew Operation Procedures
AC2100	Aircraft Service Procedures; Overall
AC2200	Aircraft Ground Servicing Points
AC2300	Aircraft Classification
AC2400	Human Factor Considerations

Table 2. Major airport elements of aircraft/airport interaction matrix.

AP 100	Air Traffic Control
AP 200	Airport Setting
AP 300	Airport Geom. Design-Airside
AP 400	Airport Config.-Airside
AP 500	Airport Capacity-Airside
AP 600	Apron Geom. Des.-Landside
AP 700	Apron-Gate Configuration
AP 800	Apron Vehicle Circulation
AP 900	Airport Capacity-Landside
AP 1000	Structural Design Of A/P Pavem
AP 1100	Airport Drainage/Snow Removal
AP 1200	A/P Lighting
AP 1300	Term. Area Des.-Pax Handling
AP 1400	Term Area Des.-Baggage/Cargo
AP 1500	Aircraft Fuel Servicing System
AP 1600	General A/C Servicing
AP 1700	Jet Blast And Noise Protection
AP 1800	Airport Emergency Service

characteristics. At the present time all the development work has used this approach, although no problems are anticipated in reversing the procedure to start with changes in airport design characteristics. This is simply a matter of making modifications to the computer program and involves no fundamental issues.

Thus, the process must start with an INPUT from the user which defines the objectives desired when using the methodology. This normally consists of two parts.

1. Conditions imposed by the user

The purpose here is to classify the problem in accordance with a variety of conditions which will then allow the most efficient utilization of the program. To accomplish this, the user is asked to describe the problem in terms of two global kinds of information.

a. Problem type - What are the system properties under consideration in formating the problem? At the present time the procedures are designed to accommodate the following user conditions (or specifications).

(1) Change in one or more aircraft dimensions.
(2) Set of design specifications for a new aircraft or an existing aircraft (or class of aircraft).
(3) A particular operational pattern.
(4) Statements similar to (1) and (2), but relating to airports.

b. Scope - In the interest of efficiency of time and cost, the bounds of the problem should be properly defined. This involves such matters as:

(1) The operational type of aircraft involved, e.g. range, gross weight, use (passenger, cargo, both).
(2) The types of terminals which should be considered, e.g. commercial, general aviation, both, major hubs only, etc.
(3) Special restrictions at terminals, e.g. used with transporter, tug for parking, etc.

2. Results desired by the user

What question or questions does the user wish to have answered? Currently, the procedures anticipate providing information relative to the following three general types of questions:

a. What effect will a given set of aircraft specifications have on one airport (or a set of airports)?

b. What aircraft could use an airport having a particualr set of design characteristics?

c. What is the largest aircraft dimension (or set of dimensions) which can be accommodated at a given airport (or set of airports)?

Once the inputs are defined, the logic of the procedure developed thus far is based on comparing the problem specifications with what is currently happening in the world's air transportation system (or the part of it specified by the user). If the aircraft specifications provided do not exceed bounds already established by the current system, then no problems should be anticipated with the new aircraft. Or, if the current system is operating with exceptions to generally accepted practices, then the position of the new aircraft relative to these exceptions needs to be analyzed. Finally, if the new aircraft specifications do exceed the bounds at one or more specific airports or groups of airports, then a complete table of the discrepancies can be obtained as computer output. The table would list for each aircraft parameter involved those interaction points at each airport where a violation of current guidelines, standards, or regulations does occur.

To make this initial comparison requires three new data banks.

a. Aircraft data - This is a catalog of all geometric and performance data for all current aircraft, aircraft engines, ground service equipment, etc. For the most part this information is available from the manufacturers, but needs to be stored and indexed properly in order to be accessible for the purposes for which it is needed.

b. Airport data - This is a catalog of all geometric and performance of operational data for the airports of the world which should be included in the system. Although some data are available from the FAA and ICAO records, it is not clear that all data which would be valuable for a compatibility analysis can be obtained without a considerable increase of effort in this regard. For example, gate assignments by airline and airline space distributions in the terminals are sometimes difficult to obtain, but would be required if it was desired to limit the analysis to one (or a subgroup) of airlines.

Table 3. Keyword list.

1. Acceleration	29. Engine	57. Narrow	85. Temperature
2. Aisles	30. Exhaust	58. Navigation	86. Terminal
3. Altimeter	31. Floor	59. Noise	87. Thickness
4. Approach	32. Food	60. Obstacle	88. Thrust
5. Area	33. Fuel	61. Operations	89. Time
6. Aspect	34. Fueling	62. Pavement	90. Tire
7. Baggage	35. Fuselage	63. Power	91. Tires
8. Brakes	36. Gear	64. Propeller	92. Touchdown
9. Cabin	37. Ground	65. Radar	93. Tower
10. Capacity	38. Heating	66. Radio	94. Traffic
11. Cargo	39. Height	67. Radius	95. Transceiver
12. Category	40. Horizontal	68. Rollout	96. Transponder
13. Cleaning	41. Hydraulics	69. Rotation	97. Turning
14. Clearance	42. Idle	70. Seats	98. Utilization
15. Cockpit	43. IFR	71. Seating	99. Velocity
16. Container	44. Impact	72. Separation	100. Vertical
17. Control	45. Instrument	73. Servicing	101. View
18. Cooling	46. Landing	74. Size	102. Visual
19. Crew	47. Lateral	75. Span	103. Volume
20. Deceleration	48. Lavatory	76. Speed	104. Wake
21. Deicing	49. Length	77. Stability	105. Water
22. Diameter	50. Light	78. Start	106. Weight
23. Differential	51. Lights	79. Stop	107. Wheel
24. Director	52. Loading	80. Structures	108. Wheels
25. Doors	53. Longitudinal	81. Sweep	109. Wide
26. Electrical	54. Maneuverability	82. Tail	110. Wing
27. Emergency	55. Medium	83. Takeoff	
28. Emissions	56. Mix	84. Taxi	

c. Airline operations data - This would be the equivalent of the Official Airline Guide tapes. These are readily available for a price and cover most areas of the world. Some manipulations of the data might be required to obtain gross activity records and their time distributions for individual airports. In some cases these later data might come from records of regulatory agencies such as the tower activity statistics maintained by FAA.

