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Airport Planning and Design

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Robert K. Whitford
Purdue University

59.1 The Air Transportation System

From the end of World War II on, air transportation has been one of the fastest-growing segments of the U.S. economy. However, the terrorist actions on September 11, 2001, have created the potential for changes in the way airports are designed. Unfortunately, the full extent of changes is still unknown and their impact on design unresolved. Airport planning and design has been slowly evolving as the system has grown, and present design practices will remain unaffected. Some of the issues that planners will

have to cope with in the future to effectively react to the type of terrorist activity that occurred are presented in this section.

In 1945 U.S. commercial airlines flew 5.3 billion revenue passenger miles (RPM), growing to 104.1 billion RPM in 1975 and to a phenomenal 704 billion in 2000. U.S. air travel is expected to top 1100 billion RPM in 2011 [FAA, 2001b]. Commercial and commuter air carriers have more than doubled their enplanements over the last 18 years, from 312 million in 1982 to 669 million in the year 2000 — an average annual growth of 4.3% [FAA, 2001c]. This growth is expected to continue — passing the 1 billion mark by 2012 [FAA, 2001b] — at a rate of about 3.6% per year. Aviation continues to be an engine for economic development. Its growth has added both economic activity and congestion in the areas of airports. Chicago's O'Hare airport alone added an estimated \$10.3 billion to Chicago's economy [al Chalibi, 1993]. Aviation in the New York metro area alone was estimated to contribute \$30 billion to that economy in 1989 [Wilbur Smith Associates, 1990]. The contribution of aviation is expected to grow, but with that growth will come more congestion in the air and on the ground.

Civil Engineering and Airport Planning and Design

As the demand for air travel increases, so does the demand for airport capacity. In the last 5 to 10 years, concern about capacity and the delay inherent in a system that operates close to saturation has caused the Federal Aviation Administration (FAA) to embark on a program to carefully examine the top 100 airports in the country and identify the needs for expanded capacity in the next 10 to 20 years [FAA, 1991]. Additional capacity is expected to be provided through a number of changes to the system. The primary focus at many airports is to provide more runways or high-speed exits. In addition, an increased number of reliever airports are planned, with improved instrument approach procedures, changes in limitations or runway spacing, provision for added on-site weather stations, and a more efficient air traffic control system.

Increased traffic and heavier aircraft place a demand on aprons. In addition, many airports face crowded conditions on the landside of their system, which will require terminal expansion or renovation, improved access by ground transportation, or increased parking.

Fundamentally, the airport is a point of connectivity in the transportation system. At the ends of a trip the airport provides for the change of mode from a ground to air mode or vice versa. As such, the airport is often analyzed using the schematic of Fig. 59.1, with the airport's *airside* consisting of approach airspace, landing aids, runways, taxiways, and aprons, all leading to the gate where the passenger (or cargo) passes through; and the airport's *landside* consisting of the areas where the passenger (or cargo) is processed for further movement on land: the arrival and departure concourses, baggage handling, curbsides, and access to parking lots, roads, and various forms of transit.

Most design aspects of the airport must reflect the composite understanding of several interrelated factors. Factors include aircraft performance and size, air traffic management, demand for safe and effective operation, the effects of noise on communities, and obstacles on the airways. All the disciplines of civil engineering are called into use in airport planning and design.

Any planning effort must take place within published goals of the FAA Strategic Plan [FAA, 2001a], which are summarized below:

1. Safety: Reduce fatal aviation accident rates by 80% in 10 years. Related objectives are (1) by 2007, reduce the commercial aviation fatal accident rate by 80%, and (2) limit general aviation accidents to 350 in fiscal year (FY) 2007.
2. Security: Prevent security incidents in the aviation system. Related objectives are to (1) improve explosive device and weapons detection, (2) improve airport security, and (3) reduce airway facility risk. *Note: This particular goal is being expanded, with new projects and implementation criteria since the attacks of September 11, 2001.*
3. System Efficiency: Provide an aerospace transportation system that meets the needs of users and is efficient in applying resources. Related objectives are (1) increase system availability, and (2) reduce rate of air travel delays.

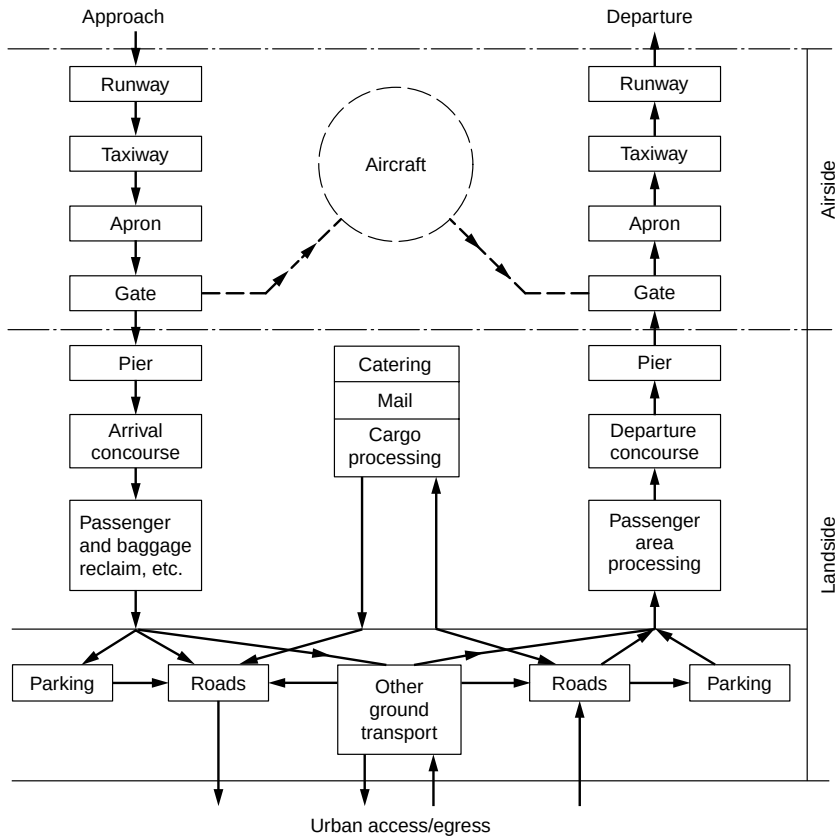


FIGURE 59.1 The airport system. (From Ashford, N., Stanton, H., and Moore, P., *Airport Operations*, Pitman, London, 1991.)

The Airport System: After September 11, 2001

Figure 59.2 shows the top 100 airports in 1999 with a pattern that mirrors the spread of population. As shown in Table 59.1, there are more than 18,000 airports in the U.S. Over 64% are privately owned; most of these are not lighted or paved. Although there are many airports, only those that appear in a given state's aviation plan are likely to involve the level of airport planning suggested here. These are public airports, with commercial operations such as air taxi or charter services, with those near major urban areas often operating as reliever airports as well.

Since September 11, 2001, security issues around all airports (especially the major ones) have been reviewed. The extent to which these issues will affect design is not clear; however, they have clearly affected the flow of vehicles (passenger cars, taxis, buses, etc.) accessing the terminal and the flow of persons and baggage within the terminal itself. Each airport is dealing with implementing the changes generally using the existing facilities. Some of the security issues that airport managers face include:

1. Access paths to the airport have been changed, meaning longer walks from the parking lots. The pickup of passengers will be more difficult. These changes could result in changes in the departure and arrival walks. One airport reported a loss of 12,000 parking spaces. Satisfying the American Disability Act (ADA) requirements may also take some special provisions.
2. Passenger screening is much stricter, meaning longer lines and multiple checks for some persons. The space for security will increase significantly, as we learn exactly what is needed. In addition, the airline is making spot or random security examinations at the boarding gates.



FIGURE 59.2 The top 100 airports in the U.S. (From FAA, 1991–1992 *Aviation System Capacity Plan*, U.S. Department of Transportation Report DOT/FAA/ASC-91-1, 1991.)

TABLE 59.1 Airports in the United States (January 1998)

Number in U.S.	All Enplanements (%)	Active GA Aircraft (%)	Definition
29	67.3	1.3.0	Enplanements >1% of U.S. enplanements
42	22.2	3.8	Enplanements between 1 and 0.25% of U.S. enplanements
70	7.1	4.7	Enplanements between 0.25 and 0.01% of U.S. enplanements
272	3.3	11.4	Enplanements between 0.01 and 0.25% of U.S. enplanements
125	0.1	2.1	
334	0	31.5	Serve to relieve airports with >250,000 enplanements
2472	0	37.3	Enplanements <2500 per year
3344	100	92.1	In <i>National Plan of Integrated Airport Systems</i>
2013		7.9	Low-activity airports (1191 privately owned; available for public use)
12,988			Low-activity strips: closed to public
4626			Limited to vertical takeoff and landing aircraft

Note: GA = general aviation.

Source: FAA, *National Plan of Integrated Airport Systems (NPIAS) 1998–2002*, March 1999.

3. Every checked bag must be screened in the future. A room and an operating procedure for this must be set up. Such checking will require that passengers be present in case the contents of the bag need to be physically inspected.
4. The level of carry-on baggage has been reduced, changing the relationship between checked and carry-on baggage.

5. The requirement of earlier (2 hours) passenger arrival for flight check-in means that there are more people in the airport at any given point. This will result in larger parking space requirements, as well as reexamination of the location of businesses in the lobby of the terminal or on the gate side of security. One result of this has been seen, as the airline clubs have reported a large upsurge in business.
6. The passenger-only rule beyond the security checkpoint. This has changed where people congregate to wait for incoming passengers.

All these factors will result in changes inside the terminal. The airport management is vitally interested in this because each airport's economic well-being results in revenue from parking and concessions. Loss in that revenue may mean larger landing fees or higher concession costs. Thus, the planning factors given in Section 59.6 will change in the future.

Focus on Planning

As part of an entire transportation system, airport planning must be broad, complete, and future oriented, because its design and operational features often exhibit strong interrelationships that reflect the long lead time of large investment decisions. The planning factors are as follows:

1. Demand for use of the airport by the community in both passengers and freight
2. Demand for airline use for hubbing
3. Operating characteristics, size, weight, and mix of potential aircraft using the airport
4. Meteorological and weather conditions at the airport
5. Volume, mix, and markets served by airlines and other aircraft operations
6. Constraints on navigation and navigable airspace
7. Environmental considerations associated with the community's land-use plan

Ownership and Management

Most public airports are owned by the municipal government(s) of the political jurisdiction(s) of the major markets the airport serves. Where multiple jurisdictions are near airport boundaries or have significant use of the airport, an authority or board is set up with representatives from the involved jurisdictions, usually with some joint operating and funding arrangement. For example, the major airports around New York City — LaGuardia, John F. Kennedy International, and Newark International — are managed by the Port Authority of New York and New Jersey. The Port Authority also manages a general aviation airport at Teterboro and two heliports in the area, encompassing about a 25-mile radius from the Statue of Liberty [Port Authority of New York and New Jersey, 1992]. On the other hand, the airports around Chicago (O'Hare, Midway, and Meigs Field) are managed by the Airport Authority of the City of Chicago. Thus, each airport is different and each faces unique operational and management challenges.

It is important for the planner to know how the airport is financed and the role the airlines play in influencing the management of the airport. Airlines are more than customers of the airport, since they often provide some of the financial underpinning. Many of the U.S. large and medium hubs have negotiated long-term agreements with the major airlines under some form of residual cost management [CBO, 1984]. (Residual cost management means that the airlines assume responsibility for paying any residual uncovered expenses the airport incurs in the year.) The airlines wield a considerable amount of power in the management decisions of these airports, because they are responsible for any cost excess and because they are always trying to hold their landing fees down. Other airports also have agreements that are not as long term. They operate with the more usual compensatory cost approach. (Compensatory cost management gives the airport management the responsibility for all airport cost accounts, and the agreements with the airlines are shorter term.) In this situation the local airport authority or board has more latitude to make plans more reflective of the community needs.

Investment Financing

Many airports raise money locally through bond issues. Airports have very good bond ratings. Where municipalities govern the airport, it is sometimes possible to raise additional revenue through local taxes. The federal government provides funding for airside investments through the Airport and Airways Trust Fund (first established in 1954 and reestablished in the Airport and Airways Development Act of 1970). The trust fund is largely funded by the 8% tax on each airline ticket. In 1988 the federal outlays for airports and airways were about \$6 billion, with \$2.9 billion from the trust fund, matched by \$3 billion from general revenue [CBO, 1988]. That money goes for airside improvements. The airports in the National Integrated Air System Plan petition the FAA for funds through the Airport Improvement Program (AIP), which furnishes a percentage of approved airport navigation, landing aids, or runway and taxiway improvements. The federal share ranges from 75% for large and medium hubs to 90% for smaller airports [Ashford and Wright, 1992].

For their share in funding airside improvements and for terminal or landside improvements, funding will usually come from the state and local governments through taxes and revenue bonds [CBO, 1984]. The Airport Safety and Capacity Expansion Act of 1990 allows airports to charge each enplaning passenger a passenger facility charge (PFC). The passenger facility charge provides the opportunity for airports to charge all users a fee not to exceed \$3 for boarding at the airport. The Department of Transportation (DOT) must approve applications for these funds, which are used for airside and terminal improvements, but do not include improvements related to concessions or parking. The PFC was instituted to make it easier for airports to make improvements to airside or landside through direct user charge.

59.2 The Airport Planning Process

There is a hierarchy of planning documents, beginning with the biannually published *National Plan of Integrated Airport Systems (NPIAS)* [FAA, 1991b], which lists those public-use airports where development is considered to be in the national interest and those eligible for funding under the most recent congressional airport act. As suggested in Fig. 59.3, each state maintains a state system plan identifying its public-use airports and indicating the needs for upgrading existing airports and development of new airports. The planning studies are partially funded by the FAA, usually with 90% from federal funds and 10% from state and local funds. The purpose of such planning is for the federal agencies in cooperation with regions and states to achieve an integrated plan facilitating further technical planning, refinements to transportation policy, integration of the various transportation modes, and multijurisdiction coordination.

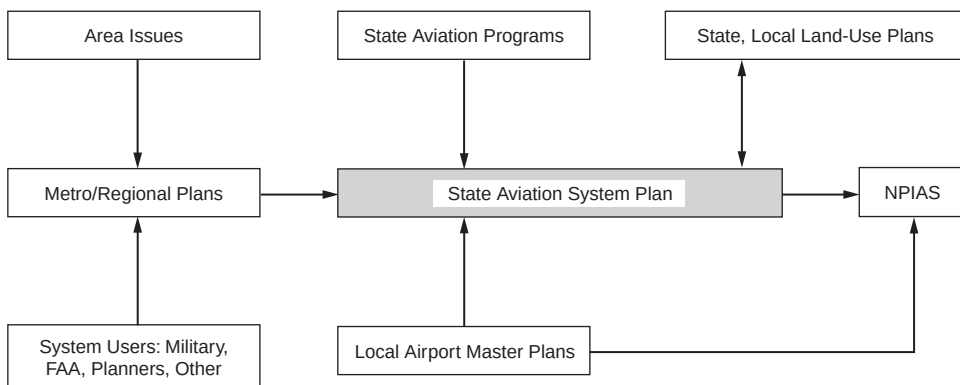


FIGURE 59.3 Planning relationships for a state aviation plan. (From FAA, *The Continuous Airport Planning Process*, Advisory Circular AC150/5050-5, 1975.)

TABLE 59.2 Steps in the Airport Master Planning Process

-
1. Decision → A new master plan is needed (includes discussion of issues for airport)
 2. Developing the study grant application (includes scope)
 3. Consultant hired after agency coordination and approval
 4. Inventory of existing capability, capacity, and resources
 5. Forecast of demand
 6. Requirements analysis and concepts development
 7. Decision → New airport or upgrade present airport?
 8. Site decision and planning
 9. Alternatives analysis
 10. Decision → Select approach desired from alternatives
 11. Detailed planning and preliminary engineering
 12. Financial plan (staged development)
 13. Implementation plan
-

Source: FAA, Airport Master Plans, Advisory Circular AC150/5070-6A, 1985.

The Master Plan

The individual airport master plan is the cornerstone of the continuing, comprehensive, and cooperative planning process [FAA, 1975]. It is a most exacting plan, generally prepared by the airport staff or consultants. It details long-range needs and implementation plans for the airport and is used by the airport's governing board or authority, the state, and the FAA in defining future funding requirements. The master plan reflects the complexity and size of the airport. A small, general aviation (GA) airport with 20,000 operations per year may require only a few pages and a short report indicating the airport's future needs. The state generally provides the forecast for such airports developed on a count of operations and on the number of aircraft based at the airport. (The number of operations at a small, nontowered GA airport is usually not well known. Some states use acoustical counters that are placed at the airport for a few weeks to monitor operations. Others make estimates based on surveys, fixed-based operator (FBO) counts, and other data.)

Large, sophisticated airports usually have ongoing studies involving several consultants and consisting of several volumes. For example, the master plan for Chicago's O'Hare Airport has some 19 volumes, with over 6000 pages. Frequently, the master plan is aimed at solving a specific problem, such as repairing runways, evaluating obstructions, or improving the navigation or terminal landing aids. Physical improvements such as added or extended runways, taxiways, and apron expansion are also identified in the master plan.

The master planning process includes the steps indicated in [Table 59.2](#). Each step involves some coordination with the FAA and the state. Public hearings may be a part of the process.

Airport Issues and Existing Conditions

Plans are not generated in a vacuum, nor are they generated if there are no issues. Almost every airport has some deficiency that the airport board or the community or some other airport stakeholder would like to see addressed. These issues can range from improving the capacity (and hence reducing the delay) to a desired improvement in the baggage-handling system. The study is undertaken by first identifying and gathering the issues obtained by examining prior studies and reports and by having in-depth discussions with the FAA region, the state aviation officials, the airport management, the air traffic controller, the airlines, the FBO, and others involved in the airport use.

Next, data are collected on the airport, the airspace infrastructure, and the nonaviation areas of airport land use. The data consist of an inventory of the existing physical plant, including an assessment of its condition and useful life, and other relevant items, such as land use surrounding the airport, financial data on the airport operation, community social and demographic data (to aid in forecasting), operational data on the airport, meteorological data, environmental data, ground access data, and air traffic management data. To avoid collecting unnecessary data, the particular issues defined in the preplanning will help to focus the efforts.

Plan Management

Ideally, the master plan should be a “living document” reflecting a current assessment of what exists at the airport, what is required to solve problems, and why. Larger airports with their management and staff must do this. Updating the airport plans to reflect current airport modifications and off-airport development is a continuing necessity. Airports receiving federal funds are required to keep their *airport layout plan* (ALP) current. However, the whole master plan needs to be updated, usually in a 10- to 20-year time frame, or in between if substantive changes in the community or in the airport’s function in the air system occur or are planned.

The approval of the master plan by the airport operator (board), the state, and the FAA should be done in a timely manner so that reimbursement for the consultant and FAA payments under federally assisted projects will be approved. The FAA approval of a given plan extends only to ensuring completion of the work elements specified in the grant agreement [FAA, 1985].

59.3 Forecasting Airport Traffic

Planning for an airport and building a credible airport investment program require that future traffic be forecast in a thorough, sensible manner. An overly optimistic forecast may cause premature investment costs and higher-than-needed operating costs; an overly conservative forecast will promote increased congestion with high levels of delay and potentially lost revenues.

In the exercise of its responsibility for investment planning, especially for the Airport and Airway Trust Fund and for future air traffic operations, the FAA has been forecasting overall traffic in the United States for a number of years [FAA, 1993]. The FAA also publishes forecasts of over 3600 airports in the U.S. that are eligible for AIP grants. The FAA forecasts are proven estimates weighing the inputs from many different sources [FAA, 1993]. Some important factors that need to be considered in the planning for a specific airport include the following:

- Unusual demographic factors existing in the community
- Geographic factors that will affect the amount of airplane use
- Changes in disposable income permitting some travelers to travel more
- Nearby airports whose operation may draw from the airport being planned
- Changes in how airlines use the airport (more hubbing, route changes, etc.)
- New local industry, meaning more jobs and more business travel
- New resort and convention industries or capacity that will bring vacation travelers

Forecasting traffic is generally handled differently for the large, medium, and small hubs than for small commercial, basic transport, general aviation airports. [Figure 59.4](#) describes the flow of systems analysis on which much of the planning is based. Unless unusual conditions exist in an area, as is the case with very large urban areas like Chicago, the flow portrayed will determine the demand. The demand can be simply stated as the percentage demand that an airport has related to the national air system total demand. In more complex areas the demand forecast would be enriched by the addition of more detail about local economic conditions, other transportation facilities, the airline operations, and aircraft to be used when demand changes.

Large, Medium, and Small Hubs

For the airports that have more than 0.05% of the national enplanements (255,000 in 1992) the forecasting is generally done by either comparing the airport in the context of the national airspace system using national statistics or using regression equations. Forecasting provides information about two important areas of design concern, namely, the prediction of passengers (enplanements) to aid in planning for terminal facilities and the anticipated number of operations (takeoffs and landings) needed for an

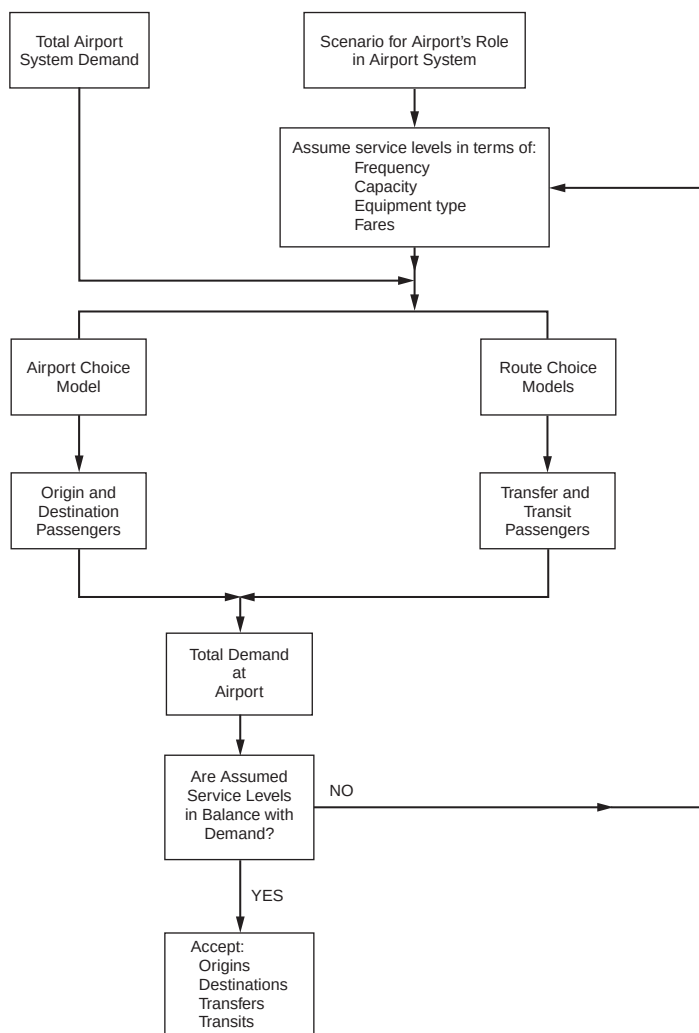


FIGURE 59.4 Flow chart of analysis for airport systems planning. (From FAA, *The Continuous Airport Planning Process*, Advisory Circular AC150/5050-5, 1975.)

appraisal of the adequacy of runways, taxiways, aprons, and air traffic control capability to handle the traffic without significant delay. The link between operations and enplanements is the capacity of the average aircraft (departing seats) coupled with the average passenger load factor, as shown in Eq. (59.1):

$$\text{DEP}_{A/C} = \frac{\text{OPS}_{A/C}}{2} = \frac{\text{ENP}}{\text{SEATS}_{\text{DEPART}} \cdot \text{LF}} \quad (59.1)$$

where $\text{DEP}_{A/C}$ is the commercial aircraft departures, $\text{OPS}_{A/C}$ is the commercial aircraft operations, $\text{SEATS}_{\text{DEPART}}$ is the departing aircraft seats averaged over commercial aircraft departures, LF is the average load factor or number of seats occupied, and ENP is the enplaning passengers.

The analyst must carefully distinguish between passengers served (a number frequently used by many airport managers) and enplanements, a number of particular importance for the airlines and for terminal design. Equations (59.2) and (59.3) convert passenger data into enplanements. Origin–destination (O-D) passengers are those who either live in the local community or come into the local community for business

or pleasure and are usually counted twice — each time they use the airport. Transferring passengers change from one airplane to another without leaving the terminal and are counted once.

$$ENP = .5? PAX_{O-D} + PAX_{TRANSFER} \quad (59.2)$$

$$PAX_{TOTAL} = PAX_{O-D} + PAX_{TRANSFER} \quad (59.3)$$

where PAX_{O-D} is the passengers passing through the airport who live, work, or visit in the airport market area (a passenger is counted once when leaving and once when arriving); $PAX_{TRANSFER}$ is the passengers who do not live or work in the airport market area and who are transferring from one aircraft to another; and PAX_{TOTAL} is the total number of passengers served, often quoted by airports.

One usually adequate method of forecasting is to decide that the airport use in the community (market area of the airport) will grow at the same rate as aviation across the U.S., and then use the present amount of the airport traffic, as it reflects a percentage of that forecast for the U.S. provided by the FAA [1993]. The FAA guarantees their forecast for only 11 years. National enplanement data beyond that date should use unofficial estimates, available from the FAA Office of Policy and Plans.

Table 59.3 shows such a sample forecast for the hypothetical TBA airport (a medium hub). Note that the top part of the table indicates the historical data and their usual sources. If enplanements are not provided, they can be calculated using Eqs. (59.2) and (59.3). In the TBA example, when the enplanements are compared to national enplanements, TBA has a history of being a 0.71% airport in the national airspace system. The planning wisdom is that the airport will stay at that level unless the community served by the airport is forecast to experience an unusual change in employment or economic capacity [FAA, 1985]. Growth or decline significantly different than the national statistics will be the cause for adjusting the simple forecast.

The past history and trends permit computation of several important planning factors, such as percentage of the U.S. airport traffic, level of transfer passengers, departing seats, load factor, freight, and general aviation. These are shown in the heavier shaded portion of Table 59.3. It is assumed that departures will equal arrivals over a year and that the airlines will change the aircraft serving the airport to increase their capacity as the demand increases. The rest of the calculations, such as general aviation operations and freight operations, emanate from the planning factors.

When dramatic changes in employment in the community occur, historical data are used to determine the elasticity of a change in enplanements per change in jobs. From these data appropriate modifications to the spreadsheet of Table 59.3 are made to generate the forecast.

It may be necessary to review the variables used by the FAA for the development of their forecast and to alter the forecast if changes for variables like disposable income, jobs, and population are vastly different from the national assumptions. (There are a number of references pertaining to the forecast methodology. However, the FAA includes in their forecast each year a list of the variables and their assumptions as to their growth.)

A number of consultants use regression equations in a manner similar to the FAA. However, the simple spreadsheet seems to offer as good a forecast. Since it is based on the FAA forecast, it should satisfy the FAA, which must approve the forecast as a part of its approval of the master plan.

