Operational Planning for General Aviation Facilities at Airports

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Airborne Instruments Laboratory (AIL), under contract FAA/BRD-403 has developed guidance material useful in determining when separate secondary runway facilities for general aviation are beneficial and what will be the resulting increase in airport capacity. Tabular and graphic material has been prepared to show the runway layouts that are practical and the resulting increase in airport capacity as the secondary runway is increased in length from a minimum of 2200 ft, to a length equaling the primary runway. The study concludes that decisions regarding the provision of a separate runway for general aviation should be based principally on the economic benefit resulting from reduced delay with separation of types of aircraft as a secondary benefit. Major benefit occurs to the larger and heavier aircraft through reduction of delay to operations. The study also analyzes the need for instrument flight rule (IFR) capability at general aviation airports and demonstrates that a good general aviation airport should have IFR approach capability. Then, based on analysis of airspace studies in various metropolitan areas, the study presents dimensioned criteria for the airspace needed around a major airport that will accommodate the heavier general aviation and air carrier type aircraft and, for an airport that serves only general aviation of the twin-engine or smaller types.

Introduction

THE role of general aviation in flying history is as old as aviation itself. Air-carrier activity, as we know it today, is relatively new. Many of us in the aviation field can still remember the days when the so-called "air carriers" used general aviation fields. As time progressed and air-carrier activity increased at airports near urban areas, these facilities were improved. Some time during this historical span, these "fields" began to be known as "air-carrier airports." Unfortunately, as saturated conditions were reached, the original tenants, light, single-engine aircraft, achieved an "undesirable citizen" status and the complexity of procedures generated by the high level of activity forced many of these operators to find other homes. Unfortunately too, this migration was far from stable, with more and more small airport real estate succumbing to housing development, shopping centers, or other incompatible (aviation-wise) pressures.

In addition, just as the entire complexion of aviation has changed, a great change has taken place within the general aviation family. With million dollar jets and hundred thousand dollar light twins in the commercial branches of the family tree, the complex control procedures and the elaborate electronic navigational and communication requirements no longer present a barrier to general aviation operation into major airports. Aircraft runway requirements and the lack of a suitable alternative may, in fact, make it necessary to operate from the air-carrier airport.

General aviation pilots are not an arbitrary group and would prefer to avoid high-density air-carrier facilities if separate but equally adequate facilities were available. This would apply whether these were separate facilities at a major airport or a completely separate airport. However, the significance of the terms "equal" and "adequate" must be thoroughly understood.

Obviously, the separate airport would not be considered an adequate base to the owner of the high-priced business aircraft if instrument approach and departure criteria were such that he would be "grounded" or unable to land during weather that would have permitted him to operate at the associated air-carrier airport. Another item of great importance is the convenience of travel available to get from the airport to downtown, place of business, etc.

Fortunately, the possibility of providing separate general-aviation facilities has received considerable attention, both from an official standpoint and from private research organizations.

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Separate Runways at Major Airports

In 1961, Airborne Instruments Laboratory (AIL) was awarded a contract by the Federal Aviation Agency to develop criteria to guide the planning and construction of general-aviation facilities in metropolitan areas and at major air-carrier airports. Porter and O'Brien provided civil engineering services. This paper describes AIL's findings.

For almost 5 years before completing this study,[1] AIL had continuously studied airport capacity and delay. These studies contributed significantly to our understanding of the effects of exits, taxiways, runway configurations, and population on airport capacity. The terms "delay," "capacity," and "population" will be explained before presenting the criteria developed.

Delay

When aircraft arrive at, or wish to depart from, an airport in random fashion, it is obvious that situations will occur wherein two or more aircraft will demand a runway simultaneously. It is equally obvious that only one can be accommodated immediately. The other(s) must be delayed. The greater the demand at any instant, the greater the number of aircraft being delayed and the larger the individual delay. Totaling the individual delays and dividing by the number of aircraft involved produces the "average" delay.

Capacity

The term "capacity" has little meaning by itself. It has meaning only when a figure of delay is accepted as being a limit. For the reasons already described, when we refer to capacity, we are referring to a movement rate that will produce an average delay of 1–4 min, depending on the mix of aircraft and the operation.