Illustration of the Methodology

To illustrate the use of the methodology an example has been constructed which has the general objective of examining potential compatibility problems of the Boeing 737-300. This was simply an arbitrary selection based on data available in publications such as Aviation Week and Space Technology, etc. Only selected dimensions and characteristics were used which would be sufficient to illustrate the procedures.

Search routine

Although major parts of this procedure are incorporated in the evaluation methodology as a subroutine, the search routine can be very valuable to the analyst, particularly when used in a very general sense. For the purposes of this illustration, let us select just two components from our B737-300 example and initiate a search based upon the possibility of changing the length and span dimensions of the aircraft.

Step 1 The routine is initiated by calling a "menu" of the various programs available to the user. The initial program selected from the menu is usually a keyword search. The computer presents the user with the keyword list shown in Table 3. The use of the keyword list is necessary in order to assure that all elements in the matrix involved with the item of concern are identified. In the current example the need for the keyword list is trivial, but in general, this is not so.

After being presented with a list, the user is instructed to enter the keyword(s) for which a search of the aircraft element file is desired. In this case two words are entered.

SPAN
LENGTH

Step 2 The aircraft element file is searched by the computer and all element numbers containing the two selected keywords are displayed. In this case they are

AC 0410 - WING SPAN
AC 0420 - OVERALL LENGTH

Step 3 The next program selected from the menu is the aircraft/airport interaction matrix. Each of the element numbers from Step 2 is entered independently and the interaction matrix is searched by the computer and all airport elements interacting with the specified aircraft elements are displayed. For this example the following are obtained.

Parameters Affected By AC0410 Are

AP0324	Runway Length
AP0511	Runway Capacity
AP0521	Acceptance Rate From Runway/TA
AP0522	Taxiway CAP/Crossing Active RN
AP0321	Runway Widths and Slopes
AP0342	Runway/Taxiway Separation
AP0341	Taxiway/Taxiway Separation
AP0630	Apron Overall Dimensions
AP0623	Taxilane To Parked A/C
AP0625	Parked A/C to A/C Separation
AP0730	Terminal Gate Size
AP0351	Holding Bay Dimensions
AP0740	Overall Apron Layout
AP0360	Overpass Structures
AP0830	Service Vehicle Row
AP0840	Transporter Row
AP0770	Terminal/Taxiway Conf.
AP0720	Terminal/Gate Parking Conf.
AP1340	Horizontal Terminal/AC Connect
AP1320	Loading Bridges and Ramps
AP1370	Concourse Design
AP0343	Runway To Runway Distance

Parameters Affected By AC0420 Are

AP0639	Apron Overall Dimensions
AP0623	Taxilane To Parked A/C
AP0625	Parked A/C to A/C Separation
AP0730	Terminal Gate Size
AP0351	Holding Bay Dimensions
AP0740	Overall Apron Layout
AP0830	Service Vehicle Row
AP0840	Transporter Row
AP0770	Terminal/Taxiway Conf.
AP0611	Apron Taxilane Width
AP0622	Taxilane to Building Separation
AP1380	Concourse Width
AP1330	Terminal/AC Connector Location

Step 4 Having obtained all the potential interaction points for each aircraft element, we next wish to determine what information is available concerning these interactions. Returning to the menu, acquisition can be made to any of the informational data banks discussed earlier. Either the entire list of interactions can be used or information on only a selected list can be requested. To illustrate, let us select the bibliography program and request information on the following interactions:

AC0410/AP0321
AC0410/AP0342
AC0420/AP0625.

The computer will search the bibliography files (which are by no means complete, but contain only a few references inserted for the purposes of illustration) and display what it finds. In the version shown below, the references are displayed by a file citation code, but full citations can be made available if desired.

References For AC0410/AP0321
ZPARS-75a
ICAO-14
150/5335-4

References For AC0410/AP0342
ZBOE-79a
BLOC-69
150/5335-1a
150/5335-4

References For AC0420/AP0625
BLOC-69
ZPARS-75a
150/5335-2

Evaluation Routine

This procedure begins with a problem definition phase which has two purposes. First, it provides the analyst with an opportunity to tailor a particular problem to specific and limited requirements on the one hand, or to run a very general problem if this is desired. Second, in the case of the limited problems, the computer time can be reduced significantly. In general the approach is to classify airports, aircraft, and airlines in appropriate ways so that the analysis can be made using all classes, single or multiple classes, or individual units as the case may be.

Four definition sections are currently used. The first, shown in Figure 1 defines the airport set of interest; the second, Figure 2, selects the airline activities of interest at the airport set; the third, shown in Figure 3, selects the general classes of aircraft to be used in comparison with the "subject" aircraft; while the fourth, also in Figure 3, establishes the scope of the interaction analysis desired.

In defining the airport set, the air carrier airports can be subdivided into classes as designated either by ICAO or FAA; general aviation airports are classified according to the four principal types defined by FAA in the National Airport System Plan.

Aircraft can be subdivided according to the following.

Range
>2600 Nmi
$1000 \le R \le 2600$ Nmi
1000 Nmi

Gross Weight
$>350{,}000$ lbs
$60{,}000 \le W \le 350{,}000$
$12{,}500 \le W \le 60{,}000$
$< 12{,}500$

Type of Terminal Involved at Airport
Commercial General Aviation
General Aviation

Basic Use of Aircraft
Passenger
Cargo
Mixed

Is a Transporter Required for Loading and Unloading?
Not Possible
When Desirable
Mandatory

Figure 1. Airport setup program.