Sometimes when a community projects a different economic pattern than is projected for the nation as a whole, the forecast must be developed using other variables. The FAA uses a regression equation with several variables, the most important being yield and disposable income. An example of the equation used in the planning of a small airport in Virginia [Ashford and Wright, 1992] is presented in Eq. (59.4), and an alternate one from the master plan update for Evansville Airport [HNTB, 1988] is shown in Eq. (59.5):

$$\ln \frac{E_i}{P_i} = 10.8 - 0.172F = 1.4 \ln(Y_i) \quad (59.4)$$

TABLE 59.3 Long-Range Forecast for the TBA Airport

Usual Source of Data																
	Calculation	Airlines	Airlines	FAA/Planning	Calculation	Calculation	FAA/ATC	Airlines	Airlines	FAA/ATC	Airports	Calculation	Carrier	Calculation ^b	Calculation	Calculation
Year	O-D PAX	Interline PAX	Enplanements	Millions of National Enplanements	Stature of Airport (%)	Transfer/Enplanement (%)	Commercial Departures	Departing Seats	Load Factor (%)	Total Annual Ops.	Freight (tons)	Freight Annual (%)	Capacity Freighter	Freight Ops.	GA Ops.	GA Ops./Total Annual Ops. (%)
1988	3,924,000	1,225,600	3,187,600	475.5	0.670	38.4	72,345	77.0	57.2	161,709	3,000			226	16,793	10.38
1989	3,904,900	1,356,000	3,308,450	480.4	0.689	41.0	75,678	79.0	55.3	166,275	3,200	6.67	26.50	242	14,677	8.83
1990	4,123,600	1,356,000	3,417,800	497.9	0.686	39.7	76,980	83.0	53.5	170,200	3,400	6.25	26.50	257	15,983	9.39
1991	4,137,000	1,343,000	3,411,500	487.0	0.701	39.4	79,300	84.0	51.2	175,620	3,650	7.35	26.50	275	16,745	9.53
1992	4,368,000	1,382,270	3,566,270	503.6	0.708	38.8	81,456	85.0	51.5	181,222	3,900	0.85	26.50	294	18,016	9.94
Projections					0.71	39			52			7.0				9.5
1993	4,491,247	1,435,727	3,681,350	518.5	0.71	39	81,844	86.5	52	179,577	4,173	7.0	27.0	309	15,580	9.5
1994	4,734,649	1,513,535	3,880,860	546.6	0.71	39	84,809	88	52	186,087	4,465	7.0	27.5	325	16,145	9.5
1995	4,971,988	1,589,406	4,075,400	574.0	0.71	39	87,081	90	52	191,082	4,778	7.0	28.0	341	16,578	9.5
2000	6,072,062	1,941,069	4,977,100	701.0	0.71	39	100,751	95	52	221,134	6,701	7.0	30.0	447	19,185	9.5
2005	7,224,108	2,309,346	5,921,400	834.0	0.71	39	111,640	102	52	245,135	9,398	7.0	32.0	587	21,267	9.5
2010	8,416,865	2,690,637	6,899,070	971.7	0.71	39	121,720	109	52	267,415	13,182	7.0	34.0	775	23,200	9.5
2015	9,294,326	2,971,137	7,618,300	1073.0	0.71	39	126,298	116	52	277,717	18,488	7.0	36.0	1027	24,094	9.5
2020	10,260,139	3,279,881	8,409,950	1184.5	0.71	39	130,427	124	52	287,130	25,930	7.0	38.0	1365	24,911	9.5

Note: Ops. = operations.

^a This is the freight that is not carried in the belly of scheduled passenger aircraft.

^b The average freight carried by freighters had been assumed at 26.5 tons (a small freighter can carry about 40 tons).

where E_i = the predicted enplanements
 P_i = the population of the market area of the airport
 F = the average U.S. fare per mile or average yield per mile
 Y = the per capita income of the market area.

$$\text{ENP} = 2.2961 ? \text{EMP}^{1.126} ? \text{YIELD}^{-0.7306} ? \text{ACP}^{0.3317} \quad (59.5)$$

where ENP = the total passengers enplaned
 EMP = the regional employment
 YIELD = the air carrier yield
 ACP = the proportion of total possible passengers served by air carrier service (this factor depends on the number of passengers from the market area that use other airports).

The coefficients of the equations are determined from regression analysis, and the average fare or yield is available from the FAA [1993].

For the larger airports it is important to forecast the peak hour operations. Since there usually is little concern about capacity and delay until an airport with a single runway reaches approximately 35 operations an hour, the problem surfaces only in medium and large hubs. Figure 59.5, clearly labeled for planning purposes only, gives an indication of how peak hour operations are related to enplanements. For example, in the year 1975 the TBA airport might have as many as 45 operations in the peak hour; in 2020 that would be expected to grow to 55 to 60, in spite of a much larger growth in passengers. It is worth noting that the two variables, enplanements and operations, are linked by load factor and seats. So a doubling of enplanements may result in only a 30 to 40% increase in flight operations, since airlines will tend to operate larger planes rather than fly more operations.

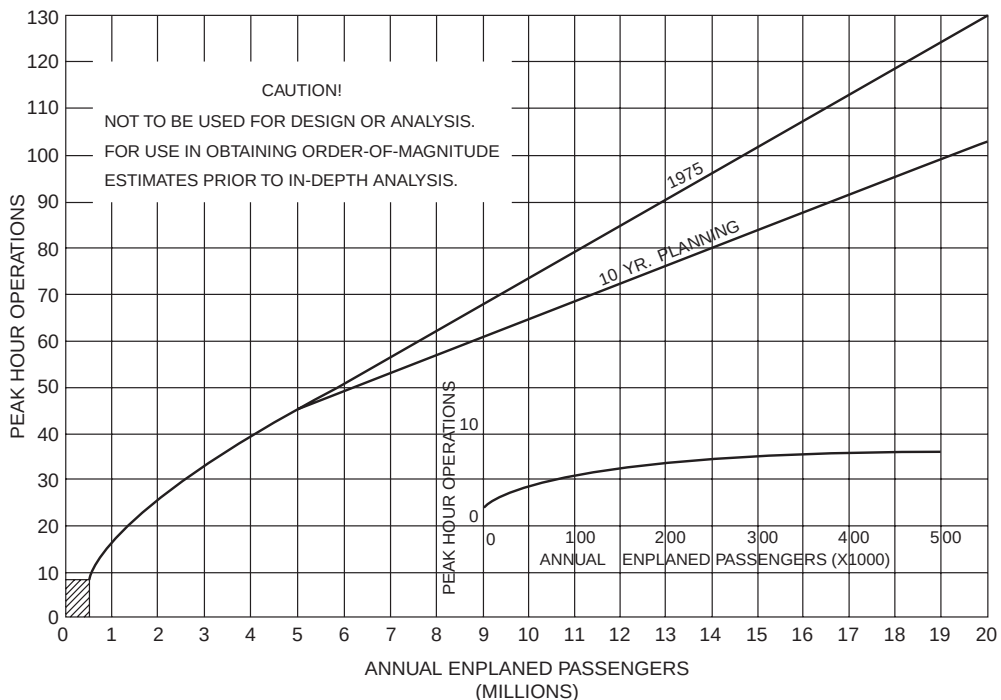


FIGURE 59.5 Estimated peak hour operations versus annual enplaned passengers. (From FAA, *Planning and Design Guidelines for Airport Terminal Facilities*, Advisory Circular AC150/5360-13, 1988b.)

Small Commercial and General Aviation Airports

At the smaller airports, traffic is predominately general aviation traffic, which includes business flying. There may be a few commercial, air charter and air taxi, and even a few military operations. Each public-use airport in the state will have a history of the number of annual operations as a function of the based aircraft plus the number of annual operations expected from air carriers (usually commuter), air charter, air taxi, and military aviation.

Another important facet in the planning process for small airports is whether or not the airport is to be equipped for instrument approaches. Upgrades of navigation equipment or improved weather observation capability will generally increase the airport's percent time for landing, thus improving the airport's accessibility in inclement weather. Many commercial companies that use aircraft depend on airports that are not closed down every time there is low visibility or inclement weather.

To forecast future airport use, it is essential that a history of operation be developed. For towered airports these data are available. However, for nontowered airports a count of traffic must be garnered by other means, such as acoustical counters on the runways. Critical aspects involved in forecasting for the smaller airports, listed in no particular order, include the following:

- The number of aircraft based at the airport, including mix or type
- The location of the airport and the weather data
- The instrument approach procedures and minimum altitudes
- Nearby airports and their relative appeal, including capability for landing
- Airport services and facilities, particularly the fixed-base operator and T-hangars
- Touch-and-go operations, usually local operations
- Availability of mechanics and maintenance parts
- Level of air taxi, charter, and air carrier (usually commuter) operations
- Markets served and aircraft use

Once the existing GA operations have been determined, usually in the range of 300 to 500 annual operations per based aircraft, discussions with the airport manager, local businesspersons, and state aviation officials should be undertaken to provide added perspective on the rate of growth of based aircraft and of corporate and business operations. Local forecasts should be checked with the FAA forecast of air taxi and air charter growth. The FAA publishes forecasts for all airports in the *National Plan of Integrated Airport Systems*. A sample of the planning data presented on such airports is given in [Table 59.4](#).

Sometimes it is necessary to develop a forecast that depends on the interaction of a number of GA airports. The Indianapolis metropolitan airport system is one such system. The area consists of 8 counties involving 16 airports: 1 air carrier airport, 7 relievers or potential relievers, 5 utility GA airports, and 3 basic GA airports. The objective of the plan is to look at the future of these airports, to decide the capabilities (e.g., runway length and width, instrumentation and lightning) each airport should have, and to decide if any new airports should be built in the area. A comprehensive inventory of each of the airports was made. A number of alternatives were addressed, including the possibility of developing new airports and closing others down. Here it is useful to indicate several questions that were analyzed:

- *How many based aircraft could be expected in the future?* Using a variety of national data and trends, and projections of jobs and businesses in the Indianapolis area (including a new major airline maintenance facility at the airport), the number of single-engine, multiengine, and turbine aircraft was projected. In spite of the general sluggishness of general aviation in the past 10 years, there has been a higher growth than in the nation in this region of the country.
- *Where would the people who are pilots or own airplanes settle?* After examining a series of potential independent variables, a regression equation involving population, households with incomes in excess of \$50,000, and number of airports within a 12-mile radius of the township (specific subarea in each county) was used to allocate the owners of aircraft to the region.

TABLE 59.4 Sample of Terminal Area Forecast Data Kept by FAA

REGION-STATE: ANN-WY CITY: CODY					LOCID: COD NONTOWERED AIRPORT: E. E. FAUST REGIONAL					BASED AIRCRAFT: 61				
AIRCRAFT OPERATIONS														
Year Actual	Enplanements (000)				Itinerant					Local			Total Ops.	Inst. Ops.
	Air Carrier	Air Taxi	Commercial	Total	Air Carrier	Air Taxi and Commercial	GA	Military	Total	GA	Military	Total		
Actual														
1982	1	0	3	5	2	1	15	0	18	15	0	15	33	
1983	2	0	7	9	1	1	15	0	17	15	0	15	32	
1984		1	8	9		2	15	0	17	15	0	15	32	
1985	0	0	5	5		10	15	0	25	15	0	15	40	
1986			9	10		3	15	0	18	15	0	15	33	
Forecast														
1988		0	10	11		3	16	0	19	16		16	35	
1989		0	11	11		4	16	0	20	16		16	35	
1990		1	11	12		4	16	0	20	16		16	36	
1991		1	12	12		4	16	0	20	16		16	36	
1992		1	12	13		4	16	0	21	16		16	37	
1993		1	13	13		4	16	0	21	16		16	38	
1994		1	13	14		5	17	0	22	17		17	38	
1995		1	14	14		5	17	0	22	17		17	39	
1996		1	14	15		5	17	0	22	17		17	39	
1997		1	15	15		5	17	0	23	17		17	40	
1998		1	15	16		6	17	0	23	17		17	40	
1999		1	16	16		6	17	0	23	17		17	41	
2000		1	16	17		6	17		24	18		18	41	

Note: Ops. = operations.

Source: FAA, *Terminal Area Forecasts FY 1988–2000*, FAA-APO-88-3, 1988.

TABLE 59.5 Summary of 2012 Aviation Forecasts for the 1993 Indianapolis Airport System Plan

Airport	Based Aircraft					
	Total	Single	Multi	Turbine	Other	Other
Boone County	72	63	9	0	0	0
Eagle Creek Airpark	153	109	28	14	2	0
Franklin Flying Field	52	47	2	0	0	3
Greenwood Municipal	135	111	15	7	2	0
Hendricks County — new airport	93	67	15	9	2	0
Indianapolis International	88	0	10	71	7	0
Indianapolis Metropolitan	160	120	28	8	3	1
Indianapolis Mount Comfort	158	120	23	12	3	0
Indianapolis Speedway	0	0	0	0	0	0
Indianapolis Terry	82	57	4	6	0	15
McDaniel	15	12	0	0	0	3
Pope Field	26	20	1	0	0	5
Shelbyville Municipal	72	61	3	7	1	0
Sheridan	25	21	2	0	0	2
Westfield	34	33	0	0	0	1
Indianapolis Downtown Heliport	14	0	0	0	14	0
Sum of above airports	1179	841	140	134	34	30
All aircraft owned by residents (including businesses) of MSA	1294	946	142	134	42	30

Note: MSA = metropolitan airport system.

Source: Indiana DOT, *Indianapolis Metropolitan Airport System Plan Update*, prepared by TAMS and al Chalibi, M., for Indiana Department of Transportation and the Indianapolis Airport Authority, 1993.

- *Where would these persons locate their aircraft?* The study examined the way present airports attract aircraft owners, considering several important attributes of a “good” airport (e.g., hangar capacity, fueling capability, mechanics, instrumented landing capability, and cost of housing) and the convenience factor for the owner, primarily driving time from home to the airport. The transportation planning “intervening opportunity” model was used to allocate the aircraft as based aircraft to airports.
- *How many local operations, itinerant operations, and instrument approaches will there be?* The national average of local vs. itinerant operation is expected to grow from 46 to 52% in the next 20 years. Instrument weather history and the landing capability of the airport were used to predict instrument landings.

Table 59.5 presents a summary of the findings, including a proposed airport in Hendricks County, Indiana.

59.4 Requirements Analysis: Capacity and Delay

Armed with the demand forecasts and having developed an inventory of the airport and reviewed its condition, the planning proceeds to determine the capability of the airport to accommodate the forecast demand. First is the determination of the capacity of the airport relative to the demand, with special attention to the delay that will be incurred at peak times.

Capacity is used to denote the processing capability of a facility to serve its users over some period of time. For a facility to reach its maximum capacity there must be a continuous demand for service. At most facilities such a demand would result in large delays for the user and eventually become intolerable. To develop a facility where there was virtually no delay would require facilities that could not be economically justified. When a single runway serves arriving aircraft, the mean delay is given by Eq. (59.6) [Horonjeff and McKelvey, 1994]:

$$W_a = \frac{\lambda_a [\sigma_a^2 + (1/\mu_a^2)]}{2[1 - (\lambda_a/\mu_a)]} \quad (59.6)$$

where W_a = the mean delay to arriving aircraft
 λ_a = the mean arrival rate, aircraft per unit time
 μ_a = the mean service rate, or reciprocal of the mean service time
 σ_a = the standard deviation of mean service time of arriving aircraft

For departing aircraft, Eq. (59.6) is used by replacing the subscript a with d . When aircraft share the same runway for landing and takeoff, arriving aircraft always have priority, so the delay for arriving aircraft is the same as Eq. (59.6). The delay for departing aircraft is found by solving Eq. (59.7):

$$W_d = \frac{\lambda_d (\sigma_j^2 + j^2)}{2(1 - \lambda_d j)} + \frac{g(\sigma_f^2 + f^2)}{2(1 - \lambda_d f)} \quad (59.7)$$

where W_d = the mean delay to departing aircraft
 λ_a = the mean arrival rate, aircraft per unit time
 λ_d = the mean departure rate, aircraft per unit time
 j = the mean interval of time between two successive departures
 σ_j = the standard deviation of the mean interval of time between two successive departures
 g = the mean rate at which gaps between successive aircraft occur
 f = the mean interval of time in which no departure can be released
 σ_f = the standard deviation of mean interval of time in which no departure can be released

During busy times the second term should approach zero if it is assumed that the aircraft are in a queue at the end of the runway [Horonjeff and McKelvey, 1994]. The following general rules for aircraft landing on a runway are important in the determination of capacity and delay:

- Two aircraft may not occupy the same runway at the same time.
- Arriving aircraft always have priority over departing aircraft.
- A departure may be released while the arriving aircraft is on approach, providing it is 2 or more nautical miles from the threshold of the runway at the time of release.
- Spacing for successive landings incorporates wake vortex requirements for mixed aircraft landings, as shown in Table 59.6.

In addition to separation on landing, the capacity is also a function of the configuration of runways, runway exit geometric design, landing speed, and braking ability. Air traffic control measures for noise abatement, heavy wind conditions, arriving and departing flight paths, and navigational aids that add complexity to the determination of capacity. Most significant is the safe spacing between successive aircraft.

TABLE 59.6 Spacing Required for Safe Landing in IFR with Wake Vortex

		Lead Aircraft			Type	Weight
		Heavy	Medium	Light		
Trailing Aircraft	Heavy	4 nmi	3 nmi	3 nmi	D	≥300,000 lb
	Medium	5 nmi	4 nmi	3 nmi	C	>12,500 lb to <300,000 lb
	Light	6 nmi	5 nmi	3 nmi	A and B	≤12,500 lb

Note: nmi = nautical miles; IFR = instrument flight rule. To convert for VFR (visual flight rule), replace 3, 4, 5, and 6 n. mi. with 1.9, 2.7, 3.6, and 4.5 n. mi., respectively.

Source: FAA, *Parameters of Future ATC Systems Related to Airport Capacity and Delay*, Report FAA-EM-78-8A, 1978.

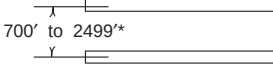
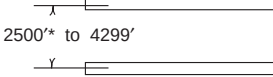
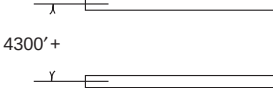
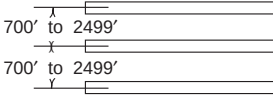
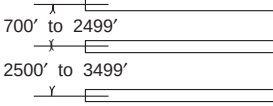
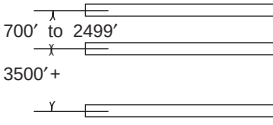
No.	Runway-use Configuration	Mix Index % (C+3D)	Hourly Capacity Ops/Hr		Annual Service Volume Ops/Yr
			VFR	IFR	
1.		0 to 20	98	59	230,000
		21 to 50	74	57	195,000
		51 to 80	63	56	205,000
		81 to 120	55	53	210,000
		121 to 180	51	50	240,000
2.		0 to 20	197	59	355,000
		21 to 50	145	57	275,000
		51 to 80	121	56	260,000
		81 to 120	105	59	285,000
		121 to 180	94	60	340,000
3.		0 to 20	197	62	355,000
		21 to 50	149	63	285,000
		51 to 80	126	65	275,000
		81 to 120	111	70	300,000
		121 to 180	103	75	365,000
4.		0 to 20	197	119	370,000
		21 to 50	149	113	320,000
		51 to 80	126	111	305,000
		81 to 120	111	105	315,000
		121 to 180	103	99	370,000
5.		0 to 20	295	62	385,000
		21 to 50	213	63	305,000
		51 to 80	171	65	285,000
		81 to 120	149	70	310,000
		121 to 180	129	75	375,000
6.		0 to 20	295	62	385,000
		21 to 50	219	63	310,000
		51 to 80	184	65	290,000
		81 to 120	161	70	315,000
		121 to 180	146	75	385,000
7.		0 to 20	295	119	625,000
		21 to 50	219	114	475,000
		51 to 80	184	111	455,000
		81 to 120	161	117	510,000
		121 to 180	146	120	645,000
8.		0 to 20	394	119	715,000
		21 to 50	290	114	550,000
		51 to 80	242	111	515,000
		81 to 120	210	117	565,000
		121 to 180	189	120	675,000

FIGURE 59.6 Runway configurations capacity and ASV for long-range planning. (From FAA, *Airport Capacity and Delay*, Advisory Circular AC150/5060-5, incorporates change 1, 1983a.)

To aid planning, capacity and delay may be estimated using the annual service volume (ASV) for the airport, in combination with the annual demand. From the outset it is assumed that any airport configuration can be approximated by one of the eight depicted configurations of runways given in [Fig. 59.6](#),

TABLE 59.7 Chart for Calculating ASV for the Peak Month

Mix Index %(C + 3D)	Arrivals (%)	Touch and Go (%)	Demand Ratios	
			Annual Demand/ Average Daily Demand	Average Daily Demand/ Average Peak Hour Demand
0–20	50	0–50	290	9
21–50	50	0–40	300	10
51–80	50	0–20	310	11
81–120	50	0	320	12
121–180	50	0	350	14

Source: FAA, *Airport Capacity and Delay*, Advisory Circular AC150/5060-5, incorporates change 1, 1983a.

TABLE 59.8 Aircraft Mix for Peak Hour Operation at TBA Airport

Aircraft Class	Typical Aircraft	Peak Hour Operations 1992		Peak Hour Operations 2020	
		VFR	IFR	VFR	IFR
A	Cessna, Piper, etc.	4[11% T&G ^a] (10%) ^b	0	6 [15% T&G ^a] (9%)	0
B	Lear Jet, Shorts	8 (22%)	4 (14%)	18 (27%)	10 (18%)
C	DC-9, B-727, MD-80	22 (61%)	22 (79%)	35 (51%)	35 (65%)
D	DC-10, B-747, B-757	2 (6%)	2 (7%)	9 (13%)	9 (17%)

^a T&G (touch and go) is a training operation where aircraft come in for landing and, once they touch down, increase power and take off again without stopping.

^b Numbers in parentheses are the percent of the total operations.

with the note that crosswind runways do not significantly increase the ASV. The other assumptions for computing ASV are:

- Percent arrivals equal percent departures
- Full-length parallel taxiway with ample entrances and no taxiway crossing problems
- No airspace limitations that would adversely impact flight operations
- At least one runway equipped with an instrument landing system (ILS) and the air traffic control (ATC) facilities to operate in a radar environment
- Operations occur within the ranges given in [Table 59.7](#)
- IFR (instrument flight rule) weather conditions occur 10% of the time
- Roughly 80% of the time the runway configuration that produces the greatest hourly capacity is used

Example 59.1

Assume the TBA airport has two parallel runways separated by 1000 feet. The forecast from [Table 59.3](#) indicates the requirement for 287,130 operations in the year 2020. The present demand is 183,000 operations. The aircraft mix during peak hours is derived from the anticipated peak hour aircraft traffic at TBA shown in [Table 59.8](#).

$$MI = (\%C) + 3 ? (\%D) \quad (59.8)$$

The calculated mix index (MI) presently is $MI_{VFR} = 61 + 3(5) = 76$ and $MI_{IFR} = 79 + 2(7) = 93$, where VFR is the *visual flight rule* and IFR is the *instrument flight rule*. In 2020 it will grow to $MI_{VFR} = 90$ and $MI_{IFR} = 116$.

It is now appropriate to develop a delay specification. Let us assume that no more delay will be allowed in 2020 than the airport is now experiencing. The present mix index is 70 in VFR and 94 in IFR. Using

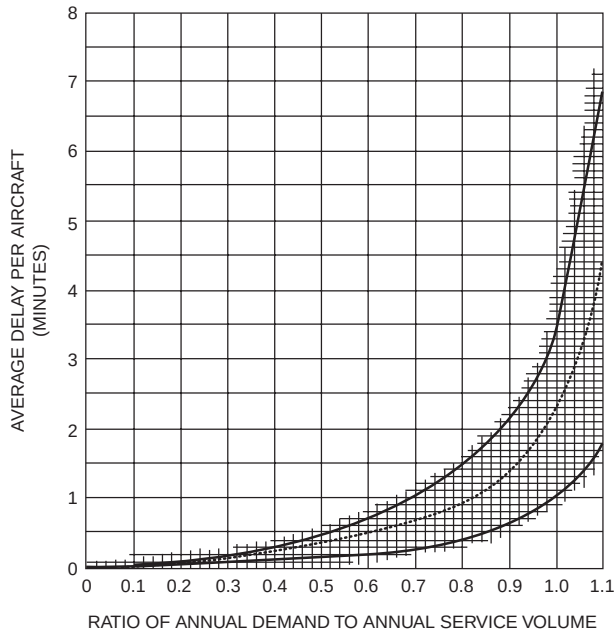


FIGURE 59.7 Average aircraft delay for long-range planning. (From FAA, *Airport Capacity and Delay*, Advisory Circular AC150/5060-5, incorporates change 2, 1983a.)

the VFR mix index, the ASV from Fig. 59.6 is 260,000, and for the number of annual operations from Table 59.3 of 181,222, the delay factor is indicated in Eq. (59.9):

$$DF = \frac{OPS}{ASV} = \frac{181,222}{260,000} = 0.7 \quad (59.9)$$

where DF is the delay factor and ASV is the annual service volume read from Fig. 59.4.

The average delay is read from Fig. 59.7 as between 0.6 and 1 min. This is reasonable, but more than what is good for the average delay over the day. Certainly during peak periods the actual delay may be five to ten times this average delay, and overall this airport is approaching a delay problem, although it is not yet major. A significant delay average of between 1.4 and 2.3 min would accrue if one of the two runways had to be shut down for any period. An *average* delay of 2 to 4 min can become quite significant during the peak period.

To maintain an average delay in the range of 0.6 to 1 min in the year 2020, an ASV of $287,130/0.7 = 410,185$ is required. For the mix index of 90, runway configuration 7 on Fig. 59.6 would satisfy the ASV. It would involve the addition of one parallel runway separated more than 3500 feet from the existing runways. The hourly capacity for VFR would be 161 operations/hour and for IFR 117. This is well above the estimated operations of 68 and 54, respectively. The average delay in 2020 would be about 0.5 min.

Many simulation runs have been performed by the FAA to obtain better design data than the simplified annual service volume approach gives. Those simulation results are summarized in design curves like the one shown in Fig. 59.8, which is for TBA runway configuration needed in 2020. For the mix index of 90 the runway set will yield $C^* = 155$ with 50% arrivals, $T = 1$ with 15% touch and go and a mix index of 90, and $E = 0.89$ with one exit at 6000 feet from the threshold. This yields an hourly capacity of 138. While much below the 161 from the advanced planning charts, it is still far above the 68 aircraft expected during the peak hour in 2020. Similar curves are presented to calculate delay for arrivals and departures. For our example the delay during peak hours is 1.2 min for departing aircraft and 0.6 min for arriving aircraft. These are the peak delays, so when averaged over the day, the delay will be less than 0.5 min.

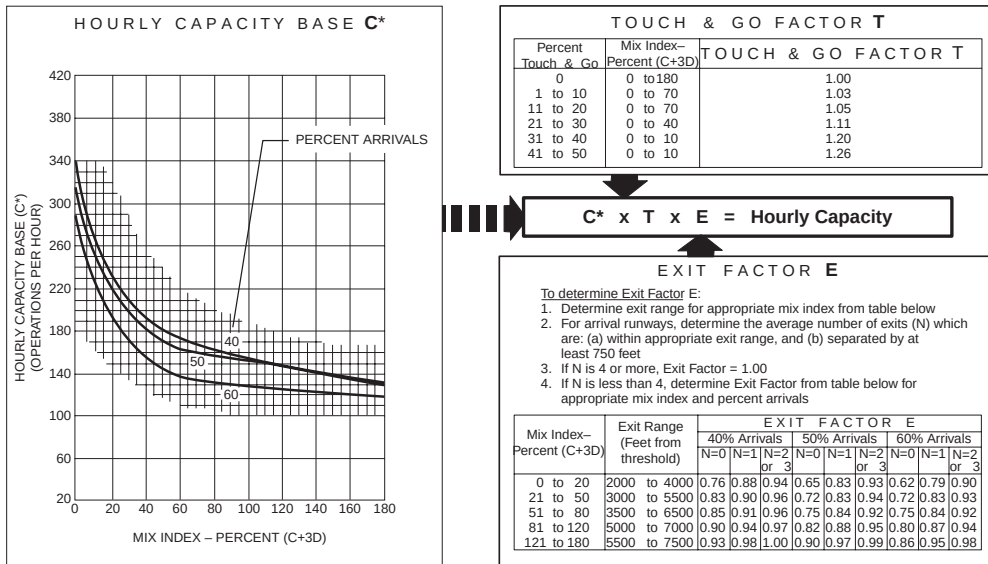


FIGURE 59.8 Example of peak hour capacity determination charts for TBA airport in VFR. (From FAA, *Airport Capacity and Delay*, Advisory Circular AC150/5060-5, incorporates change 1, 1983a.)