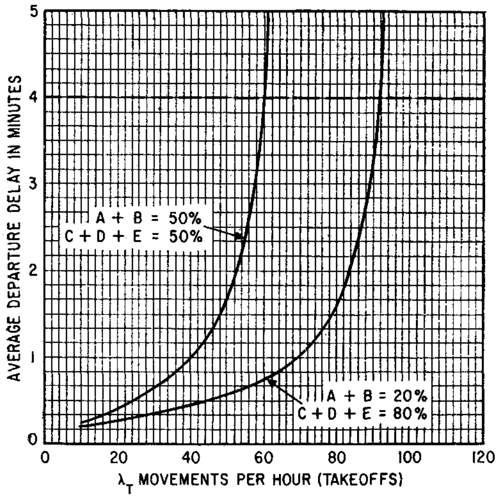

Fig. 1 Effect of population on capacity.

Population

Each aircraft type has its own particular characteristics in such areas as cruising and approach speeds, landing distances and takeoff requirements, engine runup time, etc. Our interests are concerned with such things as the time interval commencing with the time an aircraft is given permission to use a facility and ending with the time that the aircraft is no longer a factor and the facility can be released to a second aircraft or the "over threshold to off runway" time for a landing. Our studies reveal that these characteristics can be conveniently separated into five classes that make up the "population": 1) all jet aircraft normally requiring runway lengths exceeding 6000 ft (corrected to sea level) for takeoff and/or landing; 2) piston and turboprop aircraft having a normal loaded weight in excess of 36,000 lb, and jet aircraft not included in class 1 but having a normal loaded weight in excess of 25,000 lb; 3) piston and turboprop aircraft having a normal loaded weight greater than 8000 lb and less than 36,000 lb, and jet aircraft having a normal loaded weight greater than 8000 lb but less than 25,000 lb; 4) all light twin-engine piston and turboprop aircraft having a normal loaded weight less than 8000 lb and some high-performance single-engine light aircraft (such as the Beech Bonanza); and 5) all single-engine light aircraft other than those included in class 4.

Figure 1 shows how average delay increases as the movement rate increases for the two different populations under visual flight rule (VFR) conditions. It shows the average delay at specific hourly movement rates that a single runway being used for departures only will impose when 5% of the aircraft using the runway are heavy jets, 15% are heavy propeller aircraft, and 80% are medium and light twin- or single-engine aircraft. Figure 1 also shows the situation when the proportion of heavy aircraft increases to the point where the percentage of heavy jets and heavy props represents 50% of the users.

Note that with the smaller percentage of large aircraft, a movement rate of 60/hr would result in an average delay of considerably less than 1 min. This same movement rate with a larger percentage of large aircraft would result in an average delay of 4 min.

Of greater significance, perhaps, are the maximum delays that can be expected with different "average" delays. With a 2-min "average delay," 78% will have some delay, 25% will have 3 min or more, and 1% will have 9 min or more. With an average delay of 4 min 87% will have some delay, 35% will have 4.5 min or more, and 1% will have 18 min or more.

The near-supersonic jet of the air becomes the "horse and buggy" of the runway because its time intervals affecting capacity are all long compared with the intervals of light aircraft. Thus, where mixtures of heavy and light aircraft must use the same runway, the spacing between successive operations and cumulative delays will be frequently at the "horse and buggy" rate.

A moment of reflection will result in a realization that, in a mixed general aviation/air-carrier operation, the general-aviation aircraft are paying a severe penalty for the "privilege" of being part of the mix. This realization will also validate

Table 1 Airport capacity as a function of secondary-runway length

a) 10,000-ft primary-runway length

Ratio of classes 1 and 2 aircraft of total population	VFR capacity (operations/hr) secondary-runway length, ft: None	2200	3500	5000	6000	8000	10,000
0.1	70	95	140	143	...[a]	...[a]	...[a]
0.2	69	79	110	132	...[a]	...[a]	...[a]
0.3	58	65	82	118	...[a]	...[a]	...[a]
0.4	52	58	66	98	111	...[a]	...[a]
0.5	47	49	60	76	109	...[a]	...[a]
0.6	45	48	57	67	103	...[a]	...[a]
0.7	42	...[b]	...[b]	56	93	95	...[a]
0.8	42	...[b]	...[b]	50	90	94	...[a]
0.9	41	...[b]	...[b]	43	74	84	...[a]
1.0	39	...[b]	...[b]	...[b]	68	76	78

b) 6000-ft primary-runway length

Ratio of type 2 aircraft to population of classes 2, 3, 4, and 5 aircraft	VFR capacity (operations/hr) secondary-runway length, ft: None	2200	3500	5000	6000
0.05	86	152	166	...[a]	...[a]
0.1	82	143	160	...[a]	...[a]
0.2	77	109	152	...[a]	...[a]
0.3	74	97	124	143	...[a]
0.4	70	75	93	128	...[a]
0.5	63	67	70	102	124

[a] No further gain in capacity can be realized for this population.
[b] Shorter runway not warranted because of high ratio of larger aircraft.

the thinking that the "mix" should be "unmixed" when and where possible.