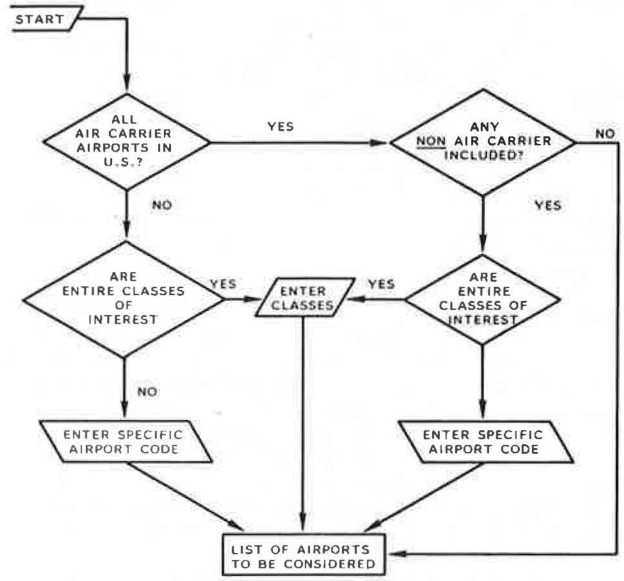
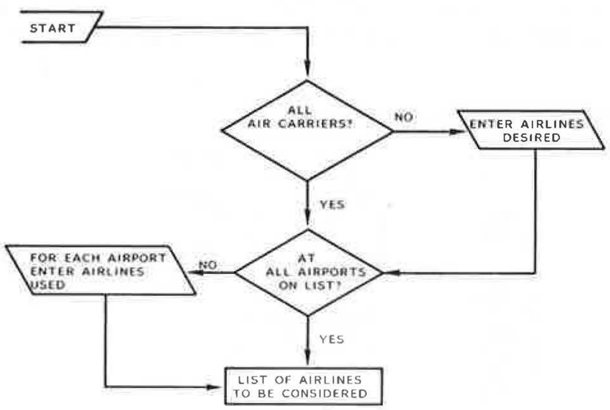


Figure 2. Airline setup program.

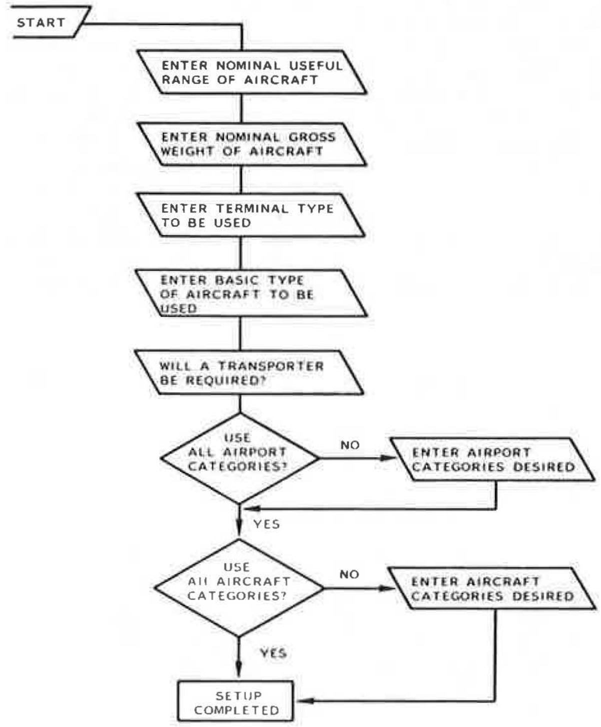


In the pages that follow, a hypothetical problem involving the potential of using a 737-300 at a selected set of airports in the Maryland-Virginia-North Carolina area will be carried through in some detail to illustrate the method. The data, which have been placed in the data banks in order to conduct this exercise, came from books and records which were immediately available to the authors. While it is believed that the aircraft data used represent current values, it was not possible to verify the figures found for the airports. Thus the conclusions reached in the exercise do not necessarily imply that this would be the actual result at the airports involved.

In presenting the problem analysis, the actual interactions between the computer and the analyst are shown. The various actions are identified as follows:

—, a question asked by the computer
[], a response made by the analyst (an input)
--, an output from the computer presenting the result of an operation which it performed.

Figure 3. Aircraft and scope setup.



In general throughout this analyses, the input information will be shown in Figures and the computer outputs will be listed in Tables. In either case, when only a few lines are required, they will be presented in the text.

Figure 4 shows the results of the definition phase for airports and airlines, while Figure 5 presents the same information for the aircraft and the general scope of the analyses. The problem has been defined as examining the potential of the candidate aircraft at six air carrier airports,

ORF - Norfolk, VA
CHO - Charlottesville, VA
RIC - Richmond, VA
ROA - Roanoke, VA
BWI - Baltimore, MD
RDU - Raleigh-Durham, NC

in comparison with the commercial passenger operations of all airlines at those airports using aircraft of range 1000-2600 Nmi, gross weight 60,000-350,000 pounds, and permitting the use of a transporter if needed. Furthermore, a complete interaction analysis is desired.

The main program begins by determining whether the current problem is to be an analysis of a candidate airport or a candidate aircraft. In this case it is an aircraft. It next requests that all the aircraft elements which are to be considered for the candidate aircraft to be entered by number. In this exercise the following list was entered:

0111, 0112, 0120, 0130, 0140, 0150, 0180
0210, 0213, 0216, 0250
0410, 0412, 0415, 0420
0520
0610, 0620, 0650
0720, 0780
0810, 0811, 0820, 0830, 0840, 0870, 0880, 0812, 0816, 0818
1010, 1110, 1170

After this entry is completed the computer then automatically goes to the aircraft/aircraft self interaction matrix and generates a printout of additional aircraft elements which should be included for a thorough analysis. This printout is shown in Table 4. Note that the interaction matrix tells us the highest level (strong, medium or weak) of the interaction with any of the original set of elements.