This in-depth analysis approach of capacity and delay utilizes the charts as shown in Fig. 59.8 and can be found in FAA Advisory Circular AC150/5060-5, *Airport Capacity and Delay* [1983a]. In addition, National Technical Information Services (NTIS) has available capacity computer programs in FORTRAN. Personal computer programs are available to calculate capacity, delay, and ASV values that are more than adequate for planning [FAA, 1983].

59.5 Air Traffic Management

The second key aspect in the requirements analysis is to assess the capability of the airport to provide the traffic controls during poor weather flying conditions (IFR) as well as during good weather conditions (VFR). Except in airspace under positive control, VFR flying is based on a “pilot beware” or “see and be seen” approach to flying. General aviation pilots flying in VFR need only a functioning radio and altimeter. Commercial aircraft and many business aircraft are equipped with beacons, radar, and other equipment that permits them to fly in instrument weather and in controlled airspace. Capability for landing on a given runway and the use of navigation aids varies from airport to airport. Instrument approach procedures (IAPs) for each airport appear in *U.S. Terminal Procedures*, published bimonthly by the U.S. Government Flight Information Publications, U.S. Department of Commerce with the FAA and the U.S. Department of Defense. Every pilot with IFR capability carries a set of these procedures for reference.

Airways, Airspace, and Air Traffic Control

“In discharging its responsibility for managing the air traffic control system and in assuring flight safety, the FAA performs a number of functions which have a direct bearing on the development of the master plan” [FAA, 1985]. Of particular interest are the following:

1. Establishment of air traffic control procedures for a particular volume of terminal airspace
2. Determination of what constitutes an obstruction to air navigation.
3. Provision of electronic and visual approach and landing aids related to the landing, ground control, and takeoff at the airport

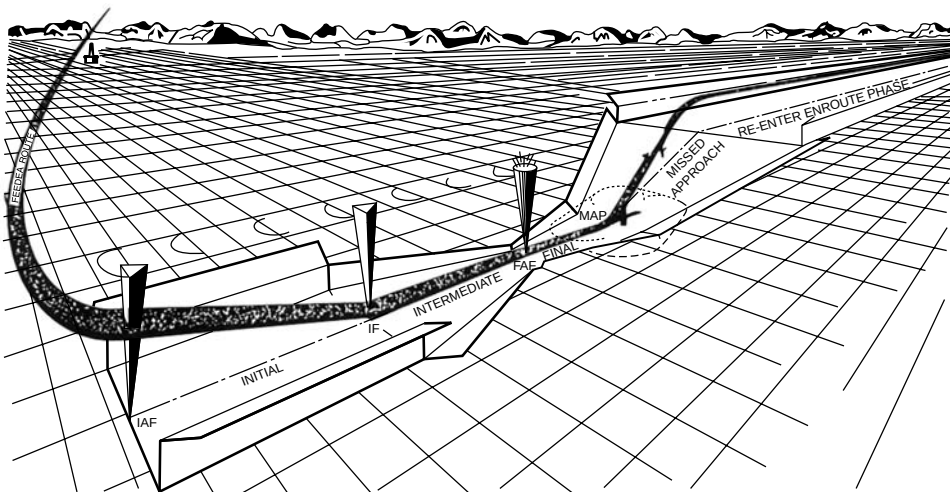


FIGURE 59.9 Markers and segmented approach for instrument landing. (From FAA, *United States Standard for Terminal Procedure* (TERPS), 3rd ed., FAA Handbook 8260.3B, 1976.)

In Fig. 59.9, the typical pattern of flight for landing, the approach commences at the initial approach fix (IAF). The initial approach can be made along an arc, radial course, heading, or radar vector, or by a combination of them. The course to be flown in the intermediate segment from intermediate fix (IF) to final approach fix (FAF) and during the final approach segment (FAF or outer marker to touchdown) are shown in the figure. The intermediate fix point is usually 5 to 9 miles from the threshold of the runway.

The initial and intermediate segments align the approach with the runway of intended landing and provide for initial aircraft stabilization and descent. In general, these two segments begin with signals from an en route navigation aid or the radio signal intersection of two aids. They are about 8 nautical miles wide, permitting the pilot to descend to within 1000 ft of any obstacle. The final approach segment is much narrower: 1 to 4 nautical miles, depending on the accuracy of the navigation aid being used. The missed approach segment transitions the pilot back to begin the approach again with 1000 ft of obstacle clearance.

The class of aircraft and amount of traffic play a significant role in determining the requirements for controlled airspace around the airport. All aircraft are categorized into one of five different approach speed categories (usually based on a landing speed of 1.3 times the aircraft's certificated stalling speed, with the maximum certificated landing weight) called *aircraft approach categories*. These are listed in Table 59.9. The airspace with its safety or buffer zones is configured with these landing speeds in mind.

TABLE 59.9 Aircraft Categories and Landing Speeds

Aircraft Category	1.3 × Stall Speed (knots)	Maximum Speed (Circling Approaches) (knots)	Typical Aircraft in This Category
A	<91	90	Small single engine
B	91–120	120	Small multiengine
C	121–140	140	Airline jet
D	141–165	165	Large jet/military jet
E ^a	>166		Special military

^a Category E is restricted to high-performance, special mission military aircraft and will not be addressed in this chapter.

Source: Modified from FAA, *United States Standards for Terminal Instrument Procedures* (TERPS), 3rd ed., FAA Handbook 8260.3B, 1976.

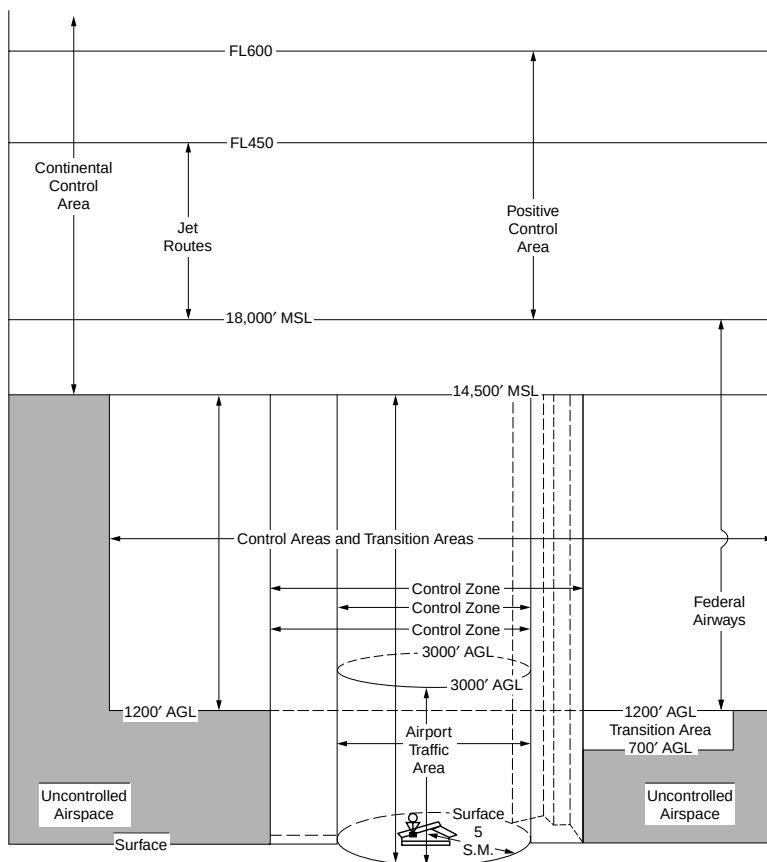


FIGURE 59.10 Controlled airspace. (From FAA, *Airport Master Plans*, Advisory Circular AC150/5070-6A, 1985.)

The volume of sky called “controlled airspace” in Fig. 59.10 gives the appearance of an upside-down wedding cake with the size dependent on the amount and nature of the traffic in the controlled zone. To maximize safety and efficiency, each aircraft within the terminal area controlled airspace volume will be under positive control by the air traffic controller when the weather is below minima. The aviation community has become used to calling these areas by their abbreviations, e.g., terminal control area (TCA) or airport radar service area (ARSA). Figure 59.11 presents the major categories of airspace control as they were reclassified in 1993.

Instrument Approaches

Instrument approach procedures developed by the FAA for use by pilots flying under instrument flight rules provide navigational guidance to an airport when weather conditions preclude navigation and landing under visual flight conditions. If a pilot is unable to sight the airport visually while at the minimum en route altitude (MEA) permitted for VFR flight when traveling along an airway, the pilot must fly the instrument approach procedure developed specifically for the destination airport in order to land. Minimum en route altitude is defined as the lowest usable altitude on an airway with acceptable navigational signals and that meets obstacle clearance requirements. MEAs therefore vary for each airway at every airport, depending on navigation transmitter placement and local terrain elevation. Whenever the ceiling at an airport is below the MEA, pilots are required to conduct an instrument approach in order to complete their flight. There are three basic types of instrument approaches: circling, straight-in nonprecision, and straight-in precision, as briefly defined in Table 59.10.

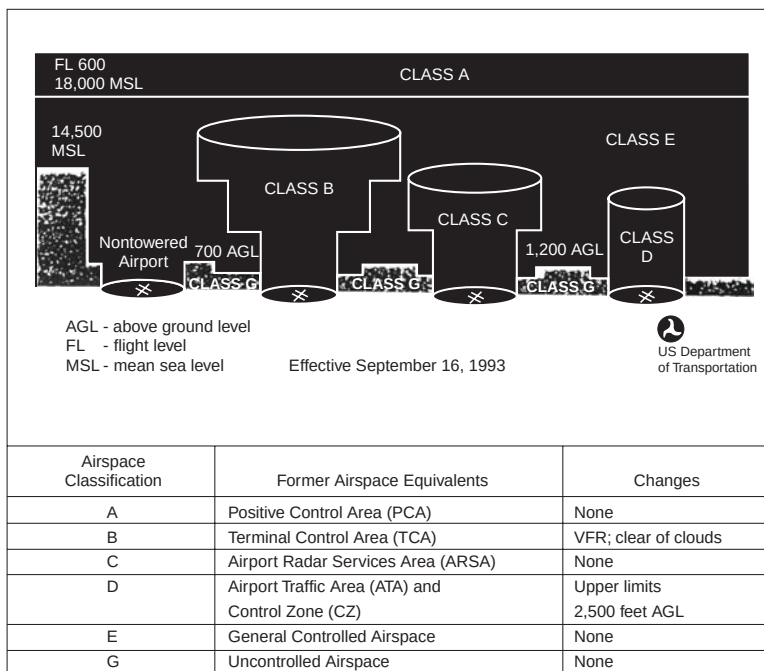


FIGURE 59.11 Airspace reclassification. (From FAA, Classification of Airspace, Brochure, 1993d.)

A nonprecision approach typically uses an existing en route navigation aid (NAVAID), such as a VHF omnidirectional range (VOR) for guidance, and provides a path from that NAVAID to the airport. Precision approach procedures utilize the specially designed category I instrument landing system or the newer microwave landing system (MLS). Both of these systems are specifically designed to provide highly accurate lateral and vertical guidance, as shown in Fig. 59.12, to minima of 200 feet height above touchdown (HAT) and ½-mile visibility. Two special ILS systems, category II and category III, will provide minima of 100-feet HAT with ¼-mile visibility and “all weather” landing minima, respectively. These two systems are very expensive and are usually installed only at the busiest commercial airports.

Circling approaches have been developed using both nonprecision and precision navigation aids, although nonprecision aids are most often used. Because a circling procedure does not align the aircraft with a specific runway but instead simply provides a path to the airport whereby the pilot decides which runway to land on and then circles to that runway, it is also sometimes considered a visual approach.

A new navigation standard based on the use of the Global Positioning System (GPS), which became operational in 1992, should be available for aviation landing aid by 2000. With the proper receiver onboard the aircraft, GPS signals will be able to be used to provide nonprecision approaches into any airport at little or no cost, other than the purchase of a low-cost satellite receiver. Precision approaches have been demonstrated with GPS. The potential for GPS signal dropout during the critical landing phase is one of the limiting concerns.

Minimum Altitude Calculations

It is the final approach segment that is of most interest to the airport planner. In general terms, the lower a pilot is permitted to descend during the final approach, the greater the likelihood that a successful landing can be made. The more precise the navigation aid being used, the easier it is to “thread” a pilot around obstructions, and to authorize a lower final approach altitude.

The basic obstacle clearance distance and visibility requirements for a nonprecision straight-in instrument approach are 250 ft of obstacle clearance and 1 statute mile visibility. Therefore, if an airport located at 750 ft mean sea level (MSL) has a 100-ft obstacle located along the final approach course, the instrument

TABLE 59.10 Definition of Instrument Approach Procedures

Circling Approaches: If the navigational aid being utilized for the instrument approach does not line up within 30 degrees of any runway heading, the pilot must navigate to the general vicinity of the airport, and then circle to line up with the runway. This type of approach, known as a circling approach, is the least preferable of the three, due to the fact that the pilot is not provided with any navigational assistance to line up with the runway of landing. A circling approach is basically akin to a nonprecision approach. Upon reaching the vicinity of the airport, the pilot must align the aircraft with the runway of intended landing. This approach may require extensive maneuvering just prior to landing, including an initial turn *away* from the airport. This approach is potentially more dangerous to execute and some aircraft operators either discourage or absolutely prohibit its use, particularly at night when ground references are less available. Instrument approaches may be specifically designed as circling approaches if navigation aids are unavailable for a straight-in approach. But most straight-in approaches can also be utilized as circling approaches to other runways located at the same airport. Circling approaches usually have higher minima than the straight-in approaches described below.

Straight-In Nonprecision: Straight-in approaches are those that align the aircraft within 30 degrees of the landing runway. Nonprecision approaches provide lateral guidance only. During a nonprecision approach, the pilot navigates along a prescribed course until reaching a navigational fix known as the final approach fix. At this point the pilot initiates a descent to the lowest safe altitude, known as the minimum descent altitude (MDA). The pilot flies along this course either until reaching a predetermined point or until a calculated period of time has elapsed. This point is known as the missed approach point (MAP). If the runway has not been sighted by the pilot before reaching the MAP, the pilot follows a procedure known as the missed approach that guides and climbs the aircraft back to a point where the approach can be initiated again, or the pilot can extend the flight to another airport where a landing is possible.

Vertical guidance is not provided to the pilot during a nonprecision approach; therefore, the lowest altitude to which a pilot may descend and the required in-flight visibility are fairly high. Usually, 300 to 900 feet is the lowest height above touchdown (HAT) to which the pilot may descend, and the required visibility is 1 to 2 miles. This type of approach is considered sufficiently accurate and safe for an airport that does not service a high level of commercial or essential air traffic.

Straight-In Precision: A precision approach is similar to a nonprecision approach; the only difference is that the precision approach provides the pilot with electronic vertical guidance in addition to lateral guidance. A glide path is transmitted from the ground and guides the aircraft on about a 3-degree descent path to the runway. The pilot simply follows the navigational directions during the descent. Since a glide path is provided, the pilot need not level off at any minimum altitude. Precision approach procedures instead define a specific altitude at which the pilot must decide whether a landing can safely be conducted. This altitude is known as the decision height (DH). If the pilot has the runway, runway lights, or approach lights in sight prior to or upon reaching the decision height, the descent to the runway can be continued and the pilot may land the aircraft. If the runway or its associated lighting is not in sight, the pilot immediately begins to execute the missed approach instructions. Precision approaches utilize either instrument landing systems or microwave landing systems.

Source: Modified from FAA, *United States Standard for Terminal Instrument Procedures (TERPS)*, 3rd ed., FAA Handbook 8260.3B, 1976.

approach will mandate a minimum descent altitude (MDA) of 1100 ft (750-ft airport elevation + 100-ft actual obstacle height + 250-ft terminal instrument procedures (TERPS)-mandated obstacle clearance height). The only methods that can be employed to reduce the 1100-ft MDA in this example are to utilize a more precise navigation aid (to navigate the pilot around the obstacle), develop an approach to a different runway with obstacles of lower height, or remove the obstruction (which may be impractical). The 250-ft basic obstacle clearance altitude may change, depending on the type of navigation aid used at the airport, as indicated in [Table 59.11](#).

Minimum Visibility

The visibility required during instrument approaches is a function of the aircraft's approach speed and the type of lighting associated with the landing runway. The standard visibility required for a nonprecision approach is 1 statute mile. The visibility value is designed so that when the pilot sights the runway, a safe and controlled descent can be made to it. Higher minimum descent altitudes typically require higher

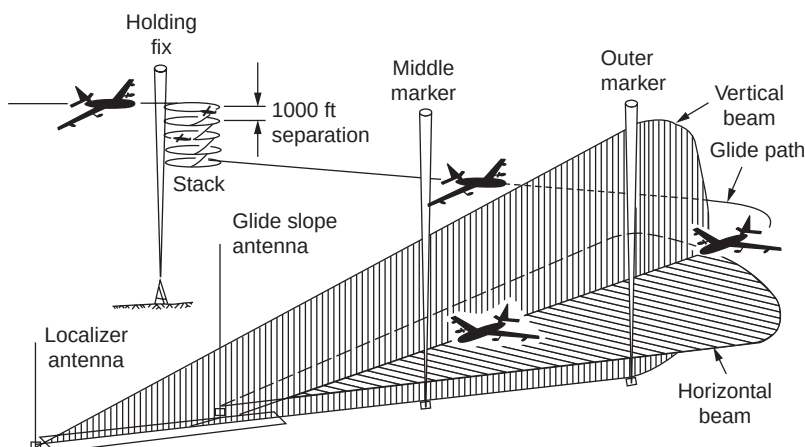


FIGURE 59.12 Instrument landing system. (From Scientific American, December 1959.)

TABLE 59.11 Obstacle Clearance Altitudes

Navigation Aid	Restriction	Obstacle Clearance Altitude (ft)
VOR	With a final approach fix	250
VOR	Without a final approach fix	300
Localizer (includes LDA and SDF)	Without glide slope	250
Nondirectional beacon	With a final approach fix	300
Nondirectional beacon	Without final approach fix	350
Circling approach	None	300
Circling approach	If an NDB approach without a final approach fix	350

Note: LDA = long distance available; NDB = nondirectional radio beacon.

Source: Modified from FAA, *United States Standard for Terminal Instrument Procedures (TERPS)*, 3rd ed., FAA Handbook 8260.3B, 1976.

visibility minima, since aircraft at those altitudes will need to sight the runway and begin a descent at a point more distant from the runway end. The basic 1-mile visibility for nonprecision approaches will be modified depending on the type of aircraft [FAA, 1976].

Required visibility can be reduced through the use of runway approach lights. In general, aircraft category A, B, or C visibility can be reduced to 3/4 mile if fairly simple approach lights are installed. Visibility can be reduced even further to 1/2 mile if higher quality approach landing systems with either sequenced flashers or runway alignment lights are installed (see Section 59.8). Visibility minima for category D aircraft, with their higher landing speeds, can usually be reduced to an even 1 mile if any approach light systems are installed [FAA, 1976].

Precision Approach Minima

Precision approach minima are based on the type of approach, approach lighting, and runway lighting system. Because of the more accurate vertical and lateral navigation guidance the basic minima for a precision approach are a decision height of 200 feet HAT and a minimum visibility of 3/4 mile for all categories of aircraft, with the exceptions presented in [Table 59.12](#).

Weather Effects

Since pilot altitude information during an instrument approach is derived from a barometric altimeter, it is crucial that when pilots are conducting instrument approaches with minimal obstacle clearance, the

TABLE 59.12 Visibility and Decision Height Exceptions

Runway and Approach Lighting	Decision Height in AGL (ft)	Minimum Visibility
None	200	3/4 mile
Approach lights	200	1/2 mile
Any of the above if no middle marker available	250	1/2 mile 3/4 mile without approach lights

Source: Modified from FAA, *United States Standard for Terminal Instrument Procedures (TERPS)*, 3rd ed., FAA Handbook 8260.3B, 1976.

aircraft’s altimeter be accurately set to the local barometric pressure. Inaccurate barometric pressure settings can result in inaccurate altitude measurement, which may reduce the aircraft’s obstacle clearance during the approach. A certified and accurate barometric pressure measurement is available to the pilot at most airports. If such a measurement is not available at or within 5 miles of the airport, a barometric pressure reading from a nearby airport can be substituted, but the instrument approach descent altitude is adjusted upward to reflect the possibility that the pressure at the remote airport could be somewhat different from that at the airport of intended landing. The penalty for using barometric pressure from a remote site is an upward adjustment of 5 feet of altitude for every mile that the remote altimeter is distant from the main airport, after the first 5 miles.

Noncommercial operations do not have as many restrictions concerning the conduct of an instrument approach placed on them as do commercial operators. It is left up to the pilot to decide whether the minima exist when conducting the approach. If no weather reporting service is available at the airport, the pilot may very often conduct the instrument approach to “look and see” what the weather conditions are. If, in the pilot’s preflight planning, the weather conditions at the destination airport appear to be unfavorable or are unknown, a pilot may not wish to risk the potential time lost to attempt an instrument approach at an airport without weather reporting. Thus the pilot may decide from the outset to fly to a more inconvenient airport with weather reporting, accepting the increased ground transportation time and cost, in order to eliminate the uncertainty and a possible unscheduled diversion to another airport.

Commercial operations require that weather observations be available at the airport during the times of arrival and departure. Previous to a recent technology change, weather reports were generated by human weather observers at the airport. Presently, automated weather observation and reporting stations, certified for airport use by the FAA, are available. They are the Automated Weather Observation System (AWOS III) and the Automated Surface Observation System (ASOS) developed by the National Weather Service. These systems permit the replacement of the human observer with the automated system, which is available 24 hours per day, rather than being available only during certain hours of the day.

Navigation Aids

Aeronautical navigation aids currently in use serve two purposes: as en route navigation aids or as instrument approach aids. In a few cases, they may do both. The master plan requires that an inventory of NAVAIDs be completed. TERPS [FAA 1976 with changes] clearly defines the capability of each of the many NAVAIDs. [Figure 59.13](#) shows the general shape and relative location of navigational aids to the runway system.

Criteria for NAVAIDs and Weather Observation

Most public-use airports in any state plan should be considered for some instrument approach procedure. The master plan for a given airport must consider the procedures and weather observation capability that will be the best for the level and type of anticipated traffic. The criteria should be based on the number of annual instrument approach (AIA) procedures that the airport could expect. For nontowered airports these data are not easily available. In lieu of complete AIA data, the number of annual operations provide an alternative measure, one which is usually forecast and is well understood.

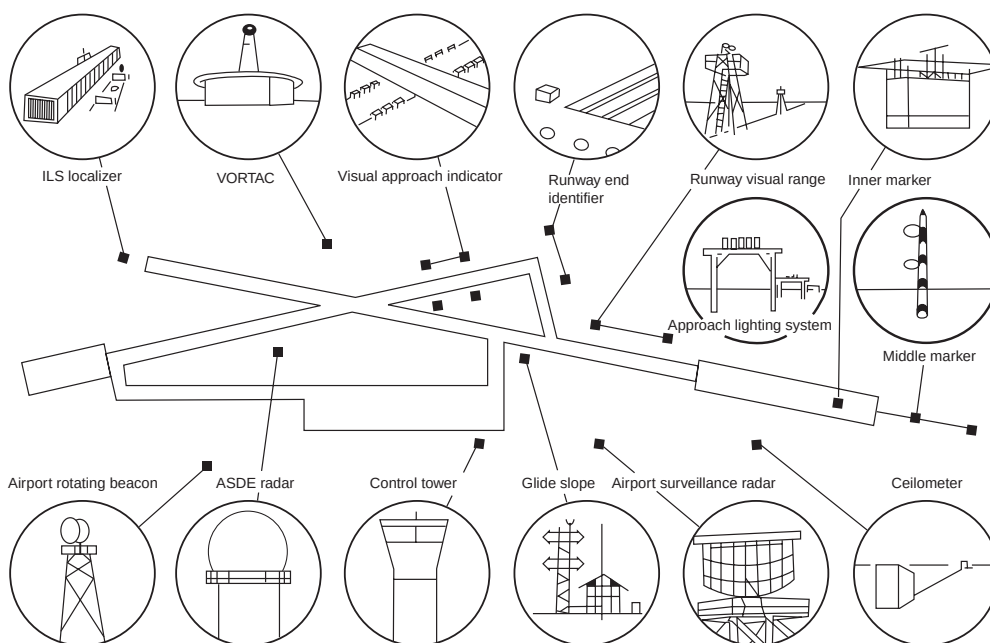


FIGURE 59.13 Relative location of terminal aids for approach to a runway system. (From FAA, Airport Design Standards: Site Requirements for Terminal Navigation Facilities, Advisory Circular AC150/5300-2D, 1980; and FAA, Airport Design, Advisory Circular AC150/5300-13, 1989.)

For one state plan [Purdue University, 1993], it has been suggested that 24,000 annual operations provide the first level of separation between a precision approach and a nonprecision approach capability. The probability of various levels of IFR weather, when used with operations data, estimates that 24,000 annual operations (12,000 landings) would reflect conservatively about 650 annual instrument approaches [FAA, 1983a]. The probabilities of various weather conditions in the state suggest that converting from VFR (usually considered to be a 1000-foot ceiling and 3-mile visibility) to a precision instrument approach capability (MDA of 200-feet HAT and ½-mile visibility) could increase possible airport use for an additional 30 to 40 days per year: a significant number of added operations (otherwise lost) for the airport.

Both the NAVAID and AWOS capabilities should be based on the number of annual itinerant operations (usually 40 to 60%) of the total general aviation operations, as shown in Table 59.13, where a precision

TABLE 59.13 Example of Instrument Approach Capability for Airports

Instrument Approach	Airport Classification	Weather
<i>Precision</i>	Primary	AWOS III or ASOS
Ceiling 200 ft	Reliever	
Visibility 1/2 mile	Commercial	
	GA transport with >24,000 annual ops.	
<i>Nonprecision</i>	GA transport with <24,000 annual ops.	
Ceiling 500 ft	GA utility with >12,000 annual ops.	All Part 135 operator airports AWOS III
Visibility 1 mile		
<i>Nonprecision</i>	GA utility with >12,000 annual ops.	Part 135 ops. or special needs
Ceiling 1000 ft	GA basic utility	
Visibility 1 mile		

Note: ops. = operations.

Source: Purdue University, Instrument Approach and Weather Enhancement Plan, Final Report on Contract 91-022-086 for Indiana Department of Transportation, Purdue University, 1993.

and two levels of nonprecision IAPs are considered. Part 135 operations are commercial air taxi and air charter operations requiring weather observation.

Benefits to each airport community will accrue due to improved access to the airport from automated weather data: fewer abandoned flight plans due to questionable weather, fewer missed approaches, and increased airport utilization with its benefits to the economy of the community.