In the course of our research, we have developed and field validated mathematical models[2] that can be used to analyze and produce delay/operating rate curves for numerous combinations of aircraft populations and runway layouts. This technique has been used to determine what would be gained by providing a separate runway for general aviation use.

In attacking an overhead airport problem, we first determine the actual percentage of each category of aircraft comprising the airport "population." We know that a second runway is necessary, but for the moment we do not know its character. We start by theoretically "unloading" the runway by removing aircraft, starting with the smallest class-light singles described in class 5. If the number of light singles is significant, the major runway may provide sufficent capacity for the remainder of the demand. The suggestion here, of course, is to build a second runway or landing strip of minimum dimensions for the exclusive use of the light singles.

In a second situation, it may be necessary to unload everything up to and including medium twins (DC-3 and smaller) as described in classes 3, 4, and 5. Under such circumstances, the second runway would have to be designed to accommodate aircraft of the DC-3 category.

In the most severe case, the unloading process could involve the largest categories, the big jets, and heavy props. Where the demand indicates that the aircraft of classes 1 plus 2 would considerably overload the main runway, the only recourse would be to provide a second major runway. Under these conditions, the second parallel should be equal in all respects to the existing facility. Our research has revealed that any difference in factors such as length, etc., notwithstanding that both are technically adequate, will result in pilot preference complicating control procedure.

Table 1a provides a guide to the length of the second runway when the total population involves various percentages of classes 1 and 2 aircraft and the main runway is 10,000 ft. The "none" column represents the capacity of the main runway and pointedly shows the capacity decrease affected by increasing the percentage of large aircraft. This table also shows that a parallel 5000-ft runway will permit achieving maximum capacity up until the time that class 1 plus 2 traffic exceeds 30% of the total. When class 1 plus 2 traffic exceeds this ratio, a 6000-ft runway will be required and will suffice until 1 plus 2 traffic exceeds 70% after which, an 8000-ft runway would suffice except for the pilot preference previously mentioned.

Table 1b shows information that would be applicable to a nonjet airport, or one restricted to the smaller types (Boeing 727). Here too, the large type of aircraft is the major factor in design and the table shows the relationship between secondary runway requirements and the class 2 aircraft in proportion to total population. Figure 2 shows a hypothetical airport with 6000- and 3500-ft runways with 700-ft separation. High-speed turnoffs service the main runway. The taxiways for the secondary runway are designed to permit users of this runway to cross the primary runway at its optimum point, i.e., the approach end. This provision is of the utmost importance because a crossing at this point can be accomplished very shortly after a departure starts rolling or an arrival has crossed the threshold. Reference to Table 1 will reveal this to be an excellent runway layout for an airport with a minimum of large aircraft in its population. Unless the class 2 population exceeded 20%, a secondary runway of longer length would be extravagant. With greater percentages of class 2 aircraft, a 5000- or 6000-ft runway would be required.

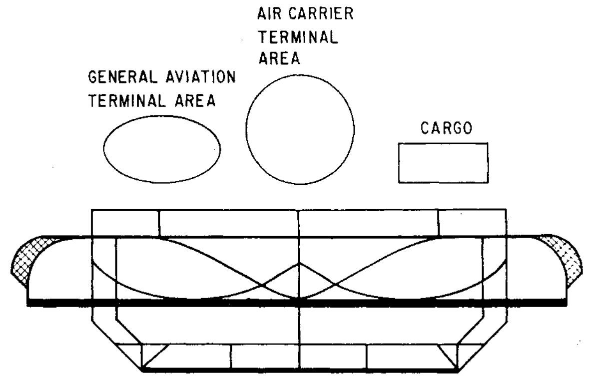

Fig. 2 6000- and 3500-ft runways with 700-ft separation.