The next several stages of the program are designed to allow the analyst to edit the list of Table 4. Either additions or deletions can be made and this can be done by either entering element code numbers, classes of code numbers or by use of the keyword list. Since these are routine operations, they are not discussed here in any detail. In the current example the edited list is shown in Table 5.

Having determined the final set of characteristics of the candidate aircraft to be used in the analysis, the program is now ready to begin the main part of the evaluation. The output will consist of the formation of two lists of airports: those, if any, at which no problems can be anticipated for the candidate aircraft, and those, if any, where potential problems cannot be eliminated, together with information on the magnitude of the possible problem. The general routine for the program is shown in Figure 6. A search is made which compares the characteristics of the candidate aircraft with aircraft that are currently operating at the selected airport set, or have operated there in the past. The search involves use of the Official Airline Guide (OAG) schedules and the airport data bank. If the OAG schedules indicate that the candidate aircraft should be acceptable at a given airport because a more restrictive aircraft has already operated there, then the airport bank is examined to see if there were any waivers or constraints on this operation. If so these are noted in the entry for that airport.

The input data for the candidate aircraft is shown in Table 6, where the option for English units has been chosen, and the output data from this procedure as applied to the illustrative example is shown in Table 7. For each airport a list is presented in Table 7 of those elements of the candidate aircraft which have not been exceeded previously by

Figure 4. Airports and airlines definition (sample problem).

START

- Aircraft Airport Compatability Set Up Program
- Identify the Airports of Interest
    - All Air Carrier Airports in U.S. (Y or N)? [N]
    - In an Entire Class of Airports of Interest (Y or N)? [N]
    - Enter 3 Letter Code for Airport (0 to Stop Entry)? [ORF]
    - Enter 3 Letter Code for Airport (0 to Stop Entry)? [CHO]
    - Enter 3 Letter Code for Airport (0 to Stop Entry)? [RIC]
    - Enter 3 Letter Code for Airport (0 to Stop Entry)? [ROA]
    - Enter 3 Letter Code for Airport (0 to Stop Entry)? [BWI]
    - Enter 3 Letter Code for Airport (0 to Stop Entry)? [RDU]
    - Enter 3 Letter Code for Airport (0 to Stop Entry)? [O]
    - Are Any Non Air Carrier Airports to be Included in Analysis? [N]
    - Are Activities of All Air Carriers Desired? [Y]

Table 4. Sample problem: output of aircraft/aircraft interaction matrix.

S	AC0110	Coefficient of Lift	S	AC0770	Landing Gear Footprint
S	AC0113	Aerodyn Effect of Wing Span	S	AC0790	Braking System
S	AC0114	Aeordyn Effect/Horztl Tail Span	S	AC0813	Engine Servicing Rqmnts
M	AC0115	Wing Dihedral	S	AC0814	Engine Noise Production
S	AC0150	Aspect Ratio	S	AC0815	Engine Emissions Levels
S	AC0160	Wing Sweep Back	S	AC0817	Engine Thrust Reversing
S	AC0170	Wing Thickness Ratio	S	AC0818	Engine Overall Width
S	AC0190	Wake Turbulence	S	AC0819	Engine Location from Nose
S	AC0211	Vertical Velocity at Takeoff	S	AC0850	Propeller Diameter
S	AC0212	TCA Maneuvering Velocity	S	AC0860	Propeller Ground Clearance
S	AC0214	Balanced Fld Take/O Dist Requi	S	AC0190	Type of Fuel Req.
S	AC0215	Landing Roll Distance	S	AC0920	A/C Fuel Capacity
S	AC0217	A/C Velocity at Lift-Off	M	AC1011	Number of Galleys
S	AC0218	L/D Ratio at Best Angl Clb Vel	M	AC1012	Number of Lavatories
S	AC0220	Touchdown Velocity	S	AC1013	Special Servicing
M	AC0230	Rollout and Taxi Speed	S	AC1014	Pax Cabin Volume
S	AC0240	Deceleration Rate	S	AC1040	Cabin Floor Height To Ground
S	AC0260	Stall Velocity	M	AC1050	# of Aisles and Crossovers
S	AC0270	Minimum Control Velocity	S	AC1060	Food Servicing
S	AC0280	Acceleration and Stop Velocity	S	AC1070	Potable Water Servicing
S	AC0290	Velocity Over 50' Obstacle	S	AC1080	Lavatory Service
S	AC0310	Longitudinal Stability/Rotation	S	AC1090	Cabin Servicing
S	AC0320	Longitudinal Stability/Landing	M	AC1110	# & Location of Doors-Cargo
S	AC0330	Longitudinal Stability/Takeoff	S	AC1120	Baggage/Cargo Floor Heights
S	AC0340	Dynamic Longitudinal Stability	S	AC1130	Baggage/Cargo Moving System-AC
S	AC0350	Directnl & Lateral Stability	S	AC1140	Baggage/Cargo Container Size
S	AC0360	Min. Control Speed Stability	S	AC1150	Maximum Cargo Weight
S	AC0370	L. Speed/Close Maneuverability	M	AC1160	Interline/Intraline Baggage Fl
S	AC0413	Fuselage Width	M	AC1180	Loose Baggage Reqs.
S	AC0414	Fuselage Length	S	AC1210	A/C Electrical Power Needs
S	AC0430	Overall Height	S	AC1220	A/C Gt[d] Heating & Cooling Rqmts
M	AC0440	Fuselage Height	S	AC1230	A/C Ground Start Reqs.
M	AC0450	Fuselage Overwing	W	AC1320	Hydraulic System
M	AC0460	Fuselage Underwing	S	AC1330	Airframe Deicing Reqs.
S	AC0470	Wing Height Above Ground	S	AC1410	A/C Position Lights
S	AC0480	Horizontal Tailheight To Ground	S	AC1440	Cabin Courtesy Lights
S	AC0490	Wing Sweep Back	S	AC1710	Terminal Control Area
S	AC0510	Wing Structures	S	AC1720	Tower Control Zone
S	AC0660	A/C Empty Weight	S	AC1810	A/C Size Differential
M	AC0710	Wheel Tread Dimensions	S	AC1820	Flight Velocity Differential
M	AC0711	Tire Pressure	S	AC1940	Lateral Separation Dual Rnwy
S	AC0712	Tire Pavement Contact Area	S	AC2010	Landing Phase-Operations Proc.
S	AC0713	Equivalent Single Wheel Load	S	AC2020	Takeoff-Operations Procedure
W	AC0714	Wheel Spacing Per Wheel Group	S	AC2110	Gate Occupancy Time
S	AC0716	Nose Wheel Turn Angle	S	AC2220	Servicing from Vehicles/Loc.
S	AC0715	Min Pavemt Width 180 Turn	S	AC2230	Staging of Servicing
S	AC0730	# of Tires on Main Gear	S	AC2310	Wide Bodies/Heavy
S	AC0740	Tire Configuration	S	AC2320	Narrow Bodies/Medium
W	AC0750	Tire Tread Design	S	AC2330	Light Transport
S	AC0760	Landing Gear Impact Dynamic	S	AC2340	Medium Class