59.6 Passenger Terminal Requirements

For many airports the data reflecting present terminal size and capacity would be a part of the master plan inventory. Airports often need to plan for a new passenger terminal or for a major expansion of the existing one. Passenger terminal design should serve to accomplish the following functions:

- *Passenger processing* encompasses those activities associated with the air passenger's trip, such as baggage handling and transfer, ticket processing, and seating. Space is set aside for these activities.
- *Support facilities* for passengers, employees, airline crew and support staff, air traffic controllers, and airport management are provided in each airport. Airlines rent space for the crew to rest and prepare for their next flights.
- *Change mode of transportation* involves the local traveler who arrives by ground transport (car, subway, bus, etc.) and changes to the air mode. The origination–destination passengers require adequate access to the airport, parking, curbside for loading and unloading, and ticket and baggage handling.
- *Change of aircraft* usually occurs in the larger hubs as passengers change from one aircraft to another. While baggage and parking facilities are not needed for these persons, other amenities, such as lounges, good circulation between gates, and opportunities for purchasing food, are important.
- *Collection space* for passengers is necessary for effective air travel. The aircraft may hold from 15 to 400 passengers, each of whom arrives at the airport individually. Boarding passengers requires that the airport have holding or collecting areas adjacent to the airplane departure gate. Because different passengers will come at different times, as shown in [Fig. 59.14](#), there should be amenities for the passenger, such as food, reading material, and seating lounges, as the group of passengers builds up to enplane. Likewise, the terminal provides the shift from group travel to individual travel and the handling of travelers' baggage when an aircraft arrives.

Passenger and Baggage Flow

Perhaps the greatest challenge for airport designers is the need for efficiency in the layout of the critical areas of flow and processing. The users of many airports experience sizable terminal delays because, under a heavy load, some areas of the terminal become saturated. Many airports designed some years ago were not prepared to handle the baggage from several heavy aircraft (e.g., DC-10, B-747, L1011, and MD-81) all landing nearly simultaneously. [Figure 59.15](#) shows the airport flow. The four potential terminal-related bottlenecks are noted in the figure:

1. Baggage and ticket check-in
2. Gate check-in and waiting area
3. Baggage retrieval area
4. Security checkpoints

Terminal Design Concepts

Several workable horizontal terminal configuration concepts are shown in [Fig. 59.16](#). To accommodate growth, many airports have added space to the existing terminal. The new space may reflect a different

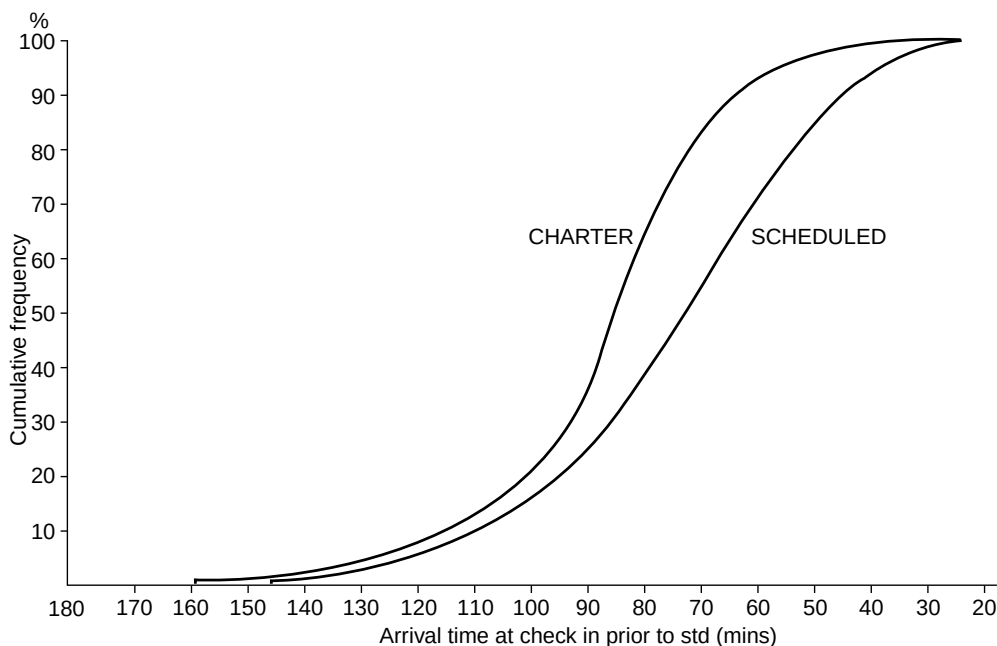


FIGURE 59.14 Typical arrival time for passengers. (From Ashford, N. et al., Passenger Behavior and Design of Airport Terminals, *Transportation Research Record* 588, 1976.)

design concept than the other parts of the terminal, due in part to the airline's desires. The San Francisco airport layout shown in [Fig. 59.17](#) provides an example of one terminal that grew and now employs several different gate configurations.

There are also different vertical distribution concepts for passengers and aircraft. In many airports the passengers and baggage are handled on a single level. For others, the enplaning function is often separated from the deplaning function, especially where the curbside for departing passengers is on the upper level and the baggage claim and ground transportation for arriving passengers are reached on the lower level. [Figure 59.18](#) shows four variations where the enplaning and deplaning passengers are separated as they enter the airport from the aircraft. The matrix shown in [Fig. 59.19](#) indicates the type of terminal concept and separation that design experience has shown are most appropriate for various size airports.

Sizing the Passenger Terminal

The sizing of the terminal consists of passenger demand, including the anticipated requirements for transfer passengers; number of gates needed for boarding; and anticipated aircraft size and mix. Three methodologies can assist the planner in determining the gross terminal size: the number of gates, the typical peak hour passenger, and the equivalent aircraft methods.

Size Estimate Using Gates

The number of gates can be crudely estimated by referring to the planning data given by the FAA in [Fig. 59.20](#). The number of gates can be better estimated by noting the different types of aircraft that will be at the airport during the peak hour and including the dwell time for each at the gate. For planning purposes the large aircraft will be at the gate approximately 60 min. The medium jets like the DC-9s and B-727s will be at the gate for 35 to 50 min. However, for contingency planning, 50 min is usually allowed for noncommuter aircraft with less than 120 passengers, and 1 hour is allowed for all other aircraft. This provides latitude for late (delayed) flights and the nonsharing of airline gates. The smaller commuter aircraft, usually with piston or turboprop engines, require about one gate for every three aircraft. The

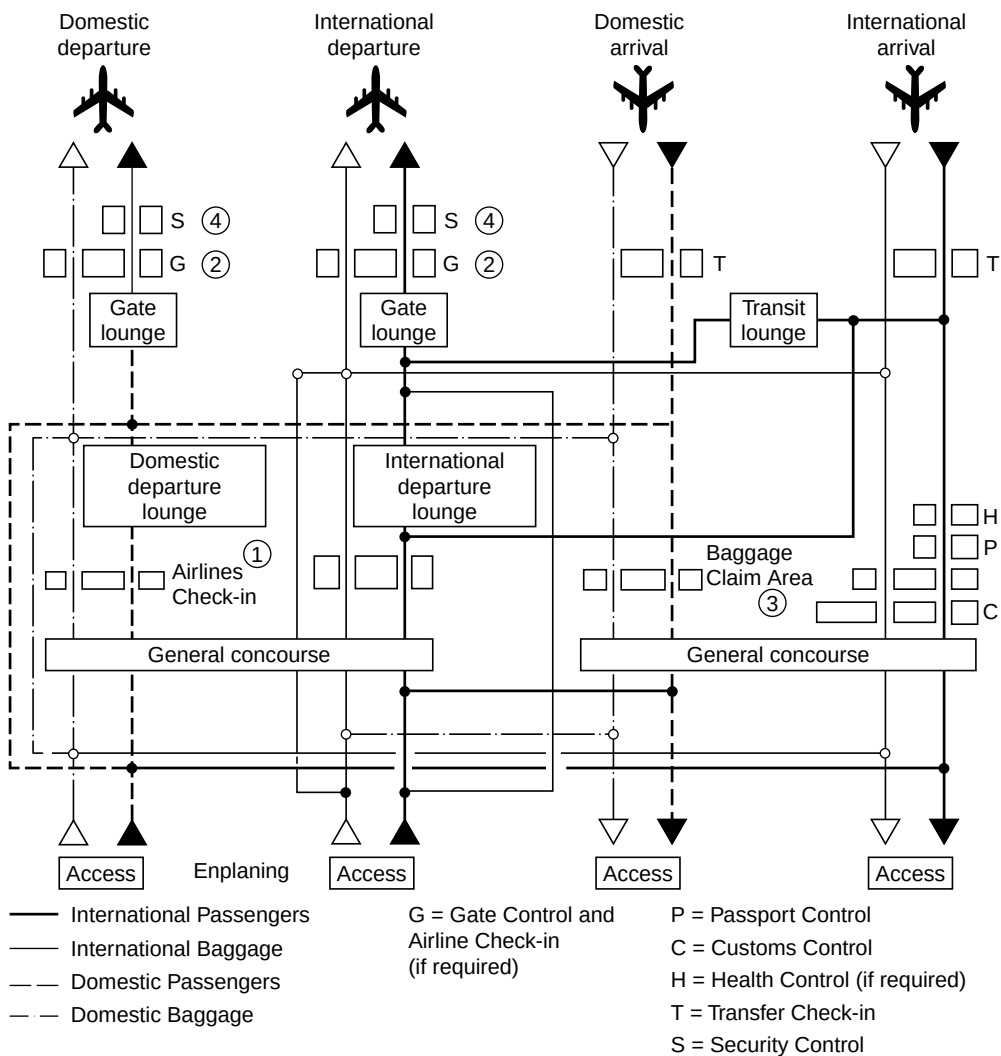


FIGURE 59.15 Passenger baggage flow system. (From Ashford, N. and Wright, P., *Airport Engineering*, John Wiley & Sons, New York, 1992, p. 290.)

gross terminal area per gate is determined using the planning chart shown in [Fig. 59.21](#). The results are indicated in [Table 59.14](#).

Size Estimate Using Typical Peak Hour Passenger

Another method for sizing the terminal involves the use of the typical peak hour passenger (TPHP). The TPHP does not represent the maximum passenger demand of the airport. It is, however, well above the average demand and considers periods of high airport usage. The TPHP is computed using Eq. (59.10a) for larger airports and Eq. (59.10b) for smaller airports (less than 500,000 annual enplanements). The curves in [Fig. 59.22](#) show the small relative change in TPHP for airports that are entirely origin–destination (no hubbing) to airports where 50% of the enplanements transfer from one aircraft to another. The results are also plotted. For airports where annual enplanements exceed 500,000,

$$\text{TPHP} = .004\text{ENP}^{0.9} \quad (59.10a)$$

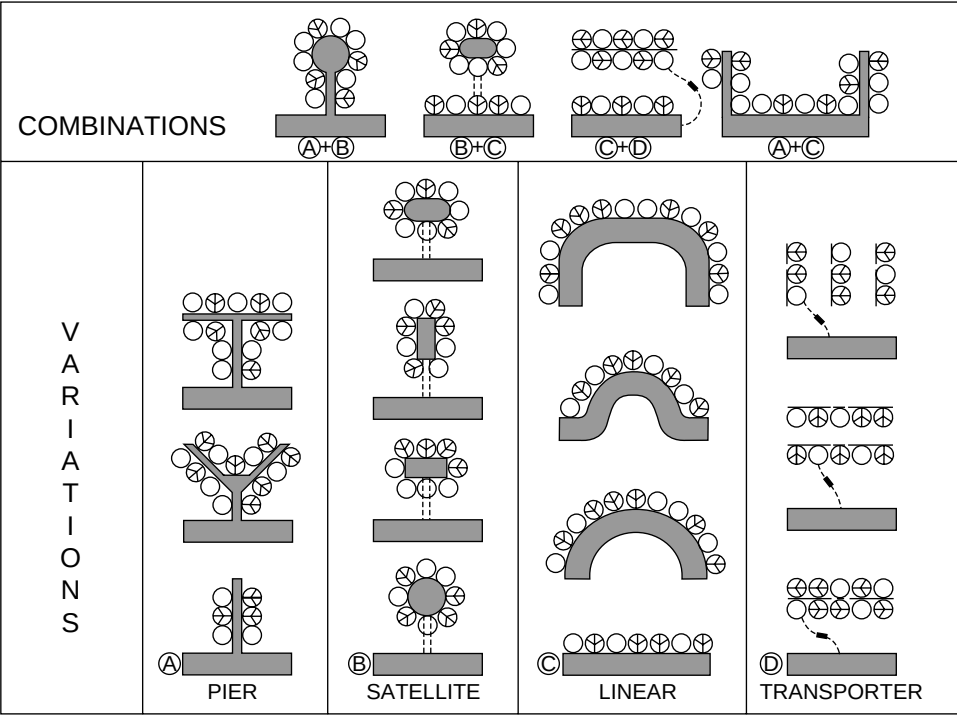


FIGURE 59.16 Terminal configurations. (From FAA, *Planning and Design Guidelines for Airport Terminal Facilities*, Advisory Circular AC150/5360-13, 1988b.)

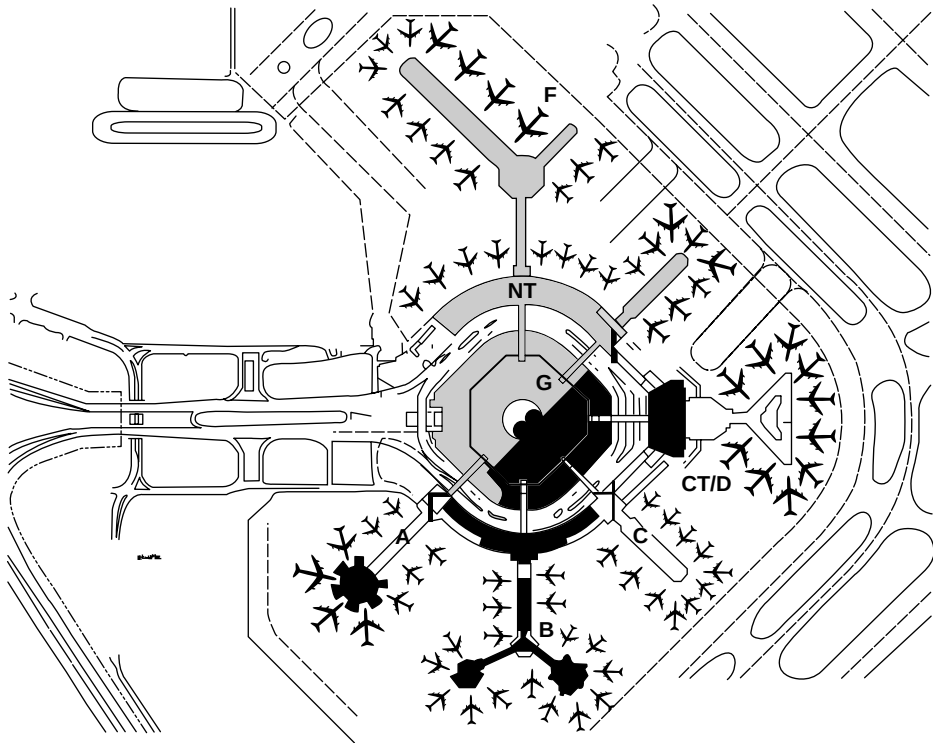


FIGURE 59.17 Layout of San Francisco Airport. (From San Francisco Airports Commission, circa 1981.)

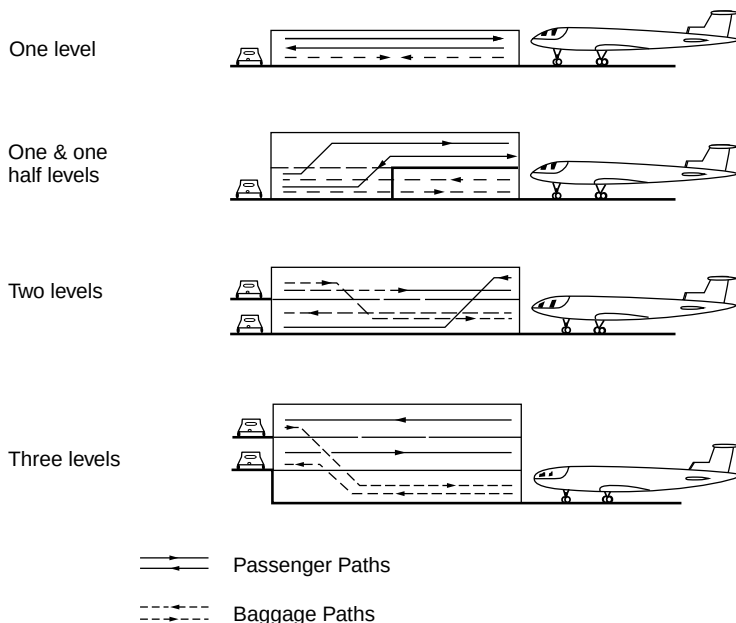


FIGURE 59.18 Vertical separation arrangements of passenger and baggage flows. (From FAA, *Planning and Design Guidelines for Airport Terminal Facilities*, Advisory Circular AC150/5360-13, 1988b.)

For airports where annual enplanements are less than 500,000,

$$\text{TPHP} = .009\text{ENP}^{0.9} \quad (59.10b)$$

where ENP equals annual enplanements.

One common measure used for long-range planning is to estimate that 120 to 150 square feet will be required by each TPHP [Ashford and Wright, 1992]. (With an international component to the airport, this number increases to about 250 square feet per TPHP. The value of 150 square feet per TPHP is quoted by Ashford and Wright in *Airport Engineering*; its origin is not clear.) The current TPHP for TBA is about 3150, suggesting a terminal size of 473,200 square feet. In the year 2000 TPHP is estimated to be 4260, resulting in approximately 639,000 square feet. In 2020 a TPHP estimate of 6820 indicates a terminal size of 1,023,000 square feet.

Size Estimate Using the Equivalent Aircraft Factor

The FAA advisory circular presents a full range of design curves that are useful for preliminary layout and consideration of the adequacy of space by airport functional area, such as baggage claim. In using the FAA references there are two major areas of information about the airport needed: (1) the number of enplanements that are from the local community, and (2) the number and types of aircraft that will use the airport in the peak hour, called the equivalent aircraft factor (EQA). The EQA for the TBA airport is shown in Table 59.15. It is based on the number of seats on arriving aircraft during the peak hour. Also shown is the departure lounge space, directly related to the EQA times the number of gates.

A terminal with a high level of hubbing results in a large number of passengers who will be changing aircraft rather than originating from the area. Thus, hubbing airports require reduced space for airline ticketing, baggage claim, curb access, and parking.

Table 59.16 gives a detailed breakdown of the area planning for a passenger terminal using the FAA design curves [FAA, 1988b]. The “how determined” column indicates how each number was computed. The estimates needed for baggage claim handling are percent arrivals (assumed during peak traffic to be 60%), the number of aircraft in the peak 20 min (assumed to be 50%), and the number of passengers

	CONCEPTS APPLICABLE	LINEAR	PIER	SATELLITE	TRANSPORTER	PHYSICAL ASPECTS OF CONCEPTS	SINGLE LEVEL CURB	MULTI LEVEL CURB	SINGLE LEVEL TERMINAL	MULTI LEVEL TERMINAL	SINGLE LEVEL CONNECTOR	MULTI LEVEL CONNECTOR	APRON LEVEL BOARDING	AIRCRAFT LEVEL BOARDING
Airport Size by Annual Enplaned Passengers														
FEEDER UNDER 25,000		X					X		X				X	
SECONDARY 25,000 TO 75,000		X					X		X				X	
75,000 TO 200,000		X					X		X		X		X	
200,000 TO 500,000		X	X				X		X		X		X	
PRIMARY OVER 75% PAX O/D 500,000 TO 1,000,000		X	X	X			X		X		X	X	X	X
OVER 25% PAX TRANSFER 500,000 TO 1,000,000		X	X	X			X		X		X	X	X	X
OVER 75% PAX O/D 1,000,000 TO 3,000,000			X	X	X		X	X		X	X	X	X	X
OVER 25% PAX TRANSFER 1,000,000 TO 3,000,000			X	X			X	X		X	X	X	X	X
OVER 75% PAX O/D OVER 3,000,000			X	X	X		X	X		X	X	X	X	X
OVER 25% PAX TRANSFER OVER 3,000,000			X	X			X	X		X	X	X		X

FIGURE 59.19 Matrix of concepts related to airport size. (From FAA, *Planning and Design Guidelines for Airport Terminal Facilities*, Advisory Circular AC150/5360-13, 1988b.)

and guests who will be getting baggage. It is assumed that 70% of arriving destination passengers will be getting baggage and each will have two guests. Use of FAA Advisory Circular AC150/5360-13 [1988b] is indicated with a page number.

As shown in [Table 59.17](#), the calculated space provides a range often useful in examining architect's renderings or developing preliminary cost estimates based on square-foot cost standards. The International Air Transport Association (IATA) has established space requirements based on the level of service rated on a scale from excellent to poor for the major used portions of the airport. Given in [Table 59.18](#), these data are useful in reviewing the terminal capabilities, capacities, and plans. The middle level is desirably the lowest level for peak operations. At the poor end, the system is at the point of breakdown.

Airport Airside Access

Parking of aircraft at the gate consists primarily of a "nose in" attitude requiring a pushback from the gate, or parking "parallel" to the terminal building. With the modern jetways, the parking space is usually governed by gate placement. The jetways themselves can be adjusted for aircraft door height from the ground and usually have sufficient extension capability to serve all the aircraft. Many airlines prefer boarding passengers on a Boeing 747 or other heavy aircraft through two doors. This requires two jetways for each gate destined to serve the heavy aircraft or for two gates. It also means that heavy aircraft will have special places to park at the gate. For the planning of the apron it is important to allow sufficient space to handle the expected aircraft according to the footprint shown in [Fig. 59.23](#). Ease of aircraft movement to and from the taxiway dictates the space between aircraft parking areas.

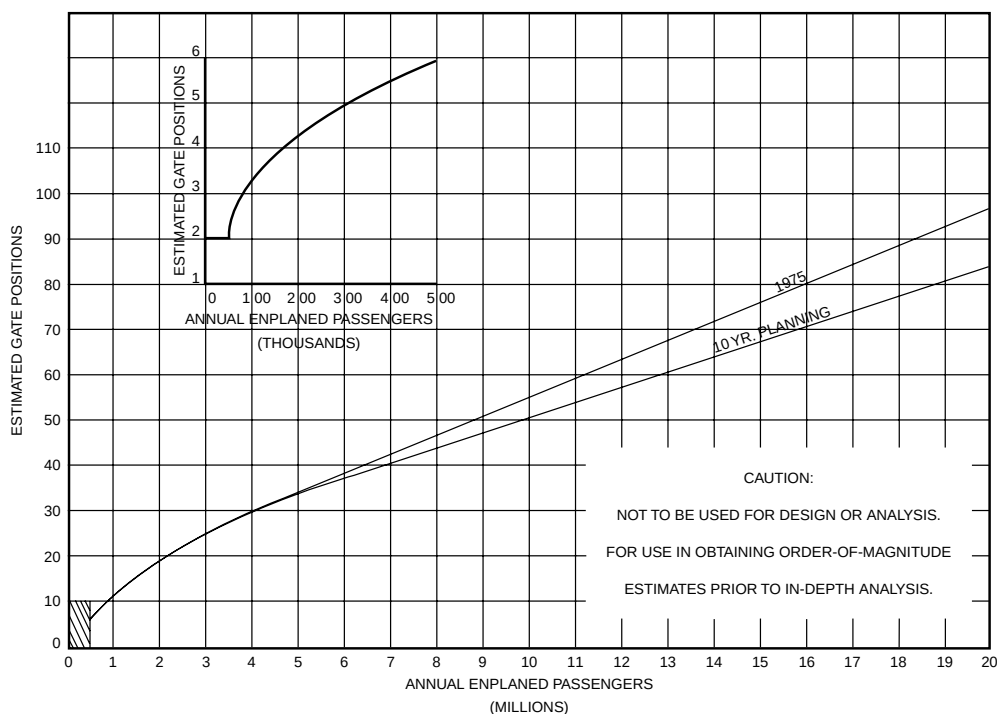


FIGURE 59.20 Planning curve to estimate the number of gates. (From FAA, *Planning and Design Guidelines for Airport Terminal Facilities*, Advisory Circular AC150/5360-13, 1988b.)

The aircraft is unloaded, loaded, and serviced on the terminal apron. The spacing on the apron itself is determined by the physical dimensions of the aircraft and the parking configuration. [Figure 59.24](#) shows the physical dimensions appropriate for pushout parking at either a satellite or a linear gate configuration. Apron dimensions are a function of the terminal concept chosen. However, for master planning where detailed geometry is not available, the total area is estimated by aircraft type. [Table 59.19](#) presents the space numbers for aircraft movement and parking [Ashford and Wright, 1992] and extends them by the number of aircraft in the TBA example airport.

In the TBA airport example, for the 8.4 million annual enplanements in the year 2020, a total of just under 3 million square feet of apron area is required. This space allocation includes adequate space for aircraft to move from the apron to the taxiway, as well as space for aircraft to move freely when others are parked at the ramp.

Airport Landside Access

Access Planning

Planning for airport access, especially by highway, is best done in conjunction with the local or state highway departments, who will have the responsibility for maintaining efficient access and avoiding gridlock outside the airport. The access portion of the airport design and planning process would also take into account the potential for rail and special bus connections. The design of the roadways around the airport and for entering and leaving the airport will need to account for the heavy traffic flows that often occur near rush hour when local industry and airport traffic usually overlap. While these design aspects are covered in the highway design portion of the handbook, [Fig. 59.25](#) presents four of the more prominent layout options for airport access.

GROSS TERMINAL AREA PER GATE - PLANNING

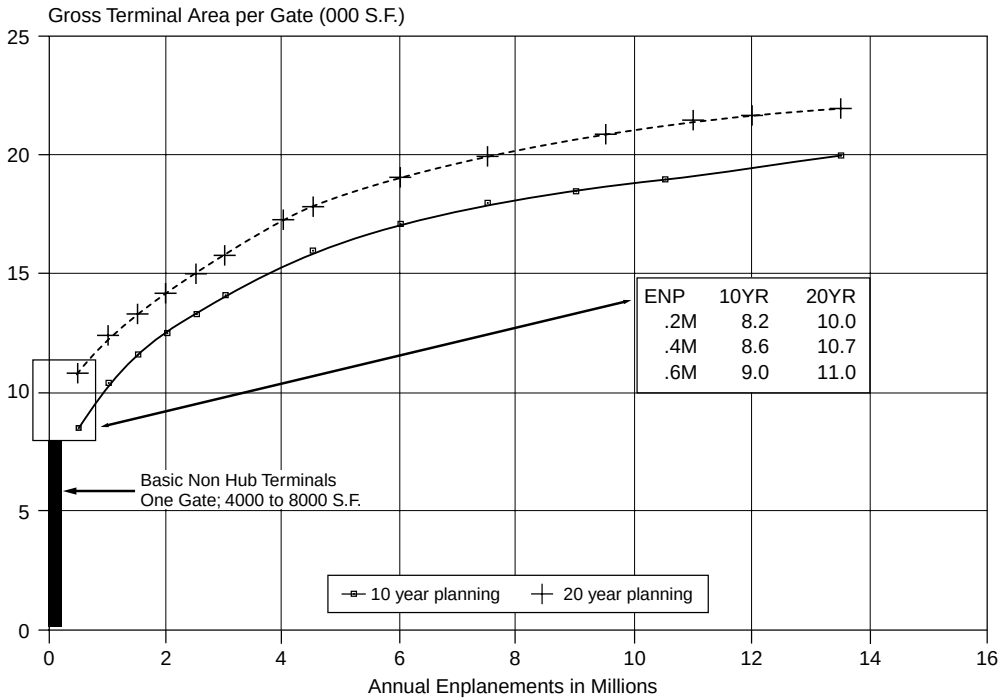


FIGURE 59.21 Using gates to estimate terminal space required. (From FAA, *Planning and Design Guidelines for Airport Terminal Facilities*, Advisory Circular AC150/5360-13, 1988b.)