Application of Criteria to Lambert Field, St. Louis

In the course of previous demand/delay studies we developed, in conjunction with Porter and O'Brien, the capability to determine desirable additions to existing facilities and to apply cost/benefit techniques to see if the cost of an added facility would be justified in savings to its users, accomplished through lower delays.

At the time we were preparing the report for Ref. 1, we were asked to apply these techniques to the planned expansion of Lambert-St. Louis Airport. This facility was being prepared for the addition of a 4600-ft runway north of, and parallel to, the existing 10,000-ft runway $(\frac{12}{30})$ for the exclusive use of general aviation. Figure 3 shows the master plan for this airport. The black areas are additional taxiways that we recommended to minimize taxi confliction.

To obtain the necessary field information for computing capacity, an observer spent one week in the tower recording actual operations. Subsequently the Federal Aviation Agency provided us with a forecast of the 1970 demand and population.

Application of Table 1a to the forecast population indicated that the best solution for a parallel runway would be 5000 ft with Sunday traffic (which had 33% 1 plus 2 traffic) and 6000 ft for week day traffic (which had 47% 1 plus 2 traffic).

In addition, a more detailed analysis using AIL-developed techniques and historical weather data determined the most efficient combinations of runway use, the capacities of these runway combinations, and the percentage of the year that (weather-wise) each runway combination could be used. We then applied the 1970 demands to each of four airport configurations. The first was Lambert Airport as it then existed. The second, third, and fourth assumed a parallel runway of 3500, 4600, and 6000 ft, respectively. Because operating costs of aircraft can be developed on a "per hour" basis, the economic cost of computed or recorded delay can also be determined. Similarly, the annual cost of a proposed added facility can be calculated.

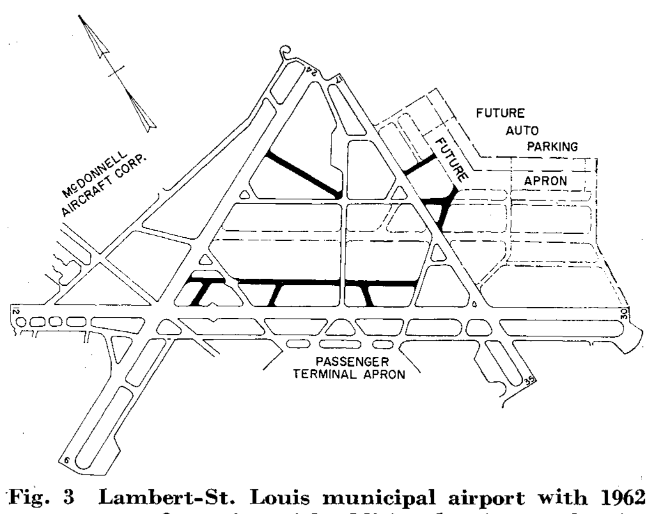

Fig. 3 Lambert-St. Louis municipal airport with 1962 runway configuration with additional taxiways, plan A.

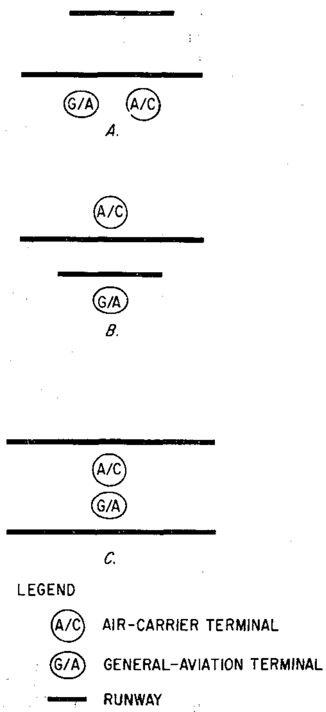

Fig. 4 Parallel runway and terminal locations for general aviation on air-carrier airports.

In view of the fact that the added facility will result in less delay and consequent lowering of aircraft operating cost, it is possible to determine if the annual operating cost of the new facility is justified by reduced aircraft operating costs.

Based on 1970 anticipated demands we found that 1) a 3500-ft parallel runway would cost $85,000 annually to maintain and would reduce aircraft operating costs by $509,000; 2) a 4600-ft runway would cost $135,000 to maintain, but would reduce aircraft operating cost by $1,097,000; and 3) a 6000-ft runway would cost $183,000 to maintain, but would reduce operating costs by $1,294,000.