Table 5. Sample problem: edited list of aircraft characteristics to be used in the analysis.

AC0120	Wing Loadings at Takeoff
AC0130	Wing Loading Landing Weight
AC0140	Thrust Loading
AC0150	Aspect Ratio
AC0180	Wing Area
AC0111	Horizontal Tail Area
AC0112	Vertical Tail Area
AC0114	Aerodyn Effect/Horztl Tail Spa
AC0210	Approach Velocity
AC0220	Touchdown Velocity
AC0240	Deceleration Rate
AC0250	Acceleration Rate
AC0260	Stall Velocity
AC0213	Takeoff Run Dist Requiremt
AC0214	Balanced Fld Take/O Dist Requi
AC0215	Landing Roll Distance
AC0216	FAA Landing Distance
AC0410	Wing Span
AC0420	Overall Length
AC0412	Horizontal Tail Span
AC0414	Fuselage Length
AC0415	Aux Wing Tip Devices
AC0510	Wing Structures
AC0520	Fuselage Structures
AC0610	Aircraft Gross Weight
AC0620	Landing Weight
AC0650	Max Fuel Weight
AC0715	Min Pavemt Width 180 Turn
AC0720	Wheel Base Dimensions
AC0760	Landing Gear Impact Dynamic
AC0770	Landing Gear Footprint
AC0780	Minimum Turning Radius
AC0810	Engine Location/Dist to A/C CL
AC0820	Engine Location/Dist Othr A/C
AC0830	Engine Height Abv Ground
AC0840	Engine Air Inlet Location
AC0870	Engine Thrust/Exhaust Velocity
AC0880	Engine Thrust/Exhaust Velocity 10
AC0811	Idle Thrust/Exhaust Velocity
AC0812	Engine Brkawy Thrust Rqmnts
AC0814	Engine Noise Production
AC0817	Engine Thrust Reversing
AC0818	Engine Overall Width
AC0819	Engine Location From Nose
AC0920	A/C Fuel Capacity
AC1010	Seating Capacity/Single Level
AC1040	Cabin Floor Height to Ground
AC1014	Pax Cabin Volume
AC1110	# & Location of Doors-Cargo
AC1170	Maximum Baggage/Cargo Volume
AC1210	A/C Electrical Power Needs
AC1330	Airframe Deicing Reqs.
AC1810	A/C Size Differential
AC1940	Lateral Separation Duel Rnwy
AC2010	Landing Phase-Operations Proc.
AC2020	Takeoff-Operations Procedure
AC2110	Gate Occupancy Time

Figure 5. Sample problem: aircraft and scope definitions.

Classification of Aircraft for Analysis

- Enter the Nominal Useful Range of the Aircraft
  - L - (Range 2600 Nautical Miles)
  - M - (1000 Range 2600)
  - S - (Range 1000)
- Enter Range Category (L,M, or S)? [M]

- Enter the Nominal Gross Weight of the Airport
  - 1 - (Weight 350,000 lbs.)
  - 2 - (60,000 Weight 350,000)
  - 3 - (12,500 Weight 60,000)
  - 4 - (Weight 12,500)
- Enter the Weight Category (1,2,3, or 4)? [2]

- Enter the Terminal Type to be Used
  - C - (Commercial
  - G - (General Aviation)
- Enter Type (C or G)? [C]

- Enter the Basic Use Type of the Aircraft
  - P - (Passenger)
  - C - (Cargo)
  - M - (Mixed)
- Enter the Use Type (P,C, or M)? [P]

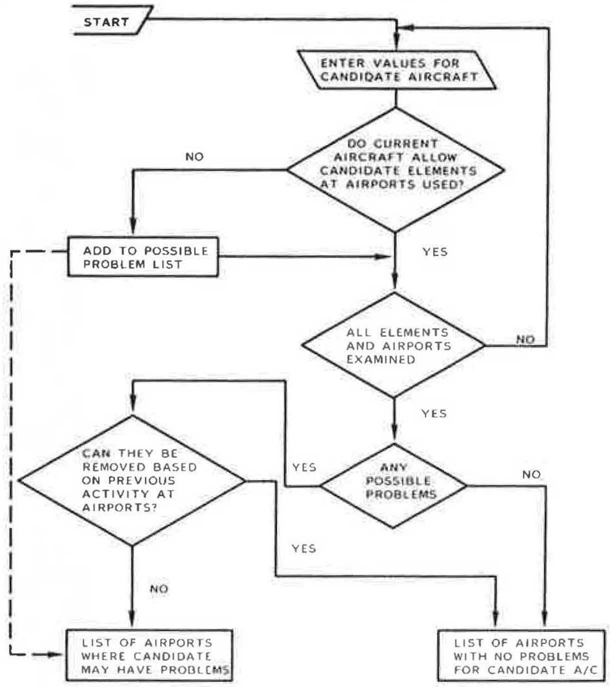
- Will the Aircraft Require Use of a Transporter for Loading and Unloading
  - 1 - (Not Possible)
  - 2 - (When Desired)
  - 3 - (Mandatory)
- Enter Category (1,2, or 3)? [2]