TABLE 59.14 Calculation of Projected Overall Terminal Area for TBA Example Airport Using Number of Gates

Year	Annual Enplanements (Table 59.3)	No. of Gates (Fig. 59.20)	Area per Gate (Ft ²) (Fig. 59.21)	Terminal Size Estimate (Ft ²)
1992 (present)	3,566,270	24	12,000 (act)	360,000
2000	4,977,100	36	16,200	583,200
2020	8,409,950	45	20,500	922,500

Terminal Curbside Dimensions

The curbside dimensions will depend on the anticipated mode of transportation that brings persons to the airport. For gross planning, 115 lineal feet per million originating passengers can be used. For a more accurate estimate, the “dwell time” and length of each arriving vehicle at the curb must be determined. Since departing and arriving passengers exhibit different dwell times, it is appropriate to consider them separately.

For example, Table 59.20 shows the average dwell times from data collected at the Fort Lauderdale–Hollywood airport. Table 59.21 then provides the curb length for the TBA airport in 2020, assuming that during the peak hour 1060 TPHPs arrive at the curb and 1060 depart (see Table 59.16). The mode split between and ridership in cars, taxis, buses, and courtesy cars would be as indicated.

Although theoretically one lineal foot of curb front can provide 3600 feet-seconds of curb front in 1 hour, it has been suggested that the practical capacity is about 70% of this number [Cherwony and

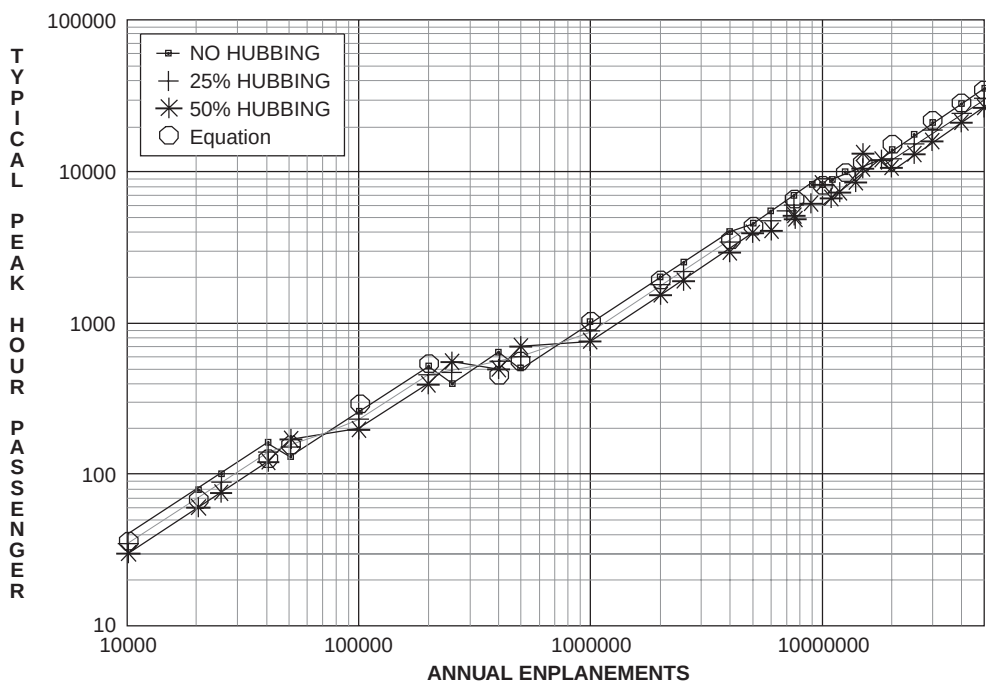


FIGURE 59.22 Typical peak hour passengers (TPHPs) as a function of enplanements using FAA relationships.

TABLE 59.15 Calculating the Equivalent Aircraft Factor

Aircraft Type	No. of Aircraft Peak Hour	Seat Range	EQA	Gates Req'd.	EQA × Gates by Type	Departure Lounge (Ft ²)	Forecast for 2020			
							No. of Aircraft Peak Hour	Gates Req'd.	EQA × Gates by Type	Departure Lounge (Ft ²)
B(a)	4	<80	0.6	2	1.2	2,400	8	3	1.8	2,100
C(b)	12	81–100	1.0	10	10.0	11,000	15	13	13.0	14,300
C(c)	10	111–160	1.4	10	14.0	15,000	20	20	28.0	30,000
D(d)	2	161–210	2.0	2	4.0	4,000	4	4	8.0	8,000
D(e)	0	211–280	2.5	—	—	—	3	3	7.5	8,100
D(f)	0	281–420	3.5	—	—	—	2	2	7.0	7,400
D(g)	0	421–500	4.6	—	—	—	—	—	—	—
28			Total	24	34.1	31,400	52	45	65.3	69,900

Note: Req'd. = required.

Source: Computed from FAA, *Planning and Design Guidelines for Airport Terminal Facilities*, Advisory Circular AC150/5360-13, 1988b.

Zabawski, 1983]. For the TBA airport in 2020, the curb necessary on the enplanement or departing level is $1,877,600/(0.7 \times 3600)$, or about 745 ft, and for the deplaning curb front, 1139 ft.

Parking

Parking requirements for airports vary widely, depending on the nature of the airport and the manner in which people come to the airport. The long-term parking serves passengers who drive and park plus the employees on the site. The short-term lot accommodates well-wishers and greeters, visitors to the airport itself, and salespersons, and is located next to the terminal. Separate lots for long-term and short-term parking should be provided when the total annual passenger volume exceeds the 150,000 to 200,000 range [FAA, 1988b].

TABLE 59.16 Example for Terminal Space Calculation

Function	How Determined	1992	2000	2020
Equivalent aircraft factor	Table 59.15	34.1	52.1	65.3
Gates	Table 59.15	24	36	45
TPHP	Eq. (59.10a)	3150	4260	6820
1. Departure lounge	Table 59.15	31,400 ft ²	51,200 ft ²	69,900 ft ²
2. Lobby and ticketing	FAA 1988b, p. 56	25,000 ft ²	40,000 ft ²	45,000 ft ²
3. Airline ticket operations	FAA 1988b, p. 65	7,200 ft ²	9,000 ft ²	11,000 ft ²
4. Airline space: crew, office, clubs	FAA 1988b, p. 69 (5000 sq. ft. per peak hour aircraft departure)	14,000 ft ²	21,000 ft ²	26,000 ft ²
5. Outbound baggage room	FAA 1988b, p. 67 (80% of the bag rooms)	17,000 ft ²	26,000 ft ²	32,000 ft ²
6. Baggage claim	60% arrivals with 50% in peak 20 min; FAA 1988b, p. 86 for baggage claim frontage; FAA 1988b, p. 87 using T-shaped flat bed, dir. feed for area	360 ft of claim 11,000 ft ²	560 ft of claim 16,000 ft ²	750 ft of claim 21,000 ft ²
7. Lobby waiting area	FAA 1988b, p. 57 (seating for 20% TPHP)	12,000 ft ²	16,000 ft ²	24,000 ft ²
8. Lobby for baggage claim	Two greeters plus one passenger; a 20-min wait uses 21 ft ² per person (see Table 59.18)	490 PAX 980 guests 30,800 ft ²	662 PAX 1314 guests 41,500 ft ²	1060 PAXmin 2120 guests 66,800 ft ²
9. Security	150 ft ² per station	1,200 ft ²	1500 ft ²	1800ft ²
10. Food and beverage	FAA 1988b, p. 92 (assume 40–50% usage factor)	40,000 ft ²	44,000 ft ²	52,000 ft ²
11. Concessions	FAA 1988b, p. 93 (upper value)	45,000 ft ²	60,000 ft ²	80,000 ft ²
12. Other circulation	Assume 80% of items 1 through 5	85,280 ft ²	130,500 ft ²	163,900 ft ²
13. HVAC, mechanical areas, structure	Use 25% of total	80,200 ft ²	114,200 ft ²	148,400 ft ²
Total space required		401,100 ft ²	580,000 ft ²	741,800 ft ²
Space per peak hour passenger		127.3 ft ² per TPHP	134.0 ft ²	108.8 ft ²

Note: HVAC = heating, ventilation, and air conditioning.

Source: Computed from FAA, *Planning and Design Guidelines for Airport Terminal Facilities*, Advisory Circular AC150/5360-13, change 1, 1988b.

TABLE 59.17 Comparison of Sizing Methods for the TBA Airport

Year	Method of Determination			Recommended (ft ²)
	Gates (ft ²)	TPHP (ft ²)	EQA (ft ²)	
1992	336,000	473,000	391,200	360,000 (act)
2000	576,000	639,000	537,700	575,000
2020	945,000	1,023,000	710,800	900,000

High fees at the short-term lot relative to those for the long-term lot tend to discourage long-term parkers (more than 3 hours) from clogging short-term parking areas. The short-term lot can usually be sized on the basis of the originating peak hour passengers; one useful ratio is two short-term spaces for every seven originating peak hour passengers [Ashford and Wright, 1992]. Another rule of thumb is that the short-term parkers will require about 20% of the total parking space [FAA, 1988b].

The long-term lot requires a vastly different approach. The best way to develop the lot size is to obtain data from an airport similar to the one being designed, noting the time and day a car arrives and its length of stay. From these data a simulation can be used to size the parking lot. The Institute of Air

TABLE 59.18 IATA Level of Service Space Standard for Airport Passenger Terminals

	Level of Service Standards in Ft ² per Occupant		
	Excellent	Good	Poor
Check-in queue area	19	15	11
Wait/circulate	29	20	11
Holding room	19	11	6.5
Bag claim area (no device)	21	17	13
Government inspection	15	11	6.5
Total	103	74	48

Source: International Air Transport Association, *Airport Terminals Reference Manual*, 7th ed., International Air Transport Association, Montreal, 1989.

Transport surveyed 12 of the larger U.S. airports in 1979 and found that the parking ranged from 3.45 spaces per million annual originating enplanements for BWI to 0.86 at New York La Guardia. While this was a 1979 study and the parking at many airports has been upgraded, it serves to indicate the disparity between airport parking facilities. Some cities have excellent transit connections to the airport that serve to relieve some of the pressure for long-term parking (at least for employees).

For preliminary planning, it would be safe to use 1.5 spaces for each originating TPHP to size the total parking need. The land needed without a parking structure equates to 100 to 125 cars per acre. For TBA in 2020, the 6 million originating passengers would equate to 5040 TPHP, resulting in an estimate of 7500 spaces or 60 to 75 acres of parking. The short-term lot would have about 1500 spaces with about 6000 allocated for long-term parking. Often the Achilles' heel of an airport, the parking lot is a good revenue producer and should be carefully managed. Shuttle buses provide courtesy transportation to the departure and arrival curbs for the convenience of the traveler.

59.7 Airport Site Determination and Considerations

It is often situations within 10 miles of the airport site that will have significant bearing on the success of an airport project. The airspace and associated ground tracks along the takeoff and landing corridors are critical not only to site location, but also for runway orientation, since they define:

- Where safe landing of aircraft for over 95% of the wind conditions must occur
- Where obstacles projecting into the flight path must be eliminated
- Where houses, buildings, and recreation sites could be subjected to unacceptable levels of aircraft noise

Siting of runways must seek to provide solutions to all three of these constraints. In addition, runways must avoid landing and takeoff paths that are over landfills and other areas that are prime bird habitats. In recognition of the severity of aircraft crashes when they occur in the vicinity of public assembly buildings, particularly schools, communities are encouraged to control the land use within 3 miles from the airport reference point (ARP), restricting the building of any such buildings [FAA, 1983a]. Other site considerations are the usual civil engineering concerns of soil condition, required grading and earthwork, wetlands, and suitable access connecting the airport with major business and industrial areas nearby.

Mandatory Control/Ownership

The land from the outer edge of the runway protection zone (RPZ) shown in [Fig. 59.26](#) to the runway threshold is the minimum amount of land, beyond that associated with the runways themselves and the terminal, that should be in the possession (under direct control) of the airport management. If ownership

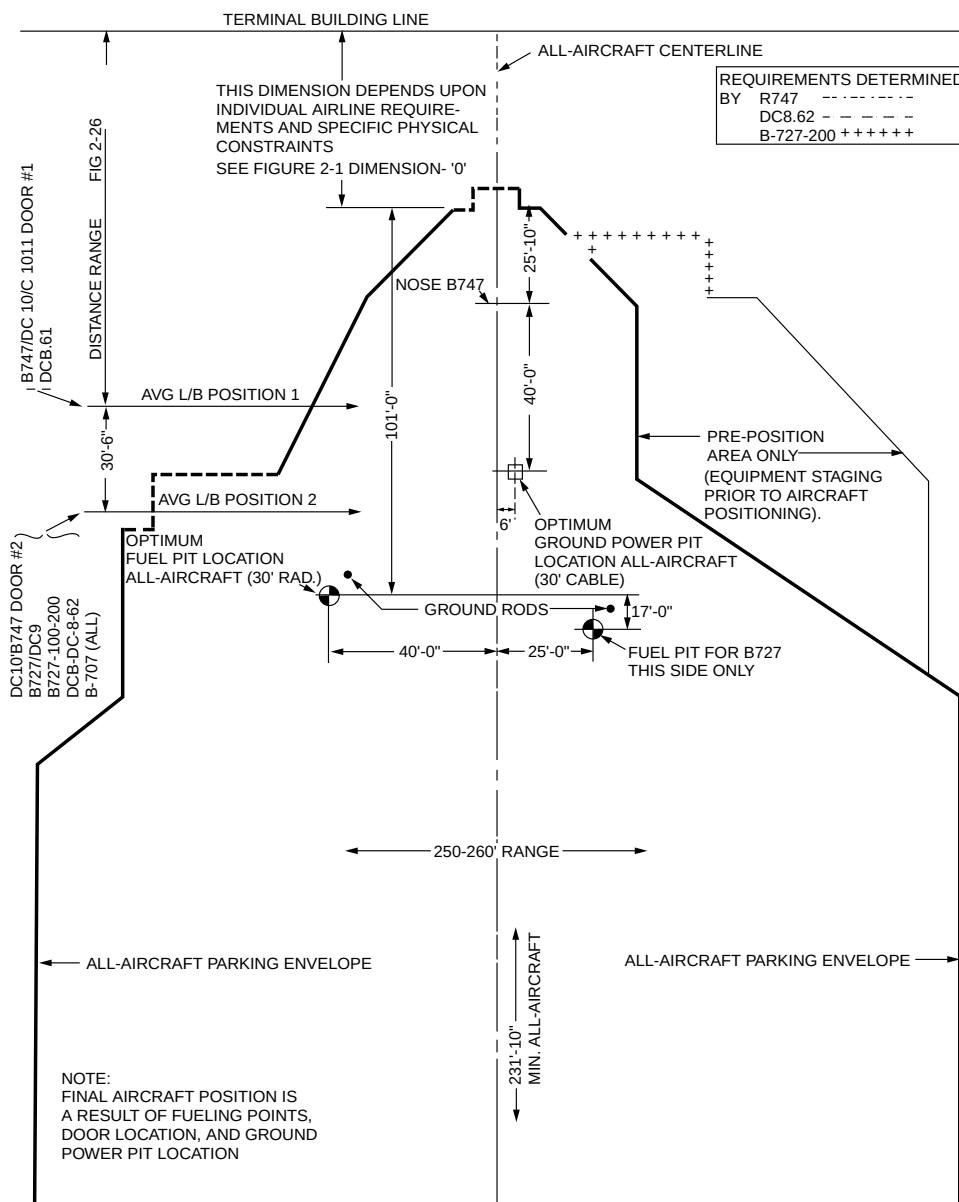
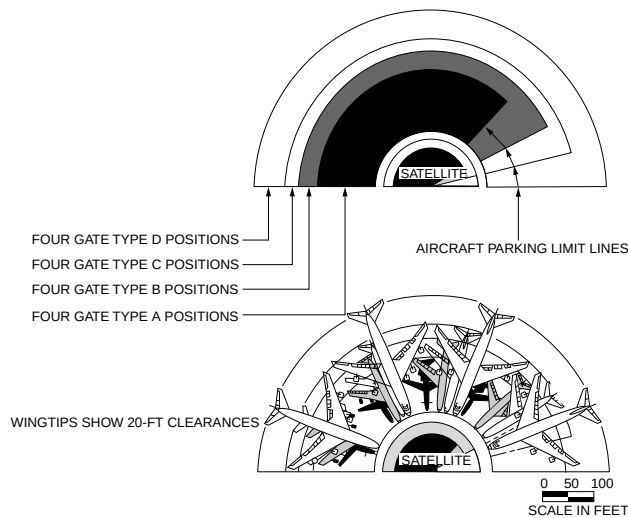


FIGURE 59.23 Aircraft and ground servicing parking envelope. (From FAA, Planning and Design Guidelines for Airport Terminal Facilities, Advisory Circular AC150/5360-13, 1988b.)

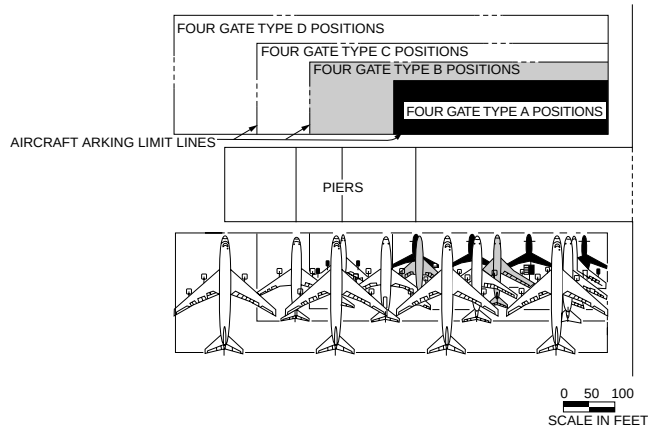
of this area is not possible, then all activity in the trapezoidal area shown in [Fig. 59.26](#) must be under total control of the airport. Sometimes special easements or other legal instruments are used to ensure positive control.

The more surrounding land the airport owns, especially land extending from the ends of major runways, the better the airport will be able to grow and expand to meet the ever growing demand for air travel while maintaining acceptable relationships with the community. As shown in [Table 59.22](#), the RPZ for paved runways (formerly called the clearway) varies in size according to the approach capability (visual, nonprecision instrument, and precision instrument) discussed in Section 59.5.

For future expansion the best plan is to obtain land equivalent to the largest RPZ dimensions, which for precision approaches extend 2700 feet from the runway threshold. This could result in a significant amount



(a) Satellite push-out gate positioning



(b) Linear configuration push-out gate positioning

FIGURE 59.24 Configurations for parking at satellite or pier. (From FAA, Planning and Design Guidelines for Airport Terminal Facilities, Advisory Circular AC150/5360-13, 1988b.)

TABLE 59.19 Apron Requirements for Parking and Aircraft Movement TBA Airport

Type of Aircraft	Space for Aircraft Movement and Parking (ft ²)	Aircraft in 2020	Apron Space Needed (ft ²)
Wide-bodied large-engine jet aircraft	160,000	9	1,440,000
Four-engine narrow-body jet aircraft	65,000	3	195,000
Three-engine narrow-body jet aircraft	43,000	17	731,000
Two-engine narrow-body jet aircraft	33,000	15	495,000
Two-engine turbojet aircraft	16,000	8	128,000
			2,989,000

of land acquisition if the airport has not planned ahead. Even though the FAA will help fund purchase of land for safety improvements, obtaining the land around an existing airport is not always easy and can have as much neighborhood impact as the noise paths. While it is possible to fly special curved approaches during landing and takeoff to minimize noise, straight-in glide slopes are recommended as the safest.

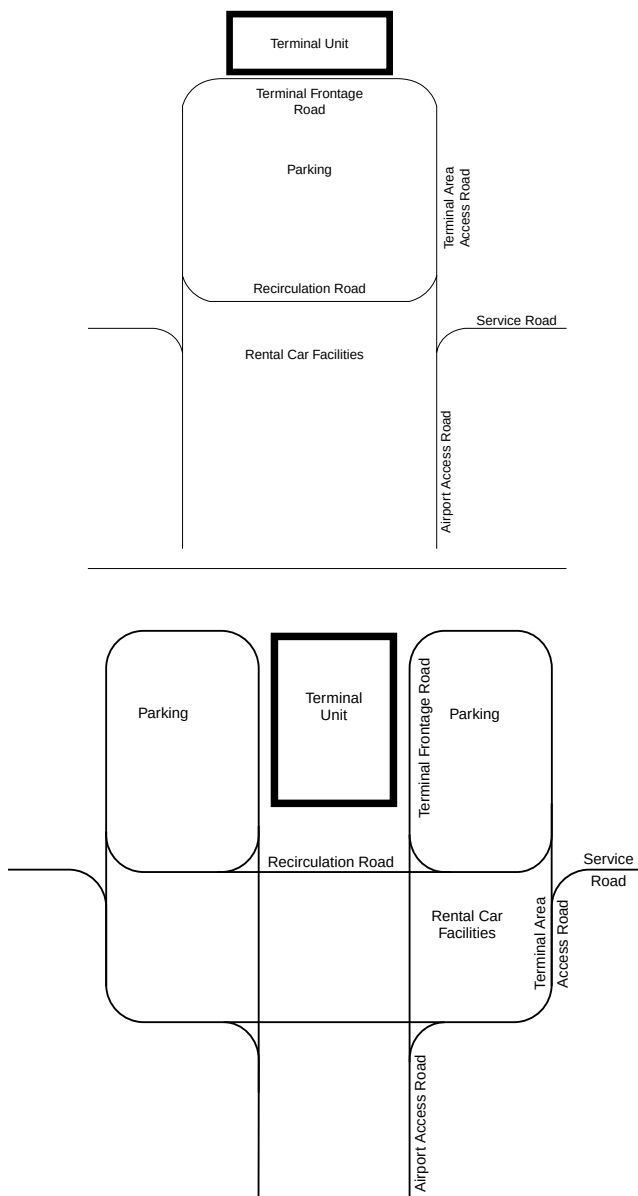


FIGURE 59.25 Four prominent ground access concepts. (From FAA, *Planning and Design Guidelines for Airport Terminal Facilities*, Advisory Circular AC150/5360-13, 1988b.)

Obstacle Control

For the pilot on final approach the runway is an extension of the glide path. The length and slope of the glide path depend on the airport's traffic and the approach capability of the runway (visual, instrument nonprecision, or precision) landing system. The glide path for landing and taking-off aircraft must be under the control of the airport to the extent that obstacles are avoided, navigation is facilitated, and landing is safe. [Table 59.23](#) presents the dimensions of the approach surface for transport airports (C and D aircraft). The obstacles along the glide path pose a most severe situation. At a 50:1 slope, the distance from the end of the runway to clear a 200-ft (60-m) obstacle by 250 ft (75 m) is 22,500 ft (6850 m or 4.3 mi).

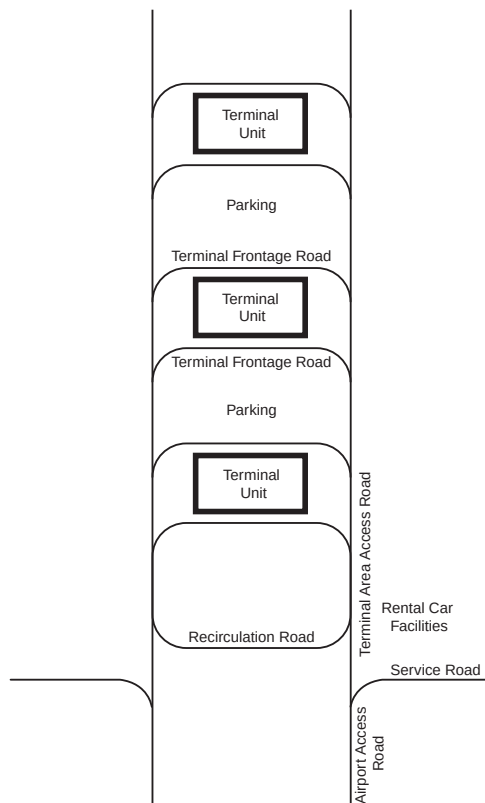
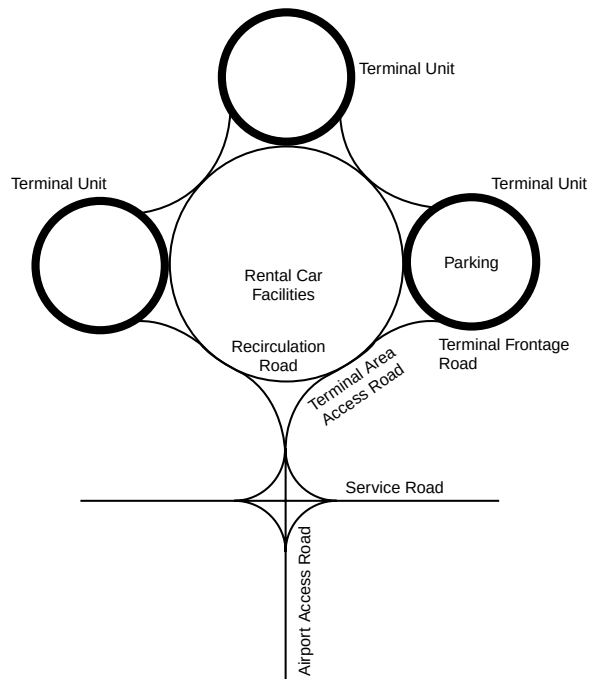


FIGURE 59.25 (continued).

TABLE 59.20 Curb Front Requirements from Fort Lauderdale–Hollywood Airport

Mode	Length (ft)	Average Dwell Time (s)		Curb Front Required (ft-s)	
		Enplaning	Deplaning	Enplaning	Deplaning
Personal auto	26	130	170	3,380	4,420
Taxi	26	75	130	1,950	3,380
Limousine	36	180	400	6,480	14,400
Courtesy vehicle	46	80	180	3,680	8,280
Bus	46	270	400	12,420	18,400
Other	36	360	190	12,960	6,840

TABLE 59.21 Example of Curb Front Design for TBA Airport

Mode	Enplaning			Deplaning		
	Passengers	Vehicles	Peak (ft-s)	Passengers	Vehicles	Peak (ft-s)
Personal auto	400	360	1,216,800	420	380	1,679,600
Taxi	100	100	195,000	100	100	338,000
Limousine	80	10	64,800	80	12	172,800
Courtesy vehicle	180	40	147,200	240	50	414,000
Bus	200	10	124,200	120	10	184,000
Other	100	10	129,600	100	12	82,000
			1,877,600			2,870,400

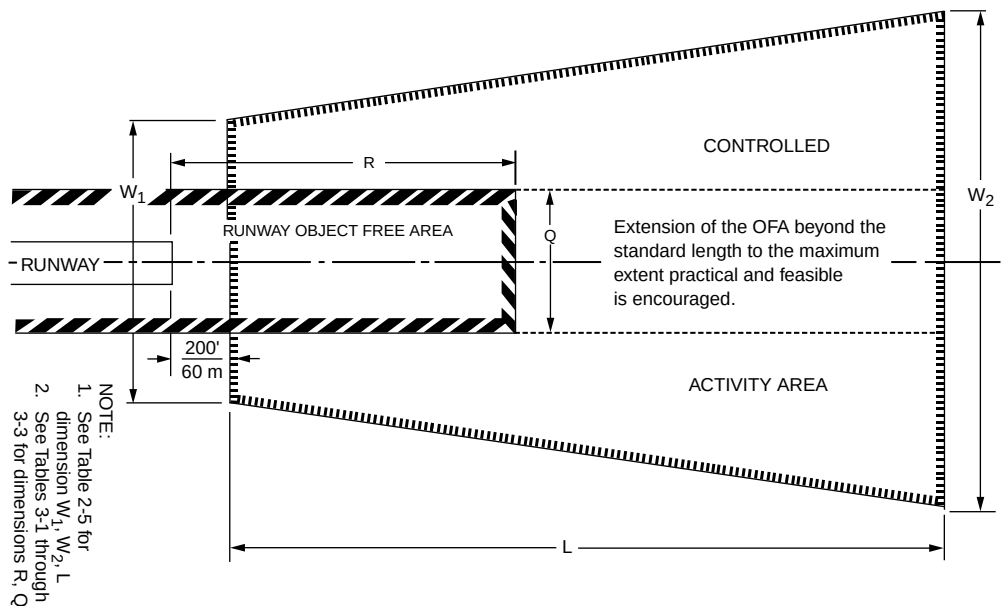


FIGURE 59.26 Runway protection zone. (From FAA, *Airport Design*, Advisory Circular AC150/5300-13, change 1, 1991c.)