The reason for the additional benefits provided by the 6000-ft runway is the fact that, by 1970, the larger types of aircraft will overload the main runway. Because they cannot be accommodated on the 4600-ft runway, they will be required to absorb additional delay. Because the larger aircraft produce the higher operating costs, moderate increases in total annual delay will, in turn, result in considerable increases in dollar losses.

Airport Configurations

The ability to "tailor" an airport in a metropolitan area to an ideal concept is seldom practical. The only available locations for aviation activities normally are limited to existing airports whose boundaries are rigidly fixed by man-made barriers in the form of building development. The more centrally located these facilities, the greater the community pressures to eliminate the facility. Therefore, a desire by air-carrier or general aviation for a sophisticated facility must be tempered with the realization that some compromise must be accepted in the distance traveled from the airport to the city.

Figure 4a shows a possible configuration where a general aviation runway has been added to an existing air-carrier airport. One of the problems to be minimized at a highly active multiple runway airport is the elimination of "grade crossings." Both general-aviation and air-carrier terminals are on the same side of the airport. Although not needed for landing or taking off, all general aviation must cross the main runway in moving between the terminal and the general aviation runway. Considerable delay can be absorbed in waiting for a gap in activity on the main runway. Figure 4b shows the general-aviation terminal on the opposite side of the runway configuration permitting almost "two airport" independence of operation. However, movement between the two terminals presents problems. Figure 4c presents an ideal situation and the utmost in flexibility. Aircraft can be assigned indiscriminately to either of the two runways. When demand permits, general aviation aircraft can be assigned to the runway nearest its terminal with air-carrier activity assigned to the other. Communication between the two terminals is most convenient. Finally, if the runways can be sufficiently separated, simultaneous invisible flight rule (IFR) approaches can be considered providing the utmost in IFR capacity. Unfortunately, the real estate required for this configuration is enormous in scope, and would normally be found only far out in the country.

Airspace Criteria

In planning a separate airport for general aviation, the problem of ground interaction between the various users is eliminated. However, of equal importance is the situation in the air where planning must insure a minimum of interference (especially in IFR weather) between adjacent airports, because we believe that major general-aviation airports should have IFR capability. As a part of our work for Federal Aviation Agency, criteria have been developed to indicate airspace needs for adjacent airports.

Airspace surrounding an airport is used to 1) progress from one point to another, 2) approach or depart from a runway, and 3) perform delaying tactics. The first function is provided by air routes, the second by final approach and initial departure courses, and the third by holding areas or path stretching in vector areas. Airspace for the first and third functions is subject to geographical adjustment. Such allocation is normally a compromise of many factors, mainly dependent on navigational practicability and activity at or associated with adjacent airports. Airspace allocation for the second function, however, is dictated by the direction of operation and aircraft performance.

It is important to determine the dimensions of the area immediately surrounding an airport that must not be violated by an aircraft other than that operating into and out of that airport. An airspace reservation with a rectangular plan has been developed to suit the observed operating characteristics of various aircraft. The size of the reservation is related to airport size.

To obtain departure requirements, radar films for a number of days at each of a number of airports (Chicago, J. F. Kennedy, Washington National) were reviewed. VFR days were selected and aircraft were observed whose destinations were in a radically different direction than that of takeoffs. The reasoning was that turns toward destination would be made as soon as practicable. The findings revealed that nonjet traffic rarely exceeded 5 miles.

To obtain approach zone requirements, approach procedures were studied at each of three airports and it was found common practice to vector aircraft to intercept the localizer some 2–4 miles outside of the outer marker. For path-stretching purposes, we considered it adequate to add to both departure and arrival needs allowing 15 miles in the approach area and 10 miles in the departure direction.

Where large aircraft are not involved, we reduced these dimensions to 10 miles in the approach direction and 5 miles in the departure direction, reflecting the much higher maneuverability of the smaller aircraft.

For the major airport, we allowed lateral dimensions of 5 miles on each side of the runway and it's extended center line and for the smaller airport 4 miles on either side. This permits radar monitored operation parallel to the runway centerlines and at the same time permits adjacent airports to be located so that their criteria can abut, but not overlap.

We recommend, for planning purposes, that runway directions at adjacent airports be parallel and that these criteria be applied. Figure 5 shows that these criteria applied to specific airports in the Washington area where the major airports already exist and runway direction is dictated by existing installation. Additional general-aviation airports with IFR capability can be provided without undue interference with the major airports. Where criteria overlap, restriction to one airport's operation on the conflicting side will be necessary, or the conflicting operation coordinated. A central IFR control facility would minimize the seriousness of the latter.