Extent of Interaction Analysis Required

- Is a Complete Interaction Analysis Involving All Airport Characteristics Desired (Y or N)? [Y]

- Is a Complete Interaction Analysis Involving All Aircraft Characteristics Desired (Y or)? [Y]

Figure 6. Airport evaluation program.



operations of any other aircraft. The value column provides the data on that element for the candidate aircraft, while the Δ column gives the differential (in the same units) by which the candidate aircraft exceeds the value of the same element for the most restrictive aircraft which has used that airport. For example, considering Charlottesville, the takeoff run distance requirement for the 737-300 is 7000 feet which is 200 feet more than the requirement for any other aircraft which has previously used Charlottesville.

The program now provides the analyst an opportunity to examine any or all of these potential problem points by comparing them with what actually exists at any or all of the airports in question. This process is illustrated by considering a few specific cases. The first step is to request the aircraft/airport interactions at each of the desired airports. The computer-analyst dialogue is as follows:

- Do You Want AC/AP Interactions For Any Airports Listed (Y or N)?

- Do You Want AC/AP Interactions For All Airports Listed (Y or N)?

- Enter Airport(s) By Three Letter Code (Enter 0 to Stop Entry)
  [CHO, BW1, 0]

The program then displays the results as shown in Table 8 for CHO and Table 9 for BW1. The indication of a Q by an entry means that quantitative data are available for those interactions.

The illustrative example then continues by examining in more detail a few of these interaction points which may be problematic. The first is prompted by the fact that the nominal landing field distance at CHO is 690 feet greater than for other aircraft using CHO. Again, the computer-analyst dialogue goes as follows:

Table 6. Numerical input of elements for candidate aircraft.

- Will the input data be in English units or metric (M - metric, E - English)? [E]
- Input the following data

AC0111	Horzontal Tail Area	Sq.Ft.?	292.5
AC0112	Vertical Tail Area	Sq.Ft.?	270
AC0120	Wing Loading at Takeoff	Lbs./Ft2?	119.9
AC0130	Wing Loading Landing Weight	Lbs./Ft2?	96.3
AC0140	Thrust Loading	Lbs./Lbs.S.Th.?	3.115
AC0150	Aspect Ratio	?	8.7
AC0210	Approach Velocity	MPH?	157
AC0220	Touchdown Velocity	MPH?	135
AC0250	Acceleration Rate	Ft/Sec2?	10.3
AC0213	Takeoff Run Dist Requiremt	Ft.?	7000
AC0216	FAA Landing Distance	Ft.?	5360
AC0410	Wing Span	Ft.?	94.8
AC0412	Horizontal Tail Span	Ft.?	42
AC0414	Fuselage Length	Ft.?	105.6
AC0415	Aux. Wing Tip Devices	Y or N?	Y
AC0420	Overall Length	Ft.?	109.6
AC0430	Overall Height	Ft.?	36.5
AC0520	Fuselage Structures	Ratio?	0.95
AC0610	Aircraft Gross Weight	Lbs.?	124500
AC0620	Landing Weight	Lbs.?	103000
AC0650	Max Fuel Weight	Lbs.?	36450
AC0715	Min Pavemt Width 180 Turn	Ft.?	65.1
AC0720	Wheel Base Dimensions	Ft.?	40.8
AC0780	Minimum Turning Radius	Ft.?	66.8
AC0810	Engine Location/Dist To A/C CL	Ft.?	16.5
AC0820	Engine Location/Dist Othr A/C	Ft.?	6
AC0830	Enginer Height Abv Ground	Ft.?	1.5
AC0840	Engine Air Inlet Location	Ft.?	2.35
AC0870	Engine Thrust/Exhaust Velocity	Ft./Sec?	85
AC0880	Engine Thrust/Exhaust Velocity 10	Ft./Sec?	86
AC0811	Idle Thrust/Exhaust Velocity	Ft./Sec?	45
AC0812	Engine Brkawy Thrust Rqmnts	Ft./Sec?	72
AC0816	Engine T.O. Thrust or H.P.	Lbs.?	40000
AC0818	Engine Overall Width	Ft.?	5.9
AC0819	Engine Location From Nose	Ft.?	34.8
AC0920	A/C Fuel Capacity	U.S. Gal.?	5360
AC1010	Seating Capacity/Single Level	Pax.?	132
AC1014	Pax. Cabin Volume	Ft.3?	5210
AC1170	Maximum Baggage/Cargo Volume	Ft.3?	1000

- Do You Want Specific Interaction Data For Any Airports Listed (Y or N)? [Y]

- Do You Want Specific Interaction Data For All Airports Listed (Y or N)? [N]

- Enter Airport(s) By Three Letter Code (Enter 0 to Stop Entry)
  [CHO
  0]

- Enter Interaction Code (AC0000/AP0000) - Enter 0 to Stop Entry
  [AC0216/AP0324]
  0

- Specific Interaction Information

AC0216	FAA Landing Field Length	5596
AP0324	Max Runway Length	6000
	Delta = - 404	

This indicates there is 404 feet of runway reserve at CHO and so the landing length will not be a problem there. Note that in this case the Landing Field length is corrected for conditions at CHO.