The airport is to be sited where it is free from obstructions that could be hazardous to aircraft taking off or landing. Imaginary surfaces are used to define the limits on potential obstacles on or near the glide slope. For takeoff these are also critical because it is required that a transport aircraft be able to take off successfully even if one engine is out. For aviation in the U.S., the imaginary surfaces are set forth in Part 77 of the Federal Aviation Regulations [FAA, 1975]. The imaginary surfaces are defined in Fig. 59.27. If the airport is ever to achieve precision instrument status, the precision instrument slope of 50:1 for

TABLE 59.22 Runway Protection Zone Dimensions for Transport Airports (C and D Aircraft)

Runway End		Dimensions for Approach End			
Approach End	Opposite End	Length (ft) [m]	Inner Width (ft) [m]	Outer Width (ft) [m]	RPZ Area (acres)
V	V, NP	1000 [300]	500 [150]	700 [210]	13.8
V	P	1000 [300]	1000 [300]	1100 [330]	24.1
NP	V, NP	1700 [510]	500 [150]	1010 [303]	29.5
NP	P	1700 [510]	1000 [300]	1425 [427.5]	47.3
P	V, NP, P	2500 [750]	1000 [300]	1750 [525]	78.9

Note: V = visual approach; NP = nonprecision instrument approach (visibility > 3/4 statute mile); P = precision instrument approach.

Source: FAA, *Airport Design*, Advisory Council AC150/5300-13, change 1, 1991c.

TABLE 59.23 Approach Surface Dimensions for Transport Airport (C and D Aircraft)

Runway End		Approach Surface Dimensions			
Approach End	Opposite End	Length (ft) [m]	Inner Width (ft) [m]	Outer Width (ft) [m]	Slope (Run:Rise)
V	V, NP	5,000 [1500]	500 [150]	1,500 [450]	20:1
V	P	5,000 [1500]	1,000 [300]	1,500 [450]	20:1
NP	V, NP	10,000 [3000]	500 [150]	3,500 [1050]	34:1
NP	P	10,000 [3000]	500 [150]	3,500 [1050]	34:1
P	V, NP, P	10,000 [3000]	1,000 [300]	4,000 [1200]	50:1
		PLUS	+	+	
		40,000 [12,000]	4,000 [1200]	16,000 [4800]	40:1

Note: V = visual approach; NP = nonprecision instrument approach (visibility > 3/4 statute mile); P = precision instrument approach.

Source: FAA, *Airport Design*, Advisory Circular AC150/5300-13, change 1, 1991c.

10,000 ft (3,000 m) followed by 40:1 for an additional 40,000 ft (12,000 m) should govern the land-use policies that restrict building and object heights. For nonprecision instrument landings and visual landings, there is still a need to control the obstacles out to at least 10,000 ft (3,000 m) at the landing slope of either 34:1 or 20:1.

In terms of safety, the FAA has established object height requirements in the vicinity of the airport as follows:

An object would be an obstruction to air navigation if of greater height than 200 ft (60 m) above the ground at the site, or above the established airport elevation, which ever is higher (a) within 3 nautical miles (5.6 km) of the established reference point of an airport with its longest runway more than 3200 feet (975 m) in actual length and (b) that height increases in proportion of 100 feet (30 m) for each additional nautical mile from the airport reference point up to a maximum of 500 ft (150 m). [U.S. Code FAR, Part 77.23(a)(2)]

Orientation for Winds

The orientation of the runway, in part, results from the physics of the aircraft. Airplanes operate best when they are flown heading into the wind, so the runway choice, if there one, is always to land (or to take off) heading directly into the wind. Since the wind varies and the runway is fixed, this is usually not totally possible. Figure 59.28 shows an aircraft landing on runway 24 in a 25-knot wind blowing from 280 degrees azimuth.

Landing into the wind has also resulted in the convention for numbering runways, where the runway number consists of the first two digits related to the azimuth of the runway rotated by 180 degrees to

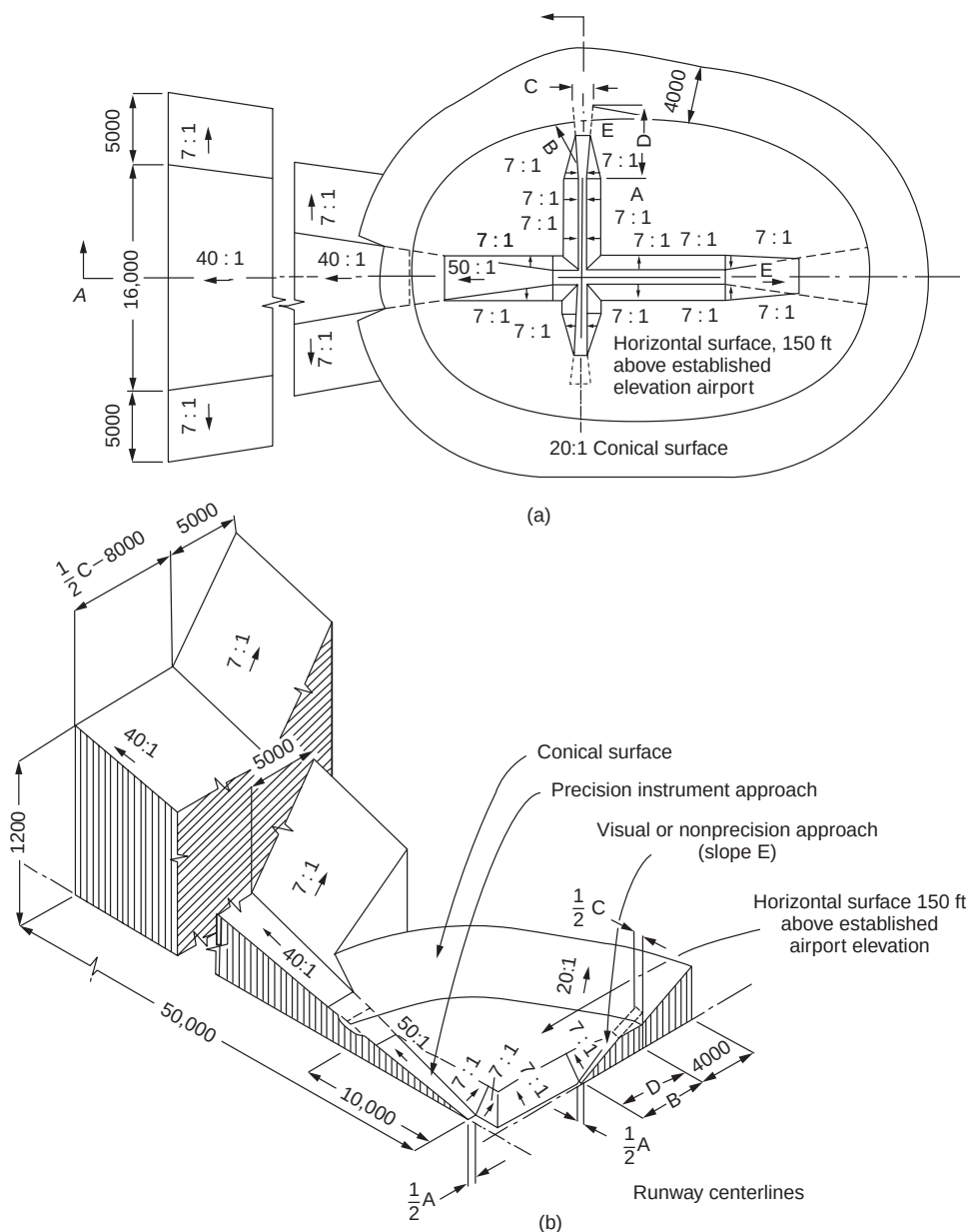


FIGURE 59.27 Imaginary surfaces used for obstacle control. All dimensions in feet. (From U.S. Code FAR, Part 77.23, 1975.)

account for the direction of the wind. Thus the pilot landing on runway 24 will have the headwind component of 19.2 knots. The crosswind component of wind is 16 knots. The polar plot displaying these is called a wind rose.

The FAA standards, given in the U.S. Code (CFR Title 14, Part 25), require that the airport must be able to accept landing (acceptable level of crosswind at 13 knots) along its runway(s) 95% of the time. When this cannot be accomplished with one runway, then the airport must add a crosswind runway. The two runways together then statistically eliminate unacceptable crosswinds to less than 5%. If possible, a 10-year sample of wind soundings taken hourly is used to establish a model of the wind velocity and direction. The wind data are then analyzed and placed in the appropriate cell, as shown in the wind rose

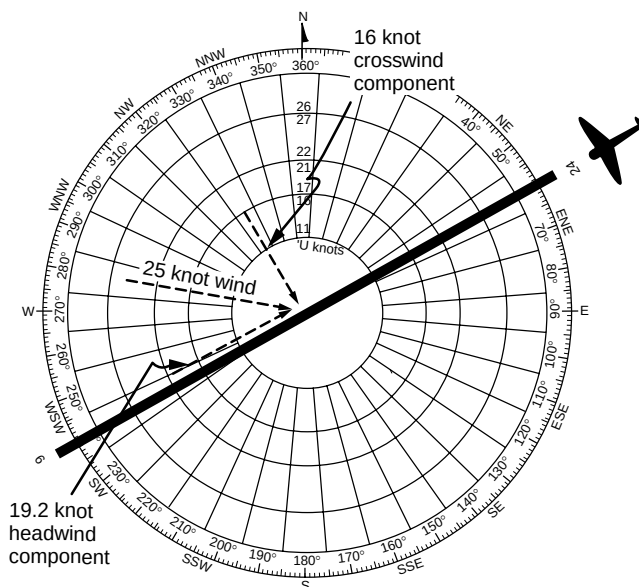


FIGURE 59.28 Head wind and crosswind components on a wind rose.

of Fig. 59.29. Thus each cell shows the percentage of the time the wind has an amplitude and a direction indicated by the cell. The runways are then placed on the wind rose to analyze for minimum crosswinds in excess of the 13-knot criterion. For each orientation the cells outside the runway template are summed to determine if the 95% criterion has been met.

The rules relate the crosswind restriction only to the width of the runway, as indicated in Table 59.24. The crosswind restriction, for example, has been changed for basic transport aircraft to 20 knots [Ashford and Wright, 1992]. However, there is a trade-off between allowable crosswind and runway width for lighter planes, which are difficult to control in heavy crosswinds. For example, a 200-foot-wide runway gives the pilot of a light aircraft much more latitude for maintaining control in a heavy (20-knot) crosswind (provided the structural integrity of the aircraft is not exceeded) than for landing on a 75-foot-wide runway. The acceptable practice for most airports has been to ensure that the runway configuration provides for a minimum of 95% against a 13-knot crosswind. Once the possible best directions of runways are established, then other factors that impinge on direction obstacles and noise become critical.

Noise

Airport noise has restrained development, constrained operations, and restricted the expansion of many airports in the U.S. Its presence continues to plague airport managers and operators, who find it continually impinging on their desire to maintain good community relations. Aircraft primarily produce noise from their engines and from the flow of air over the aerodynamic surfaces. Jet-turbine-driven aircraft produce considerably more noise than did their piston engine predecessors.

Noise from airports has evoked numerous lawsuits and excess media attention, much to the frustration of airport officials. Noise is a real disturbance and its effects and acceptability are best measured in the ears of the hearer. The critical factors in considering noise impacts are:

- Length or duration of the sound
- Repetition of the sound
- Predominant frequency(ies) generated
- Time of day when the noise occurs

WIND DIRECTION VERSUS WIND SPEED

STATION: Anywhere, USA

HOURS: 74 Observations/Day

PERIOD OF RECORD: 1964–1973

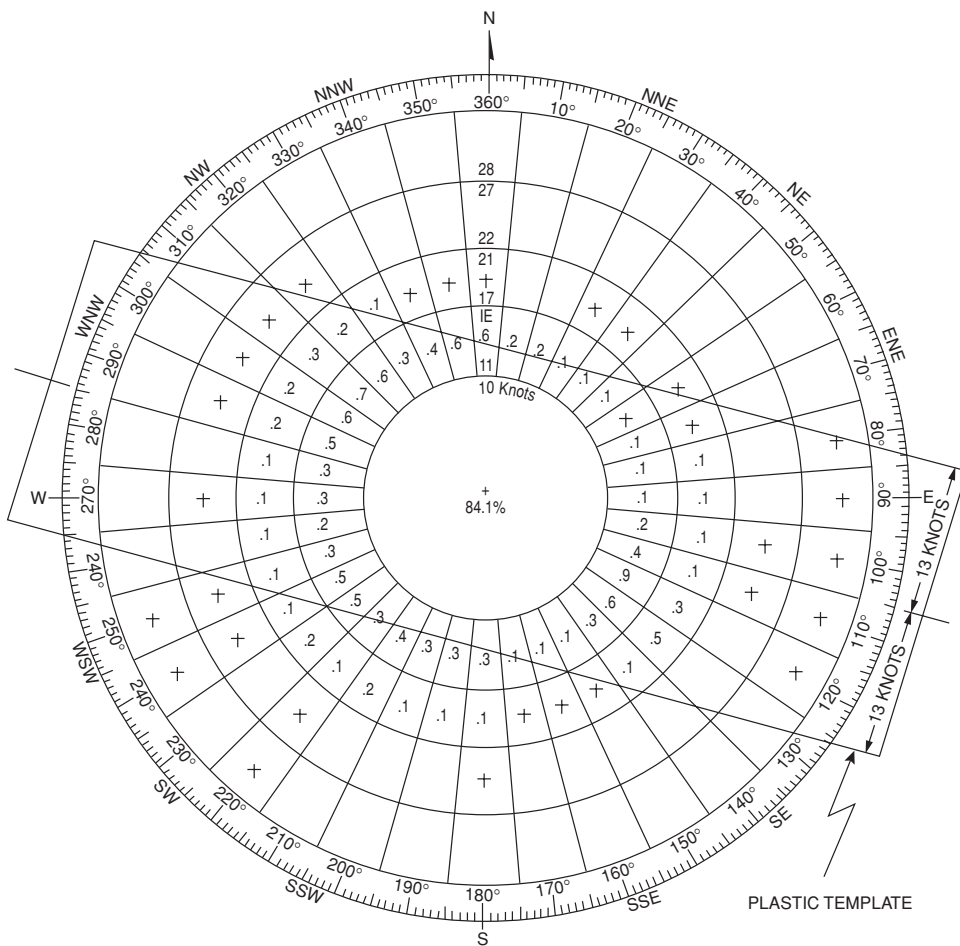
Direction	HOURLY OBSERVATIONS OF WIND SPEED										AVERAGE SPEED	
	0–3	4–6	7–10	11–16	17–21	KNOTS 22–27	28–33	34–40	41 OVER	TOTAL	KNOTS	MPH
	0–3	4–7	8–12	13–18	19–24	MPH 25–31	32–38	39–46	47 OVER			
01	469	842	568	212						2091	6.2	7.1
02	568	1263	820	169						2820	6.0	6.9
03	294	775	519	73	9					1670	5.7	6.6
04	317	872	509	62	11					1771	5.7	6.6
05	268	861	437	106						1672	5.6	6.4
06	357	534	151	42	8					1092	4.9	5.6
07	369	403	273	84	36	10				1175	6.6	7.6
08	158	261	138	69	73	52	41	22		814	7.6	8.8
09	167	352	176	128	68	59	21			971	7.5	8.6
10	119	303	127	100	98	41	9			877	9.3	10.7
11	323	506	268	312	111	23	28			1651	7.9	9.1
12	618	1397	624	779	271	69	21			3779	8.3	9.6
13	472	1375	674	531	452	67				3571	8.4	9.7
14	647	1377	974	781	129					3008	6.2	7.1
15	338	1093	348	135	27					1947	5.6	6.4
16	560	1399	523	121	19					2622	5.5	6.3
17	587	883	469	128	12					2079	5.4	6.2
18	1046	1904	1068	297	83	10				4496	5.8	6.7
19	499	793	506	241	92					2211	6.2	7.1
20	371	946	615	243	64					2239	6.6	7.6
21	340	732	528	323	147	8				2078	7.6	8.8
22	479	768	603	231	115	38	19			2253	7.7	8.9
23	107	1008	915	413	192					2715	7.9	9.1
24	458	943	800	453	96	11	18			2779	7.2	8.2
25	351	699	752	297	102	21	9			2431	7.2	8.2
26	368	731	379	208	53					1739	6.3	7.2
27	411	748	469	232	118	19				1997	6.7	7.7
28	191	554	276	287	118					1426	7.3	8.4
29	271	642	548	479	143	17				2100	8.0	9.3
30	379	873	526	543	208	34				2563	8.0	9.3
31	299	643	597	618	222	19				2398	8.5	9.8
32	397	852	521	559	150	23				2510	7.9	9.1
33	236	721	324	238	48					1567	6.7	7.7
34	280	916	845	307	24					2372	6.9	7.9
35	252	931	918	307	24					2611	6.9	7.9
36	501	1568	1381	569	27					4046	7.0	8.0
00	7729									7720	0.0	0.0
Total	21676	31828	19849	10437	3357	529	166	22		87864	6.9	7.9

FIGURE 59.29 Wind data and wind rose analysis. (From FAA, *Airport Design*, Advisory Circular AC150/5300-13, change 1, 1991c.)

Loudness is the subjective magnitude of noise that doubles with an increase of 10 decibels. The human ear is not sensitive to all noise in the aircraft-generating frequency range of 20 to 20,000 Hz. Usually it perceives noise in the middle of the range, 50 to 2000 Hz, called the A range. Sound-measuring devices generally measure noise in the A range in decibels (dBA). However, with aircraft noise, the simple dBA or sound intensity was discarded as a definitive measure because it lacked correlation to the perceived noise disturbance heard by the human ear [Ashford et al., 1991].

This led to two *single-event* noise measures: the sound exposure level (SEL) and the effective perceived noise level (EPNL). SEL is computed by accumulating instantaneous sound levels in dBA over the time the sound of the individual event is detectable. EPNL incorporates not only the sound level, but its frequency distribution and duration as well. Equation (59.11) shows how the EPNL is calculated:

$$\text{EPNL} = 10 \log \frac{1}{T} \int_0^T 10^{0.1L(t)} dt \quad (59.11)$$



A runway at the airport represented by the wind data on the left that is oriented 105° - 285° (true) would have 2.72% of the winds exceeding the design crosswind/crosswind component of 13 knots.

FIGURE 59.29 (continued).

TABLE 59.24 Runway Width and Allowable Crosswind for Landing

Runway Width W (ft)	Allowable Crosswind Component (knots)
$W < 75$	10.5
$75 \leq W < 100$	13
$100 \leq W < 150$	16
$W \geq 150$	20

Source: FAA, *Airport Design*, Advisory Circular AC150/5300-13, change 1, 1991c.

where $L(t)$ = the sound level in dBA

$T = 20$ to 30 seconds to avoid quiet periods between aircraft

Since the irritation from noise comes not from a single event but from the integrated or cumulative measure of many events, EPNL and SEL, in and of themselves, are not useful metrics for modeling the impact from aircraft noise in the vicinity of an airport.

One of the models that has come to be accepted is the *noise exposure forecast* (NEF), which embeds EPNL in its definition [Ashford et al., 1991]. The NEF has two different measures, depending on the time of day of the aircraft operation. Equation (59.12) indicates the NEF for day or night, while Eq. (59.13) shows how the day and night measures are combined.

$$\text{NEF} = \text{EPNL} + 10 \log_{10} N - K \quad (59.12)$$

where N = the number of occurrences exceeding 80 decibels (peak level of noise from a Boeing 707 at full power at a 12,000-foot altitude)

$K = 88$ for daytime operations (0700–2200) and 76 for nighttime operations (2200–0700)

$$\text{NEF}_{\text{day/night}} = 10 \log_{10} \left(\text{antilog} \frac{\text{NEF}_{\text{day}}}{10} + \text{antilog} \frac{\text{NEF}_{\text{night}}}{10} \right) \quad (59.13)$$

More recently the FAA, airports, and community officials have adopted a cumulative noise measure based on SEL [FAA, 1983a]. Nighttime operations are weighted by a factor of 10, due to the additional disturbance from such operations. The measure is called the average day–night sound exposure or L_{DN} . Equation (59.14) indicates how L_{DN} is determined for each significant noise intrusion for the i th aircraft class and the j th operational mode. Each single event (i, j) is then summed on an energy basis to obtain the total L_{DN} :

$$L_{\text{DN}} = 10 \log_{10} \sum_i \sum_j (10) \frac{L_{\text{DN}}(i, j)}{10} \quad (59.14)$$

where Ops_{day} = the number of daytime operations (0700–2200 hours)

$\text{Ops}_{\text{night}}$ = the number of nighttime operations (2200–0700 hours)

SEL = the average sound exposure level

i = the i th aircraft class

j = the j th operational mode

Having computed the noise level generated by each specific aircraft using the schedule of flights, it is then necessary to determine the effect the noise will have on the community. How much noise is too much? In what situations? Figure 59.30 shows one sample from a social survey indicating that below 50 decibels on the day–night average sound level there is virtually no annoyance. Table 59.25 describes how communities and Housing and Urban Development (HUD) have integrated the noise impacts into land-use planning recommendations (or regulations) in the community. While noise levels of L_{DN} below 65 decibels are considered acceptable by some, experience has indicated that airports would do well to plan their land acquisition program for L_{DN} levels below 60 or even 55 decibels.

Integrated Noise Model

The computer software for determining the impact of noise around an airport is called the Integrated Noise Model (INM). Available for licensing from the FAA Office of Environment and Energy, it can give the contours of equal noise exposure for any one of four different measures indicated in Table 59.26. The inputs are the airport elevation, ambient temperature, runway geometry, percentage use of each runway,

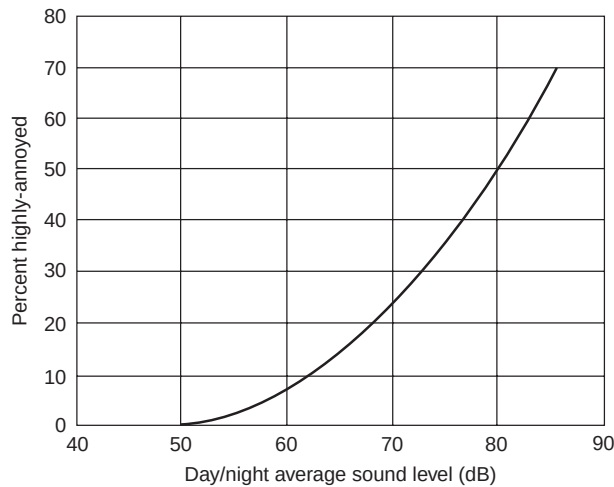


FIGURE 59.30 Degree of annoyance from noise observed in social surveys. (From Schultz, T.J., Synthesis of social surveys on noise annoyance, *J. Acoustical Soc. Am.*, 64, 1978.)

TABLE 59.25 Land Use for Various Levels of Airport Noise

Land-Use Zones	Noise Exposure Class	L_{DN}	NEF	HUD Noise Guidelines	Suggested Land-Use Controls	Recommended Land Use
A	Minimal	0–50	0–20	Acceptable	Normally requires no special consideration	Residential, cultural, public assembly, schools, resorts, mobile homes, parks, service
B	Low moderate	55–60	20–25	Normally acceptable	Some sound-reducing controls may be useful	Residential, hotels, apartments, business services, office complexes, light industry
BC	High moderate	60–65	25–30	Sometimes acceptable	Some sound-reducing controls may be useful	See note
C	Significant	65–75	30–40	Normally unacceptable	Noise easements required with strict land-use controls	Manufacturing, retail trade, construction services, refining, paper/pulp
D	Severe	>75	>40	Clearly unacceptable	Should be within the airport boundary; use of positive compatibility controls required	Highway right way, motor vehicle transportation, rail transit, undeveloped area, heavy industry, farming

Note: Airport consultants pay special attention to areas impacted or potentially impacted by noise levels of NEF 25–30 and L_{DN} 60–65. Experience indicates that owners of property in these areas of noise transition from normally acceptable to normally unacceptable noise are frequently involved in noise litigation suits. The FAA has set L_{DN} limits at 65. Practitioners consider residential uses regardless of density as unacceptable land use below 60 dB. This is particularly true under the glide paths or tracks for landing or takeoff. The Environmental Protection Agency suggests that the safe L_{DN} criterion for “health and welfare” is 55 dB [EPA, 1974]. They set 60 dB with a 5-dB safety margin for outdoor noise in a residential neighborhood. (Adapted from FAA, *Airport Land Use Compatibility Planning*, Advisory Circular AC150/5050-6, 1983.)

number of operations during the day and at night, expected aircraft in each time space, and expected tracks of approach and takeoff in several altitude and distance segments.

Figure 59.31 shows a three-runway airport with the operational flight tracks that are to be used in computation of the noise. The noise along each track will differ depending on the number of aircraft in a day, the nighttime traffic, and the specific aircraft that are anticipated to fly each track. The model stores a database of existing aircraft by make, model number, the number of aircraft in a day, the nighttime traffic, and the specific aircraft that are anticipated to fly each track. Included are their altitude profiles

TABLE 59.26 Capabilities of INM

Measure of Noise	Symbol	Description
Noise exposure forecast	NEF	Based on EPNL as a unit of aircraft noise; nighttime operations are weighted by 16.7 per one operation
Equivalent sound level	SEL	Summation of aggregate noise environment dBA
Day–night average sound	L_{DN}	Based on SEL with nighttime operations weighted by a 10-dB penalty; see Eq. (59.13)
Time above threshold of A-weighted sound	TA	Time in min that a dBA level is exceeded in a 24-h period

Source: FAA, *Integrated Noise Model*, Version 3, revision 1, DOT/FAA/EE-92/02, 1992.

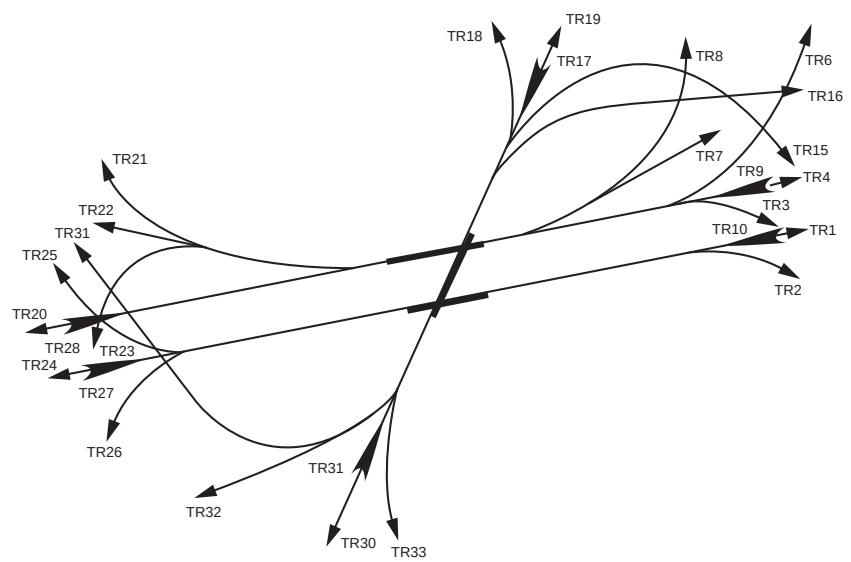


FIGURE 59.31 Input flight tracks to the integrated noise model.

for generating noise as a function of trip length (takeoff weight and flap setting) and flap setting on landing. [Figure 59.32](#) shows a typical output of the program in terms of L_{DN} .