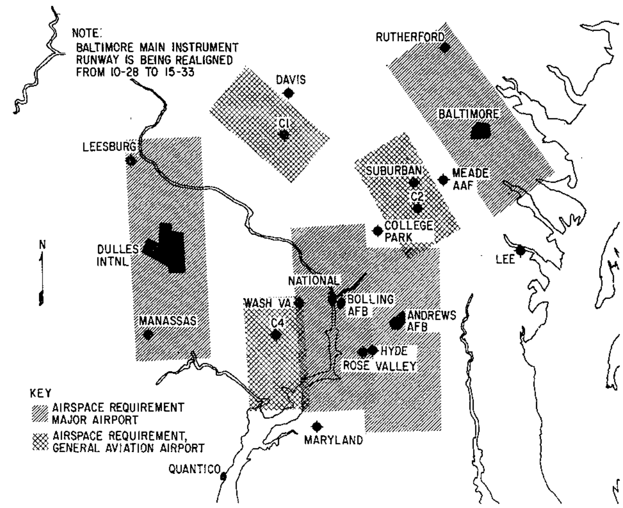

Fig. 5 Airport criteria applied to Washington, D. C. area.

Other Airspace Considerations

Considerable progress is being made in achieving some measure of segregation on the ground. In the air, it is fortunate that some normal segregation is achieved at cruising altitude because of aircraft design. The speed differentials between jets and pressurized multiengine props at cruising altitude are not a problem inasmuch as the two groups normally operate in different strata. In addition, most of these aircraft, either voluntarily or through regulation, adhere to IFR procedures and air-traffic control supervision.

In the unpressurized aircraft area involving the lowest altitude structure, the considerable speed differentials between the small singles and the larger singles and small twins present hazards, even at cruising altitudes. These hazards are compounded in terminal areas where all classes of aircraft violate the lower levels to land or takeoff.

These conditions have been recognized and are adequately described in Project Beacon. So too, are the almost insurmountable problems that must be solved to reduce these hazards. A few areas have received the benefit of official experiment (Atlanta, Washington, and New York). In other areas, controllers have developed local procedures to effect partial segregation.

Segregation as the word implies, means separation. In an area such as New York, the relinquishing of any airspace suitable for the control of IFR traffic can only be accomplished by the sacrifice of some IFR control capability. In view of the fact that IFR overload in itself produces hazards, it is debatable whether such procedure would accomplish its objective.

Radar monitoring of VFR traffic presents problems. Radar control presents additional problems. Radar monitoring or "flight following" and subsequent advisories are simple but requires target identification. Lacking beacon equipment this can be difficult and can require extensive air-to-ground communication. Radar control entails specific ground-originated instruction. Controllers must be constantly on the alert to insure that an instruction will not result in violation of a pilot's equipment or license limitations. In handling VFR flights in borderline weather, caution must be exercised to insure that an issued instruction will not inadvertently place a VFR flight in an IFR condition.

We believe that low-cost IFR facilities such as instrument landing system, air traffic control radar beacon system, and other navigational equipment coupled with simplified IFR flight techniques will encourage greater participation in IFR flying. We also feel that the many areas of experimentation in the field of automating air-traffic control will be fruitful and permit that function to keep pace with the increased demand for its services. Finally, we believe that experiments such as that being conducted in Atlanta should continue and that techniques so developed be applied in whatever geographical areas are compatible.

Conclusions

No one contests the fact that the growth of general aviation will far outstrip the growth of air-carrier activity. We have shown that extensive relief can be provided at major airports by adding appropriate facilities for general-aviation use. There is, however, a limit to which such facilities can be expanded. It is timely to plan for that time when additional airports will be required. It is of the utmost importance that the "system concept" be used in formulating these plans. Airspace needs and convenience to the airport users are some of the system features to consider. The addition of a single airport, because of real estate and air space availability, may dictate a location resulting in an unbalanced situation insofar as convenience is concerned because, to many of the potential users, the facility would be on the "far side of town." For equity, it may be necessary to simultaneously provide a number of general-aviation satellites to the metropolis being served. Such studies should, therefore, revolve around the airports as a system. The planning criteria that have been developed and briefly described herein will serve as guides to get maximum capacity from existing airports, and to properly locate new airports.

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