Next, the use of a potential problem area where only qualitative information is available is illustrated.

- Do You Want Specific Interaction Data For Another Airport or Airport Set (Y or N)? [Y]

- Enter Airport(s) By Three Letter Code (Enter 0 to Stop Entry)
  [CHO
  0]

- Enter Interaction Code (AC0000/AP0000) - Enter 0 to Stop Entry
  [AC0120/AP0324
  0]

- Specific Interaction Information
  AC0120 Wing Loadings At Takeoff
  AP0324 Max Runway Length

  AC0120/AP0324 Wing Loadings Will Affect Runway Distance In That As Wing Loadings Increase Holding Other Variables Constant, Runway Length Increases

This calls attention to the takeoff length problem and so this is examined in more detail.

- Do You Want Specific Interaction Data For Another Airport Or Airport Set (Y or N)? [Y]

- Enter Airport(s) By Three Letter Code (Enter 0 To Stop Entry)
  [CHO
  0]

- Enter Interaction Code (AC0000/AP0000) - Enter 0 To Stop Entry
  [AC0213/AP0327
  0]

- Specific Interaction Information

AC0213	Takeoff Dist Requirements	7100
AP0327	Takeoff Field Length	6900
	Delta = + 200	

Here we see that there will be a problem (the runway is short by 200 feet) and, from the data provided, the analyst could compute the reduction in weight required for operation at CHO, or apply some standard average cost allowance for increasing runways by 200 feet. Such standard computation programs could be included in the computer package if desired.

Conclusions

A methodology has been devised which will assure that all aspects of the problem of determining aircraft-airport compatibility are taken into account when considering the design of new aircraft or derivatives of existing vehicles. The methodology is programmed in an interactive mode using Wang Basic.

Dimensions and operating characteristics of the candidate aircraft must be entered and then the following information is automatically provided to the extent requested.

1. Other aircraft dimensions or characteristics which might be affected by changes in the original set.

2. All airport dimensions or characteristics which will be affected by this expanded aircraft set.

3. Other airport quantities which might have to be altered if there are any changes required in those quantities involved in Item 2.

Table 7. Potential incompatibilities of candidate aircraft at airport set.

ORF - Norfolk, VA		Value	Δ
AC0120	Wing Loadings at Takeoff	119.9	+ 4.7
AC0412	Horizontal Tail Span	42	+ 5.2
AC0415	Aux. Wing Tip Devices		
AC0820	Engine Location/Dist Othr A/C	6	- 1.7
AC0830	Engine Height Abv Ground	1.5	- .2
CHO - Charlottesville, VA			
AC0120	Wing Loadings at Takeoff	119.9	+ 4.7
AC0213	Takeoff Run Distance Requiremts	7000	+ 200
AC0216	FAA Landing Distance	5360	+ 690
AC0210	Approach Velocity	157	+ 5
AC0220	Touchdown Velocity	135	+ 3
AC0412	Horizontal Tail Span	42	+ 6
AC0415	Aux. Wing Tip Devices		
AC0820	Engine Location/Dist Othr A/C	6	- 1.7
AC0830	Engine Height Abv Grond	1.5	- .2
AC0840	Engine Air Inlet Location	2.35	- .25
AC1010	Seating Capacity/Single Level	132	+ 1
RIC - Richmond, VA			
AC0120	Wing Loadings At Takeoff	119.9	+ 4.7
AC0412	Horizontal Tail Span	42	+ 5.2
AC0415	Aux. Wing Tip Devices		
AC0820	Engine Location/Dist Othr A/C	6	- 1.7
AC0830	Engine Height Abv Ground	1.5	- .2
AC0840	Engine Air Inlet Location	2.35	- .25
ROA - Roanoke, VA			
AC0120	Wing Loadings at Takeoff	119.9	+ 4.7
AC0216	FAA Landing Distance	5360	+ 560
AC0210	Approach Velocity	157	+ 5
AC0220	Touchdown Velocity	135	+ 3
AC0412	Horizontal Tail Span	42	+ 6
AC0415	Aux. Wing Tip Devices		
AC0820	Engine Location/Dist Othr A/C	6	- 1.7
AC0830	Engine Height Abv Ground	1.5	- .2
AC0840	Engine Air Inlet Location	2.35	- .25
AC101	Seating Capacity/Single Level	132	+ 1
BWI - Baltimore, MD			
AC0126	Wing Loadings at Takeoff	119.9	+ 4.7
AC0415	Aux. Wing Tip Devices		
AC0820	Engine Location/Dist Othr A/C	6	- 1.7
AC0830	Engine Height Abv Ground	1.5	- .2
AC0840	Engine Air Inlet Location	2.35	- .25
RDU - Raleigh/Durham, NC			
AC0120	Wing Loadings at Takeoff	119.9	+ 4.7
AC0412	Horizontal Tail Span	42	+ 5.2
AC0216	FAA Landing Distance	5360	+ 310
AC0415	Aux. Wing Tip Devices		
AC0820	Engine Location/Dist Othr A/C	6	- 1.7
AC0830	Engine Height Abv Ground	1.5	- .2
AC0840	Engine Air Inlet Location	2.35	- .25

Table 8. AC/AP interactions at CHO which are potential problems.