To identify the places of noise impact the contours are overlaid on a map of the community. [Figure 59.33](#) shows the impact on the community for the Standiford Airport in Louisville, Kentucky. The takeoff and landing tracks are critical and can have a large impact on the community noise patterns. The data appearing in the inset of Fig. 59.33 indicate the level of community impact.

The noise models using either L_{DN} or NEF are essential for airport authorities in planning and working with communities. For simple planning, an area about 2 miles wide and 6 miles from the end of the runway should provide a quick, hopefully conservative, view of potential noise problems.

59.8 Airside Layout and Design

Design begins with the knowledge of both the performance and physical characteristics of the aircraft that will use the airport. As defined in Section 59.5, the approach or landing speed defines an aircraft category as A, B, C, or D. The designation of aircraft size is based on grouping aircraft according to the length of their wingspan, called *aircraft design group* (ADG), as follows:

- Group I: up to but not including 49 ft (15 meters)
- Group II: 49 ft (15 m) up to but not including 79 ft (24 m)

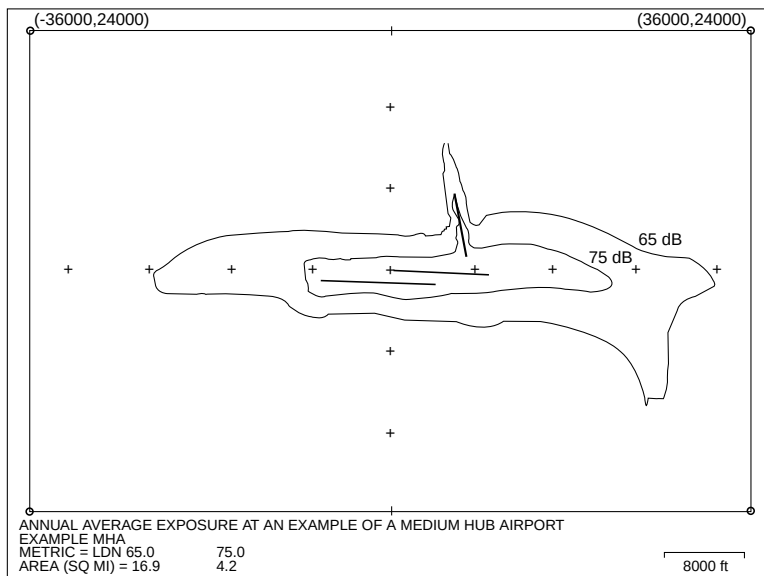


FIGURE 59.32 Noise contours for planning purposes.

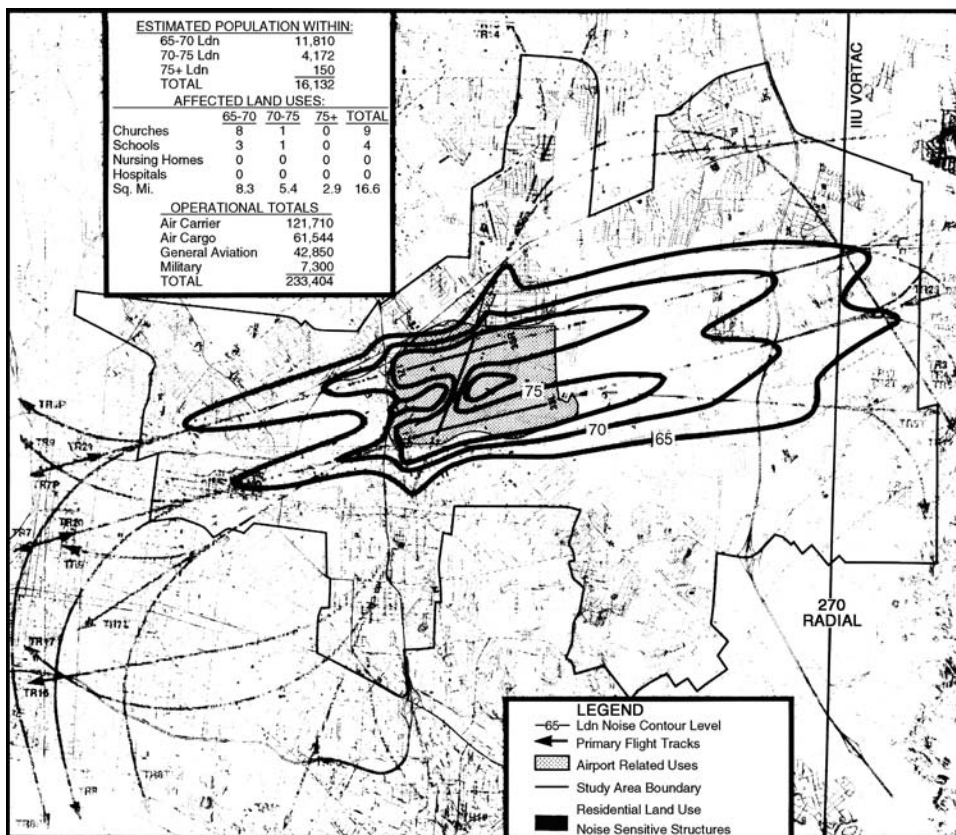


FIGURE 59.33 Sample of noise contours and community land-use plan. (From FAA, *Final Environmental Impact Statement*, Standiford Field Airport, Louisville, KY, 1990.)

MODEL	MAXIMUM TAKEOFF WEIGHT	MAXIMUM LANDING WEIGHT	A	B	C	D	E	F	G	J	K	M	N	P	TURN RADIUS
100	160,000 LB 72 575 KG	137,500 LB 62 369 KG	108'0" 32.92M	133'2" 40.59M	34'3" 10.44M	53'3" 16.23M	68'4" 20.83M	18'9" 5.72M	9'3" 2.82M	42'6" 12.95M	10'4" 3.15M	14'4" 4.37M	5'8" 1.72M	12'0" 3.66M	72'0" 21.95M
100-C	160,000 LB 72 575 KG	137,500 LB 62 369 KG	108'0" 32.92M	133'2" 40.59M	34'3" 10.44M	53'3" 16.23M	68'4" 20.83M	18'9" 5.72M	9'3" 2.82M	42'6" 12.95M	10'4" 3.15M	14'4" 4.37M	5'8" 1.72M	12'0" 3.66M	72'0" 21.95M
200	172,000 LB 78 018 KG	150,000 LB 68 039 KG	108'0" 32.92M	153'2" 46.68M	34'11" 10.65M	63'3" 19.28M	78'4" 23.86M	18'9" 5.72M	9'3" 2.82M	42'4" 12.90M	10'4" 3.15M	16'11" 5.16M	4'9" 1.44M	12'0" 3.66M	82'0" 24.99M
NOTE: OPTIONAL TAKEOFF AND LANDING WEIGHTS:															
100	160,000 LB (72 575 KG) 142,500 LB (64 637 KG)	169,000 LB (76 657 KG) 142,500 LB (64 637 KG)	MAXIMUM TAKEOFF WEIGHT, MAXIMUM LANDING WEIGHT,												
100C	160,000 LB (72 575 KG) 140,000 LB (63 503 KG)	169,000 LB (76 657 KG) 142,500 LB (64 637 KG)	MAXIMUM TAKEOFF WEIGHT, MAXIMUM LANDING WEIGHT,												
200	184,800 LB (83 824 KG) 154,500 LB (70 080 KG)	190,500 LB (86 409 KG) 154,500 LB (70 080 KG)	197,000 LB (89 358 KG) 154,500 LB (70 080 KG)	209,500 LB (95 028 KG) 161,000 LB (73 028 KG)	MAXIMUM TAKEOFF WEIGHT, MAXIMUM LANDING WEIGHT,										

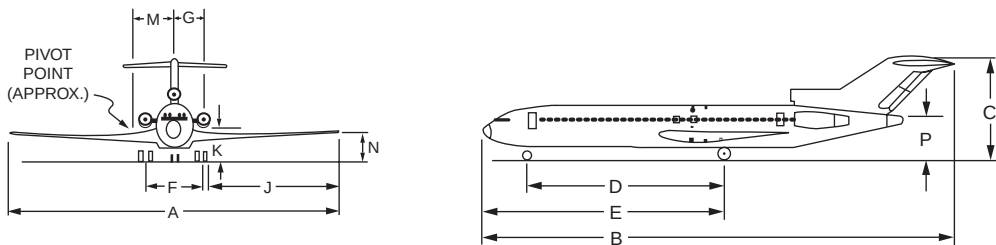


FIGURE 59.34 Sample aircraft dimensions (Boeing 727) for airport design. (From FAA, *Airport Design*, Advisory Circular AC150/5300-13, change 1, 1991c.)

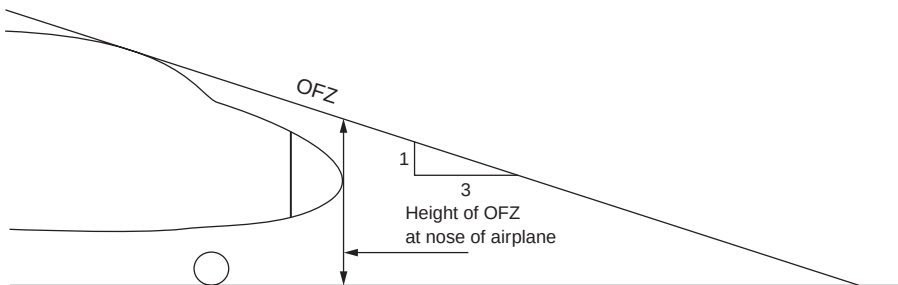


FIGURE 59.35 Object-free zone requirements as viewed from the cockpit. (From FAA, *Airport Design*, Advisory Circular AC150/5300-13, change 1, 1991c.)

- Group III: 79 ft (24 m) up to but not including 118 ft (36 m)
- Group IV: 118 ft (36 m) up to but not including 171 ft (52 m)
- Group V: 171 ft (52 m) up to but not including 214 ft (65 m)
- Group VI: 214 ft (65 m) up to but not including 262 ft (80 m)

The important physical characteristics of the aircraft affecting airport design are maximum takeoff weight (W), wingspan (A), length (B), tail height (C), wheel base (D), nose to centerline of main gear (E), undercarriage width ($1.15 \times$ main gear track, F), and line-of-sight/obstacle-free zone at the nose of the aircraft. For reference, these are presented for the Boeing 727 in Fig. 59.34 [FAA, 1991c].

Figure 59.35 displays a major problem faced by aircraft as they land and travel on the runway, taxiway, or taxilane system. The pilot’s view of the ground directly in front of the aircraft is obscured by the nose. This blind zone for the pilot is known as the object-free zone (OFZ) and is important for safe ground movement of aircraft. It affects the geometric design of the runway and taxiway. Table 59.27 shows the approach speed and physical characteristics for several specific aircraft.

Other input data to the computer program are the primary navigation capability, the altitude or elevation of the airport, and the mean temperature of the hottest month of the year. The program outputs

TABLE 59.27 Aircraft Data Used by Design Program (Representative Sample)

Aircraft Make/Model	Airport Reference Code	Approximate Approach Speed (knots)	Wingspan (ft)	Length (ft)	Tail Height (ft)	Maximum Takeoff Weight (lb)
Cessna-150	A-I	55	32.7	23.8	8.0	1,600
Beech King Air-B100	B-I	111	45.8	39.9	15.3	11,800
Gates Learjet 54-56	C-I	128	43.7	55.1	14.7	21,500
Dornier LTA	A-II	74	58.4	54.4	18.2	15,100
Shorts 360	B-II	104	74.8	70.8	23.7	26,453
Grumman Gulfstream III	C-II	136	77.8	83.1	24.4	68,700
DHC-8, Dash 8-300	A-III	90	90	84.3	24.6	41,100
Fairchild F-27	B-III	109	95.2	77.2	27.5	42,000
Boeing 727-200	C-III	138	108	153.2	34.9	209,500
Boeing 737-400	C-III	138	94.8	119.6	36.6	150,000
MDC-DC-9-50	C-III	132	93.3	133.6	28.8	121,000
Airbus 300-600	C-IV	135	147.1	177.5	54.7	363,763
Boeing 757	C-IV	135	124.8	155.3	45.1	255,000
Boeing 767-300	C-IV	130	156.1	180.3	52.6	350,000
MDC-DC-8-50	C-IV	133	142.4	150.8	43.3	325,000
MDC-DC-10-30	D-IV	151	165.3	181.6	58.6	590,000
MDC-MD-11	D-IV	155	169.8	201.3	57.8	602,500
Boeing 747-200	D-V	152	195.7	231.8	64.7	833,000
Boeing 747-400	D-V	154	213.0	231.8	64.3	870,000
Lockheed C5A	C-VI	135	222.7	247.8	65.1	837,000

Source: FAA, *Airport Design*, Circular AC150/5300-13, change 1, 1991c.

include runway lengths, widths, and clearance standards. Outputs that develop taxiway design data, such as widths and clearance standards, steering angles on tangent sections, circular curve layouts, spiral curve layouts, offset distances on taxiway intersections, offsets on exit taxiways, and the wing tip clearance on taxiways, are possible. The program has plotting capability for exit taxiways, taxiway intersections, or the curved track for wing tip clearance on taxiways, as demonstrated in the spiral-double-back exit taxiway and acute-angled taxiway plotted in [Fig. 59.36](#). The design program will also calculate the wind rose data. (See Section 59.7.)

Runway Length

The length of the runway is determined by the aircraft, maximum takeoff weights, engine capabilities, landing and braking capabilities, flap settings, and required safety factors. For example, the runway length for landing must be capable of permitting safe braking if touchdown occurs one third the length of the runway past the threshold. The runway must also be long enough to meet the obstacle-free capability to permit each aircraft to take off with one engine out. The stopping zone must include ample stopping distance in case the pilot chooses to abort takeoff just before rotating to become airborne (called stopway). As discussed, the runway safety areas are a must for airport control. [Figure 59.37](#) shows the stopway, to prevent accidents at the end of the runway, and the clearway, also called the runway protection zone.

The altitude of the airport and the temperature also have a significant impact on the airport runway length, because lift capability is proportional to the air density, which diminishes as the altitude and temperature increase. [Figure 59.38](#) illustrates how dramatic that change is for a Boeing 727-200 with a JT8D-15 engine, a takeoff weight of 150,000 pounds, and its wing flaps set at 20 degrees. The requirement for longer runways increases significantly as the altitude of the site above sea level increases. At an average temperature of 65 degrees Fahrenheit, the increase is from 4900 feet at sea level to 8660 feet at an altitude of 8000 feet, or about 370 feet of added runway for each 1000-foot increase in altitude. The increase due to temperature, especially when the temperature is high, is equally dramatic. Going from 65 to 80 degrees Fahrenheit for an airport at a 4000-foot elevation requires an increase in runway length of about 24 feet per degree Fahrenheit. For the shift from 95 to 110 degrees Fahrenheit for an airport at a 4000-foot

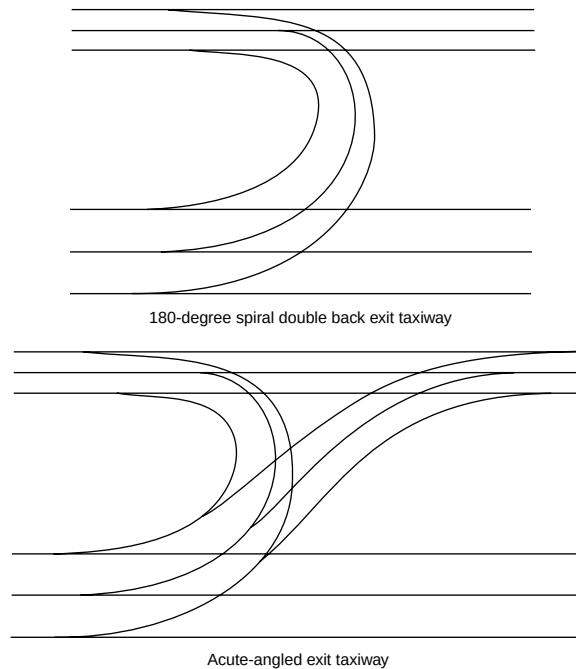


FIGURE 59.36 Sample of steering and taxiway fillet design from airport design program.

elevation the rate of increase in runway length is 58 feet per degree Fahrenheit. Thus on any specific runway there is a maximum allowable takeoff weight (MATOW), depending on the ambient temperature, the specific aircraft (with its specific engines), and the altitude of the airport.

The advisory circular [FAA, 1990a] on runway length presents the takeoff weight data for several different flap angles. Taking off with a low flap angle permits a higher MATOW, but takes a longer runway to attain the speed to become airborne. Figure 59.39 plots the MATOW for various flap angles for a temperature of 90 degrees Fahrenheit at the TBA airport. The curve beginning at the lower left is constrained by the length of the 9500-foot (2900-meter) runway, while the curve beginning at the upper left is constrained only due to aircraft engine thrust capability of the JT8D-15 engines, assuming sufficient runway length is available. A setting of flap angle at about 17 degrees will give the highest MATOW of 167,500 lb (76,050 kg) for a day with a 90-degree-Fahrenheit temperature.

The major operational constraint, when there is a weight limitation caused by a shorter-than-optimum runway, is the range that can be achieved. The 727-200 with JT8D-15 engines has an empty weight of 109,211 lb and a structural payload weight of 40,339 pounds [FAA, 1990a]. Tables such as the example shown in Table 59.28 are available for most aircraft and for a range of flap angle settings for each aircraft. If the flaps are set at 15 degrees at the MRA airport on a 90-degree-Fahrenheit day, it can be seen that the MATOW should be 175,400 pounds (79,725 kilograms), as indicated by A on Table 59.28. By use of the reference factor of 86.9 (B on Table 59.28) and linear interpolation at the bottom portion (C), the runway would have to be 10,680 ft (3250 m). Since the runway is only 9500 feet (2900 meters), interpolation would indicate a MATOW of 166,500 lb (75,680 kg).

Using this value, several different options of weight and range can be considered. These options are presented in Table 59.29 as the “Max Payload” case, the “1500-Mile-Range” case, and the “50% Load Factor” case. The two critical numbers for all these cases are the fuel rate of 22 pounds per mile for this aircraft and the average weight of passengers with their luggage of 200 lb per passenger. In the first case, a full load would be determined by subtracting the structural payload weight of 40,339 lb plus the operating empty weight of 109,211 lb from the MATOW of 166,500 lb. This leaves 16,950 lb for fuel, which at 22 lb per mile gives a range of 770 miles.

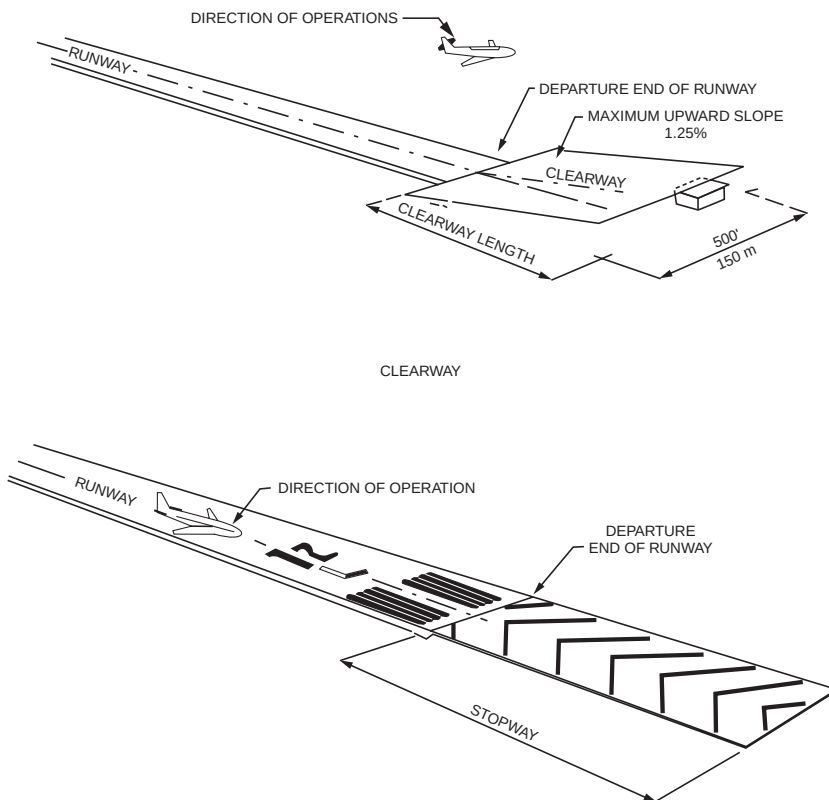


FIGURE 59.37 View of the clearway and stopway. (From FAA, *Airport Design*, Advisory Circular AC150/5300-13, change 1, 1991c.)

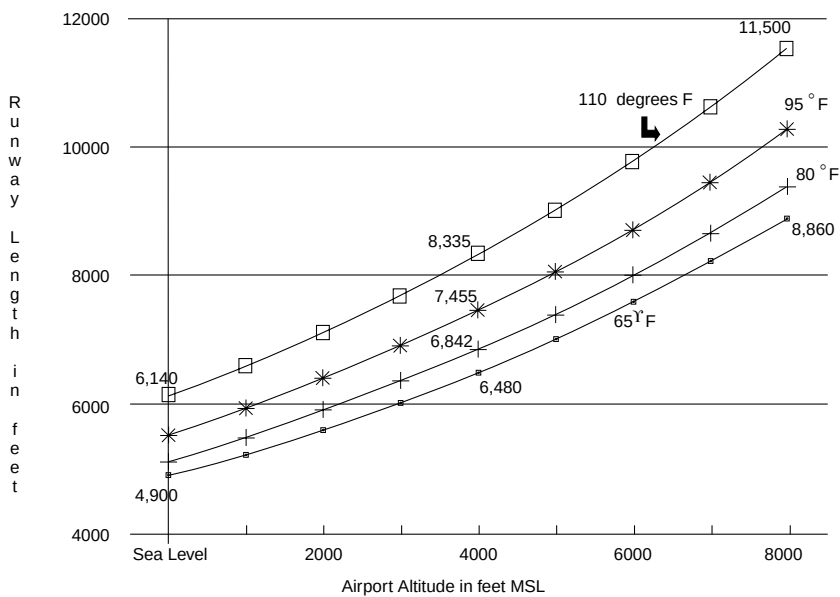


FIGURE 59.38 Change of required takeoff runway length due to temperature and altitude.

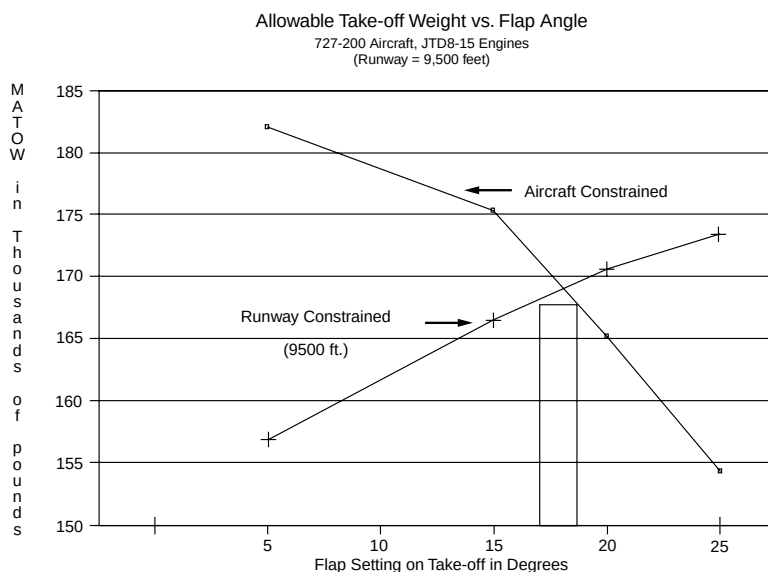


FIGURE 59.39 Takeoff weight as a function of flap angle setting.

The next case for a 1500-mile flight. After removing the operating empty weight and enough fuel for 1500 miles (33,000 lb) the weight left for passengers and cargo is 24,289 lb, which (if all of it is allotted to passengers) gives 141 passengers. The final case assumes a 50% load factor of 81 passengers or 16,200 lb, leaving 41,089 lb for fuel. This amount of fuel would give a range of 1867 miles. The airlines will assign aircraft to meet the range or payload requirements of the markets they serve. It behooves the airport planner to make sure that the runway is long enough to serve the most distant markets that will attract airlines, while also accounting for the hot summer weather.

The other runway length limitation is on landing, which usually requires less runway than does takeoff. Critical items are landing weight and flap settings. At the TBA airport, with a 90-degree-Fahrenheit temperature, the maximum allowable landing weight is 154,500 lb (70,230 kg) with 30-degree flaps, which would require 5720 ft (1750 m) of runway. Since the aircraft does not have the weight of fuel when landing, there is usually a good margin for landing.

“Declared distances” are distances the airport owner declares available and suitable for satisfying the airplane’s takeoff distance, accelerate–stop distance, and landing distance requirements. The distances are:

- Takeoff run available (TORA): the runway length declared available and suitable for the ground run of an airplane takeoff
- Takeoff distance available (TODA): the TORA plus the length of any remaining runway or clearway (WY) beyond the far end of the TORA
- Accelerate–stop distance available (ASDA): the runway plus stopway (SWY) length declared available and suitable for the acceleration and deceleration of an airplane aborting a takeoff
- Landing distance available (LDA): the runway length available and suitable for a landing airplane

Runway and Taxiway Width and Clearance Design Standards

The FAA has developed a set of standard dimensions that determine runway width, separations between runways and taxiways, safety areas around runways and taxiways, shoulder width (possible areas of less-than-full-strength pavement), pads to deflect jet blast, object-free areas, and the like. These standards are a function of approach speed and aircraft size. [Figure 59.40](#) presents the overall dimensions that are involved in parallel runways and taxiways, while [Table 59.30](#) shows the standards for airports that service aircraft in the approach speed categories C and D. [Figure 59.41](#) shows the plan view of major runway

TABLE 59.28 Aircraft Performance, Takeoff Boeing 727–200, JT8D-15 Engine, 15° Flaps

Maximum Allowable Takeoff Weight (1000 lb)									
Airport Elevation (100 ft)									
Temp (°F)	0	1000	2000	3000	4000	5000	6000	7000	
50	197.0	197.0	197.0	193.4	186.9	180.2	173.5	166.9	
60	197.0	197.0	197.0	193.4	186.9	180.2	173.5	166.9	
70	197.0	197.0	197.0	193.4	186.9	180.2	173.5	166.9	
80	197.0	197.0	196.2	189.0	182.2	175.8	169.5	163.4	
90	197.0	195.8	188.7	181.9	175.4 (A)	169.0	162.9	156.8	
100	194.5	187.7	181.0	174.5	168.2	162.0	156.0	150.2	
110	186.5	179.7	173.1	166.8	159.7	154.8	149.0	143.4	
Reference Factor									
Airport Elevation (1000 ft)									
Temp (°F)	0	1000	2000	3000	4000	5000	6000	7000	
50	58.6	61.6	65.7	70.7	76.5	83.0	90.2	97.9	
60	58.4	62.0	66.3	71.3	77.0	83.4	90.5	98.4	
70	59.4	63.5	68.1	73.2	78.9	85.4	92.6	100.6	
80	61.4	65.9	70.8	76.2	82.2	88.9	96.4	104.9	
90	64.5	69.4	74.7	80.5	86.9 (B)	94.0	102.0	111.0	
100	68.7	73.9	79.6	85.9	92.9	100.7	109.4	119.0	
110	74.0	79.4	85.5	92.5	100.3	109.0	118.5	129.0	
Runway Length (1000 ft)									
Reference Factor									
Weight (1000 lb)	58	68	78	86.9	88	98	108	118	128
130	396	455	520		5.90	6.61	7.28	7.88	8.39
135	423	489	559		6.30	7.00	7.66	8.28	8.82
140	451	525	599		6.73	7.44	8.13	8.78	9.39
145	481	563	642		7.19	7.94	8.67	9.38	10.08
150	513	602	687		7.69	8.49	9.29	10.09	10.90
155	546	644	735		8.23	9.10	9.98	10.89	11.85
160	582	686	785		8.81	9.77	10.76	11.80	12.93
165	618	731	838	9.31	9.42	10.49	11.61	12.81	14.13
166.5				9.50(D)					
170	657	777	892	9.95	10.08	11.26	12.53	13.92	
175	697	825	949	10.62	10.76	12.10	13.54		
175.4				10.68(C)					
180	737	874	1009	11.34	11.49	12.98			
185	783	925	1071		12.25	13.92			
190	828	978	1135		13.05				

Source: FAA, *Runway Length Requirements for Airport Design*, Advisory Circular AC150/5325-4A, 1990a.

elements. The runway protection zone was shown in Fig. 59.26. There are similar data for airports serving approach categories A and B. These dimensions are all listed in the airport design computer program output [FAA, 1991c].