AC0120		**Wing Loadings at Takeoff**	
	AP0324	**Runway Length Requiremts**	
	AP0327	**Takeoff Field Length**	**Q**
AC0216		**FAA Landing Distance**	
	AP0324	**Runway Length Requiremts**	**Q**
AC0210		**Approach Velocity**	
	AP0118	**Aircraft Traffic Flow Control**	
	AP0153	**Glideslope Requirements - Electronic**	
	AP0241	**Part 77 - Approach Surface**	
	AP0511	**Runway Capacity**	**Q**
	AP1213	**Glideslope Requiremts, - Visual**	
AC0220		Touchdown Velocity	
	AP0324	Runway Length Requiremts	Q
	AP0334	High Speed Exit Design	
	AP0335	Runway Exit Locations	Q
	AP0512	Runway Occupancy Time	Q
AC0412		Horizontal Tail Span	
	AP0342	Runway/Taxiway Separation	Q
	AP0341	Taxiway/Taxiway Separation	Q
	AP0511	Apron Taxilane Width	
	AP0521	Apron Taxilane/Taxilane Separation	Q
	AP0623	Taxilane to Parked A/C	
	AP0625	Parked A/C to A/C Separation	
	AP0720	Terminal/Gate Parking Configuration	Q
	AP0730	Terminal Gate Size	Q
	AP0830	Service Vehicle Rights of Way	
	AP0840	Transporter Rights of Way	
	AP1320	Loading Bridges and Ramps	
	AP1340	Horzontl Terminal/AC Connector Locatn	
	AP1370	Concourse Design	
AC0415		Aux. Wing Tip Devices	
	AP0720	Terminal/Gate Parking Configuration	
	AP0830	Service Vehicle Rights of Way	
	AP0840	Transporter Rights of Way	
	AP1320	Loading Bridges and Ramps	
	AP1340	Horizontl Terminal/AC Connector Locatn	
AC0820		Engine Location/Dist Othr A/C	
	AP0830	Service Vehicle Rights of Way	
AC0830		Engine Height Abv Ground	
	AP1223	Runway Lights and Signs	Q
	AP1231	Taxiway Lights and Signs	Q
	AP1350	A/C to Building Connectors	
	AP1610	A/C Service Equip Design	
	AP1710	Airport Blast Deflectors	Q
AC0840		Engine Air Inlet Location	
	AP0370	Surface Debris - Runway/Taxiway	
	AP0650	Surface Debris - Apron Area	
	AP1130	Snow Removal Requiremts	Q
AC1010		Seating Capacity/Single Level	
	AP0931	Pax Flow Rates and Acceptance	Q
	AP0932	Holdroom Capacity	Q
	AP0933	Pax/Visitor Capacity	Q
	AP0934	Concourse Flow Rates	Q
	AP0935	Transporter Capacity	Q
	AP1310	A/C Availability - Deplan/Enplan	Q
	AP1320	Pax Loading Bridges and Ramps	
	AP1330	Multiple Location of Connectors	
	AP1360	Transporter Design	
	AP1311	Transporter Fleet Size	Q
	AP1420	Baggage Flow Rates	Q

Table 9. AC/AP interactions at BWI which are potential problems.

AC0120		**Wing Loadings at Takeoff**	
	AP0324	**Runway Length Requiremts**	**Q**
	AP0327	**Takeoff Field Length**	
AC0415		Aux. Wing Tip Devices	
	AP0720	Terminal/Gate Parking Configuration	
	AP0830	Service Vehicle Rights of Way	
	AP0840	Transporter Rights of Way	
	AP1320	Loading Bridges and Ramps	
	AP1340	Horizontl Terminal/AC Connector Locatn	
AC0820		Engine Location/Dist Othr A/C	
	AP0830	Service Vehicle Rights of Way	
AC0830		Engine Height Abv Ground	
	AP1223	Runway Lights and Signs	Q
	AP1231	Taxiway Lights and Signs	Q
	AP1350	A/C to Building Connectors	
	AP1610	A/C Service Equip Design	
	AP1710	Airport Blast Deflectors	Q
AC0840		Engine Air Inlet Location	
	AP0370	Surface Debris - Runway/Taxiway	
	AP0650	Surface Debris - Apron Area	
	AP1130	Snow Removal Requiremts	Q

4. All available data, constraints, literature, analysis, etc. pertaining to any of the interactions referred to above.

5. A determination of whether or not aircraft having dimensions or characteristics greater than those of the candidate aircraft currently operate or have operated in the past at any particular airport of concern.

6. A list of those airports for which compatibility with the candidate aircraft cannot currently be established, and, for each airport on this list, a notation of the interaction points in question together with all data relating to these points.

Opportunity for editing is provided so that the user may establish the scope of the analysis desired. This can involve either restricting the process to a limited portion of the analyses (e.g. only selected interactions) or operations at a limited set of airports, etc.

The intent of the methodology is to identify and define (quantitatively whenever possible) the potential problem areas. It does not offer solutions, but can be very useful to a designer by providing assistance in arriving at solutions. For example, the designer can enter a range of numbers for each of the key aircraft dimensions under consideration, and by repeated application of the routine can follow the trends in compatibility and the changes in interaction points.

One of the key features of the methodology is that it can be used in real time in the design process. Thus it should make an important addition to automated aircraft design procedures such as IPAD. As the designer begins to determine relationships between configuration and performance from the normal IPAD process, the compatibility of the various configurations with the world's airport system can be ascertained immediately. It is recommended that an objective of making this methodology compatible with IPAD be given high priority in the near future.

The application of the methodology is dependent upon the availability of several rather large and detailed data banks:

1. Design and performance specifications for existing aircraft.

2. Dimensional and operating data for all airports of potential concern -- including any restrictions placed on operations of any specific aircraft at these airports.

3. Schedules of current and past aircraft operations at the various airports.

4. Literature, design equations, regulations, constraints, etc. relating to all aircraft/ airport interactions points.

<u>Reference</u>

1. A detailed presentation of the subcomponents of aircraft/airport mutual interaction matrix and the aircraft/aircraft self interaction matrix, and the actual aircraft/airport matrix can be found in A. R. Kuhlthau and Ira D. Jacobson, "Aircraft/Airport Compatibility Methodology," Final Report, Contract NAS1-14908, Task 10, University of Virginia Report UVA/528184/MAE-CE81/101, August 1981. The aircraft/aircraft matrix is currently available from the authors, and it will be published together with the airport/airport matrix as soon as the latter is completed.