Runway Gradients

Longitudinal Gradient

The desire at any airport site is to have the runways and taxiways as level as possible, allowing for drainage with the design of the transverse grade. In many locations the grading for a perfectly level site would be too expensive when most aircraft can easily accept 1% grade. Where longitudinal grades are used,

TABLE 59.29 Range/Payload Calculation for 727-200 with JT8D-15 Engines and 15° Flaps

Characteristic	Units/Notes	Max Payload Case	1500-Mile-Range Case	50% Load Factor Case
Maximum allowable takeoff weight	Table 59.30 gives 175,400 lb as the maximum takeoff weight; however, that much weight requires a runway length of 10,680 ft; see Table 59.30(C)			
Takeoff weight	Calculated using reference factor (86.9): Table 59.30 (D)	166,500 lb [76,650 kg]	166,500 lb [76,050 kg]	166,500 lb [76,050 kg]
Typical operating empty weight plus reserve	Given (1.25 h of fuel reserve required for domestic flight)	109,211 lb [49,650 kg]	109,211 lb [49,650 kg]	109,211 lb [49,650 kg]
Remaining for payload and fuel		57,289 lb [26,040 kg]	57,289 lb [26,040 kg]	57,289 lb [26,040 kg]
Passenger	Maximum = 162	162 (100% load factor)	141 (87% load factor)	81 (50% load factor)
162 maximum passengers	200 lb [90 kg] per passenger	32,400 lb ^a [14,730]	24,289 lb [11,040 kg]	16,200 lb [7365 kg]
Max belly air cargo	Fill to structural payload limit of 40,339 lb ^a [18,335 kg]	7,939 lb [3605 kg]	0 lb	0 lb
Amount of fuel		16,950 lb [7,700 kg]	33,000 lb [15,000 kg]	41,089 lb [18,675 kg]
Distance of market served range	Fuel rate given 22 lb/mile [6.2 kg/km]	770 miles [1240 km]	1500 miles [2415 km]	1867 miles [3005 km]

^a Calculated from data in FAA, *Runway Length Requirements for Airport Design*, Advisory Circular AC150/5325-4A, 1990a.

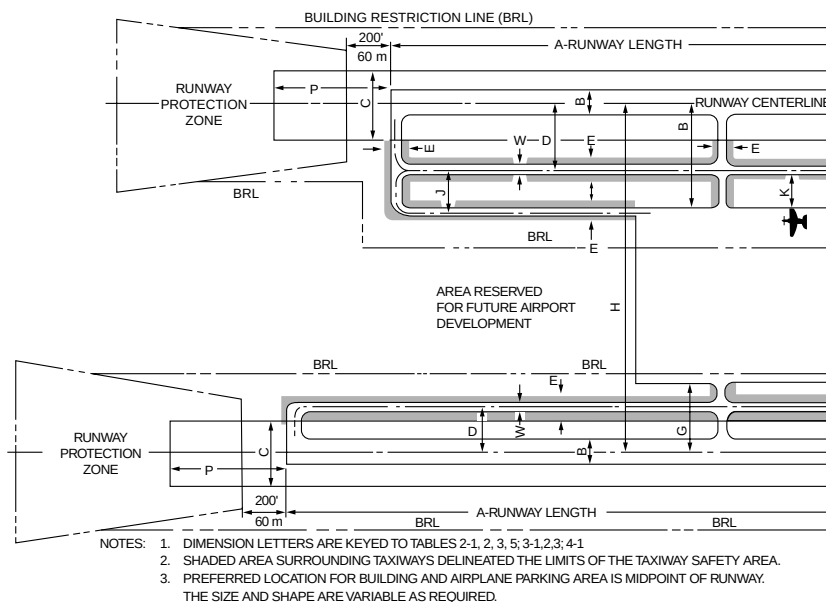


FIGURE 59.40 Runway and taxiway dimensions. (From FAA, *Airport Design*, Advisory Circular AC150/5300-13, change 1, 1991c.)

parabolic vertical curves are used for geometric design, as shown in Fig. 59.42. The penalty for gradients is to reduce the effective runway length by 10 feet per foot of difference between maximum and minimum elevation of the runway [FAA, 1992]. Table 59.31 defines the gradients in terms of approach category.

For example, if the runway at TBA were 10,200 feet long but there was a differential between the highest point and the lowest point along the runway of 70 feet, the effective runway length for MATOW calculations would be 9500 (10,200 – 70 × 10) feet.

TABLE 59.30 Separation Standards for Transport Airport Design (Approach Categories C and D)

Design Item	Figs. 59.40 and 59.41 Dimensions	Airplane Design Group					
		I	II	III	IV	V	VI
For Runways							
Safety area width (ft)	C	500	500	500	500	500	500
Safety area length beyond runway end (ft)	P	1000	1000	1000	1000	1000	1000
Width (ft)	B	100	100	100	150	150	200
Shoulder width (ft)		10	10	20	25	35	40
Blast pad width (ft)		100	100	140	200	220	280
Object-free area width (ft)	Q	800	800	800	800	800	800
Object-free area length beyond runway end	R	1000	1000	1000	1000	1000	1000
Nonprecision instrument and visual runway centerline to:							
Parallel runway (simultaneous VFR ops. ^b) (ft)	H	700	700	700	700	1200	1200
Taxiway/taxilane centerline (ft)	D	300	300	400	400	400–500 ^a	600
Aircraft parking area (ft)	G	400	400	500	500	500	500
Precision instrument runway centerline to:							
Parallel runway (simultaneous IFR ops. ^c)	H	4300	4300	4300	4300	4300	4300
Taxiway/taxilane centerline (ft)	D	400	400	400	400	400–500 ^a	600
Aircraft parking area (ft)	G	500	500	500	500	500	500
For Taxiways							
Safety area width (ft)	E	49	79	118	171	214	262
Width (ft)	W	25	35	50	75	75	100
Edge safety margin (ft)		5	7.5	10	15	15	20
Shoulder width		10	10	20	25	35	40
Object-free area width (ft)		89	131	186	259	320	386
Centerline to:							
Parallel taxiway/taxilane centerline (ft)	J	69	105	152	215	267	324
Fixed or movable object (ft)	K	44.5	65.5	93	129.5	160	193
For Taxilanes							
Object-free area width (ft)		79	115	162	225	276	334
Centerline to:							
Parallel taxiway/taxilane centerline (ft)		64	97	140	198	245	298
Fixed or movable object (ft)		39.5	57.5	81	112.5	138	167

Note: ops. = operations.

^a 400 ft applies for airports from sea level to 1345-ft altitude; 450 ft from 1345- to 6560-ft altitudes; and 500 ft for altitudes greater than 6560 ft.

^b Separations less than 2500 ft require wake turbulence procedures.

^c Other separations are possible for simultaneous departures only: with radar 2500 ft, without radar 3500 ft.

Source: FAA, *Airport Design*, Advisory Circular AC150/5300-13, change 1, 1991c.

Line of Sight

The line-of-sight requirements also determine the acceptable profile of the runway. Any two points 5 feet above the runway centerline must be mutually visible for the entire runway or if on a parallel runway or taxiway for one half of the runway. Likewise, there needs to be a clear line of sight at the intersection of two runways, two taxiways, and taxiways that cross an active runway. Most line-of-sight requirements are within 800 to 1350 feet of the intersection, depending on the configuration.

Transverse Gradients

The transverse gradients are important to ensure adequate drainage from the runways and the taxiways. The plan view shown in Fig. 59.41 indicates the typical gradients that are included in runways and taxiways. The chief concern is drainage and the line of sight to adjacent runways or taxiways.

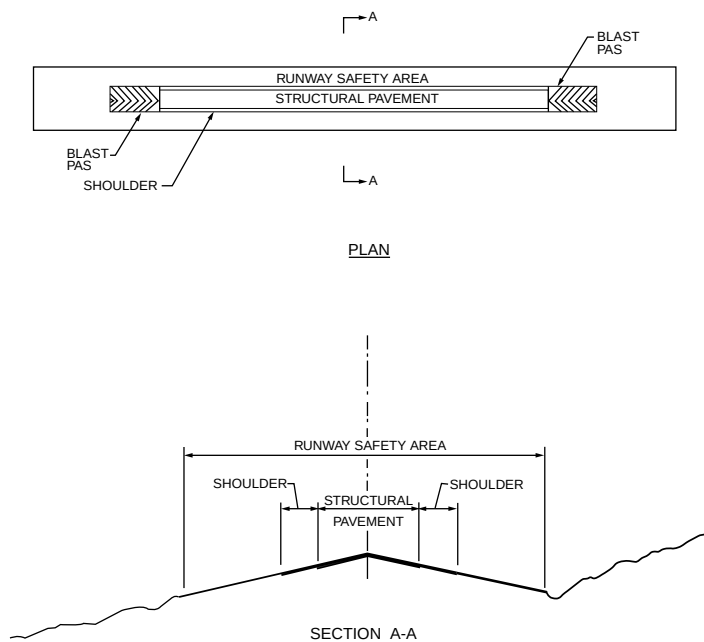
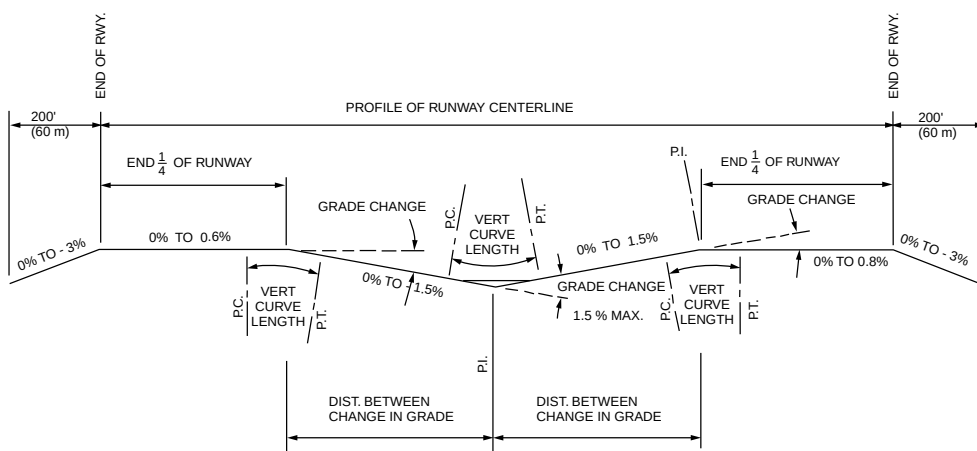


FIGURE 59.41 Plan and cross section view of the runway elements. (From FAA, *Airport Design*, Advisory Circular AC150/5300-13, change 1, 1991c.)



MINIMUM DISTANCE BETWEEN CHANGE IN GRADE = 1000' (300 m) x SUM OF GRADE CHANGES (IN PERCENT).

MINIMUM LENGTH OF VERTICAL CURVES = 1000' (300 m) x GRADE CHANGE (IN PERCENT)

FIGURE 59.42 Longitudinal grade criteria for airports (C and D approach criteria). (From FAA, *Airport Design*, Advisory Circular AC150/5300-13, change 1, 1991c.)

Drainage

Drainage on the airport surface is a prime requisite for operational safety and pavement durability. The drainage design is handled like most drainage for streets and highways. Avoidance of ponding and erosion of slopes that would weaken pavement foundations is critical for design. Because of the need for quick and total water removal over the vast, relatively flat airport surface, an integrated drainage system is a must. Runoff is removed from the airport by means of surface gradients, ditches, inlets, an underground

TABLE 59.31 Longitudinal Gradients for Runways and Taxiways

Design Item	Aircraft Served	Maximum Rate of Change	Vertical Curve (ft/% change)	Remarks
Runway	A and B	$\pm 2\%$	300	Vertical curve not needed for changes less than 0.4%
Runway	C and D	$\pm 1.5\%$	1000	Grade on first and last one fourth of runway $\pm 0.8\%$; vertical curve not needed for changes less than 0.4%
Runway	A and B	$\pm 2\%$	100	Elevation between taxiway and corresponding point on parallel runway
Taxiway	C and D	$\pm 1\%$	100	Taxiway or apron edge is 1.5% of shortest distance between the two
Apron	A and B	$\pm 2\%$		Consistent with drainage
Apron	C and D	$\pm 1\%$		Direct drainage away from building

Source: FAA, *Airport Design*, Advisory Circular AC150/5300-13, change 1, 1991c.

system of pipes, and retention ponds. [Figure 59.43](#) shows one portion of an airport drainage system. Because of their large contiguous area, aprons are critical and must have an adequate sewer system. Runoff water treatment is required when there are fuel spills or during the winter, when a deicing chemical is used.

Lighting and Signing

Runway

Lighting and signing of the runway shown in [Fig. 59.44](#) provide the pilot visual cues to ensure alignment with the runway, lateral displacement, and distance along the runway. Runway edge lights standing no more than 30 inches and no more than 10 ft from the runway edge are 200 ft or less apart and are white, except for the last 2000 ft of runway, when they show yellow. Centerline lights are white and set 2 ft off the centerline of the runway, except for the last 3000 ft. In this area they are alternating red and white for 2000 ft, and they are red 1000 ft from the runway end. When aircraft are approaching the runway to land, the pilot determines the threshold because it is marked by a bar of green lights. However, those lights show red when aircraft approach the end of the runway from the other direction. As shown in [Fig. 59.45](#), painted markings also indicate where the aircraft is relative to distance past the threshold. Exits, particularly high-speed exits, are clearly marked by signs placed at a distance of 1200 to 1500 ft before the exit.

Airfield

The airfield is marked with a variety of signs delineating the taxiways, stoplines, holding areas, and the like. Blue lights indicate taxiway edges. Stop bars before crossing or entering an active runway are yellow. There have been a number of accidents and near accidents on the ground, especially when the visibility is low. The FAA is experimenting with a new lighted stop bar. The controller controls the lights. When the bar is lit there are now center lights ahead, creating a black hole effect. Once the aircraft is permitted on the runway, the light bar is extinguished and the taxiway/runway lights are illuminated to guide the pilot onto the runway for takeoff [FAA, 1993b].

Typical airfield markings give the pilot directions to the ramp, parking areas, fuel, gates, areas for itinerant aircraft, ramps for military aircraft, cargo terminals, international terminals, and other airside functions. Visual cues also aid the pilot in docking the aircraft at the gate. Generally there is also an airline ground employee with handheld signal lights to direct the pilot as the aircraft pulls into the gate. [Figure 59.46](#) shows the FAA's 1993 guide to airfield signs.

Approach to the Runway

The approach lighting system (ALS) dictates the navigation and approach capability. Light bars may extend as much as 3000 feet from the threshold along the aircraft's desired glide path. Lighting systems

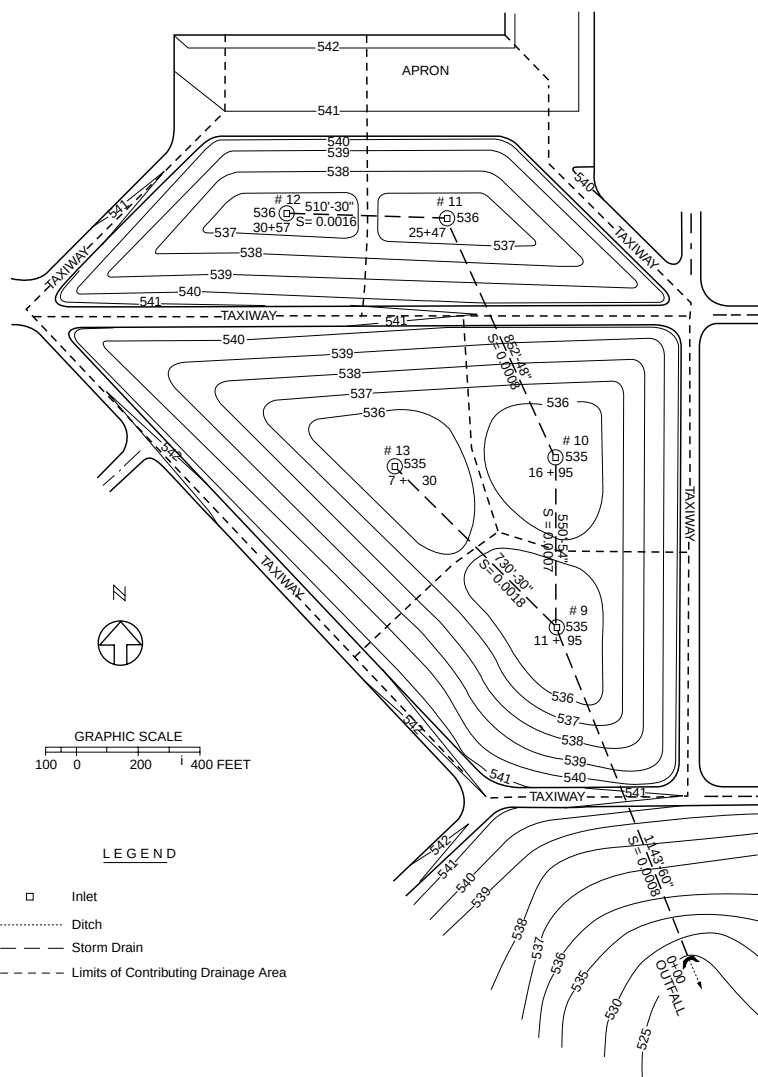


FIGURE 59.43 Portion of an airport showing drainage design. (From FAA, *Airport Drainage*, Advisory Circular AC150/5320-5B, 1970.)

are available to provide runway glide slope cues indicating whether the pilot is above, below, right, or left of the hypothetical wire representing the proper descent trajectory. The visual approach slope indicator systems (VASIS) provide at the side of the runway red and white light bars.

The precision approach path indicator (PAPI) system provides upper and lower lights of red and white that in various combinations indicate whether the pilot is too low or too high. For example, an all-white bar indicates the aircraft is on a glide slope greater than 3.5 degrees, while an all-red bar is less than 2.5 degrees. Equal red and white indicates the aircraft is on the 3-degree glide slope.

Positioning along the glide path is accomplished by the use of light bars extending from the runway along the flight path. There are several different approach lighting systems, as suggested in [Fig. 59.47](#). For precision approaches (category I, II, or III) ILS, the high-intensity approach lighting system with sequenced flashing lights (ALSF) is employed. The ALS consists of light bars 3000 ft from the threshold. From 3000 to 1000 ft the lights are a sequenced flasher that gives the appearance of a rolling ball leading to the runway centerline. From 1000 ft (inner marker) to the threshold there are white light bars in the

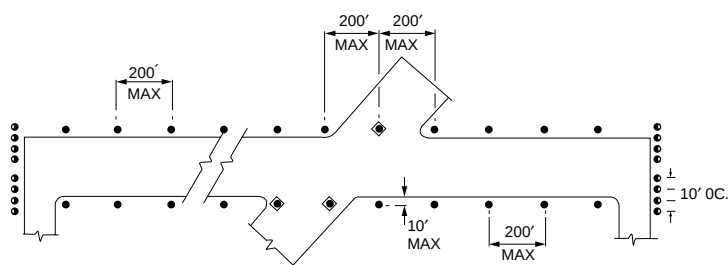
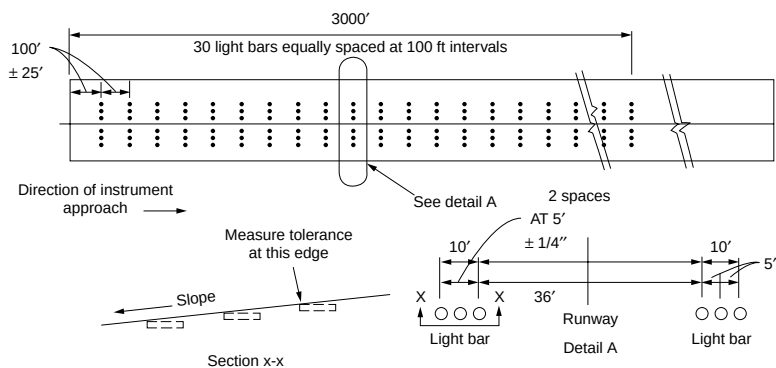


FIGURE 59.44 Runway lighting. (From FAA, *Standards for Airport Markings*, Advisory Circular AC150/5340-IG, 1993c.)

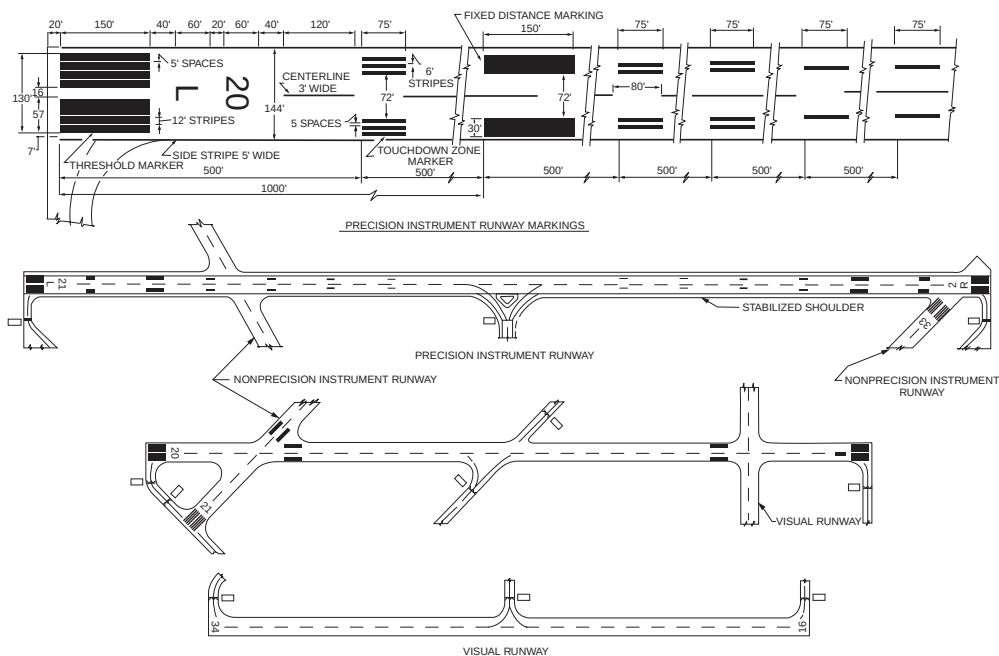


FIGURE 59.45 Marking along the runway. (From FAA, *Standards for Airport Markings*, Advisory Circular AC150/5340-IG, 1993c.)

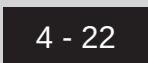
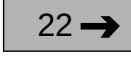
GUIDE TO AIRFIELD SIGNS (U.S.)	
SIGN and LOCATION	PILOT ACTION or SIGN PURPOSE
 On Taxiways at Intersection with a Runway	Controlled Airport - Hold unless ATC clearance has been received. Uncontrolled Airport - Proceed when no traffic conflict exists.
 Runway/Runway Intersection	Taxing - Same action as above. Taking Off or Landing - Disregard unless a "Land, Hold Short" clearance has been accepted.
*  Taxiway in Runway Approach or Departure Area	Controlled Airport - Hold when instructed by ATC. Uncontrolled Airport - Proceed when no traffic conflict exists.
*  ILS Critical Area	Hold when approaches are being made with visibility less than 2 miles or ceiling less than 800 feet.
 Areas where Aircraft are Forbidden to Enter	Do not enter.
 Taxiway	Identifies taxiway on which aircraft is positioned.
 Runway	Identifies runway on which aircraft is positioned.
*  Edge of Protected Area for Runway	These signs are used on controlled airports to identify the boundary of the runway protected area. It is intended that pilots exiting this area would use this sign as a guide to judge when the aircraft is clear of the protected area.
Notes: 1. See the <i>Airman's Information Manual</i> for additional information on airfield signs. 2. The signs shown on this guide comply with FAA standards. In some cases ICAO's proposed sign standards differ with FAA's. The asterisk (*) in the left column denotes these cases so the pilot can be aware that some differences may be encountered outside the United States.	

FIGURE 59.46 Guide to airfield signs. (From FAA, *Standards for Airport Markings*, Advisory Circular AC150/5340-IG, 1993c.)

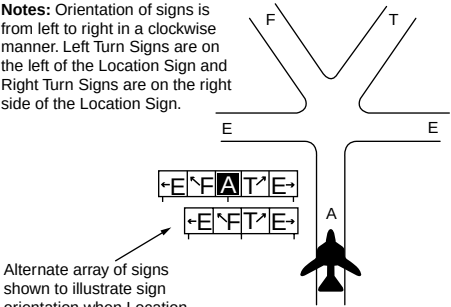
center and bars of red lights on either side of the centerline spaced 100 ft apart. An extra light bar is placed at 500 ft to provide an added visual cue.

MALSR is a medium-intensity ALS with a runway alignment indicator light. It is the U.S. standard for ILS operations during category I visibility minima. Five sequenced lights begin at 2400 ft from the threshold and extend to 1400 ft. Thereafter eight flashing light bars are installed along the extended runway centerline at 200-ft spacing extending to the threshold. Other medium-intensity approach lighting systems are for nonprecision approaches and consist of the white center marking bars sometimes augmented with the sequenced white flashers.

SIGN and LOCATION	PILOT ACTION or SIGN PURPOSE
★  Edge of ILS Critical Area	These signs are used on controlled airports to identify the boundary of the ILS critical area. It is intended that pilots exiting this area would use this sign as a guide to judge when the aircraft is clear of the ILS critical area.
 Taxiways and Runways	On Taxiways - Provides direction to turn at next intersection to maneuver aircraft onto named taxiway. On Runways - Provides direction to turn to exit runway onto named taxiway
 Taxiway	Provides general taxiing direction to named runway.
 Taxiways and Runways	Provides general taxiing direction to identified destination
 Runway	Provides remaining runway length in 1,000 feet increments.

Arrangement of Signs at an Intersection

Notes: Orientation of signs is from left to right in a clockwise manner. Left Turn Signs are on the left of the Location Sign and Right Turn Signs are on the right side of the Location Sign.



Alternate array of signs shown to illustrate sign orientation when Location Sign not installed.

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Time Conversion to UTC (Z)			
	Add hrs.		Add hrs.
EDT.....	4	MDT.....	6
EST.....	5	MST.....	7
CDT.....	5	PDT.....	7
CST.....	6	PST.....	8
Hawaii & Alaska.....			10

FIGURE 59.46 (continued).

Runway Pavement Design

Pavement design methods are based on the gross weight of the aircraft. Since it is impracticable to develop design curves for each type of aircraft, composite aircraft are determined and loads are converted from the actual aircraft to the design aircraft, the design aircraft being the one that requires the greatest thickness of pavement. The traffic forecast, which includes the mix of aircraft anticipated, is converted to a traffic forecast of equivalent annual departures.

FAA Advisory Circular AC150/5320-6C CHG 2 [1978] presents a number of curves to be used to design the pavement thickness for both flexible and rigid pavements. The process is outlined in Chapter 62.

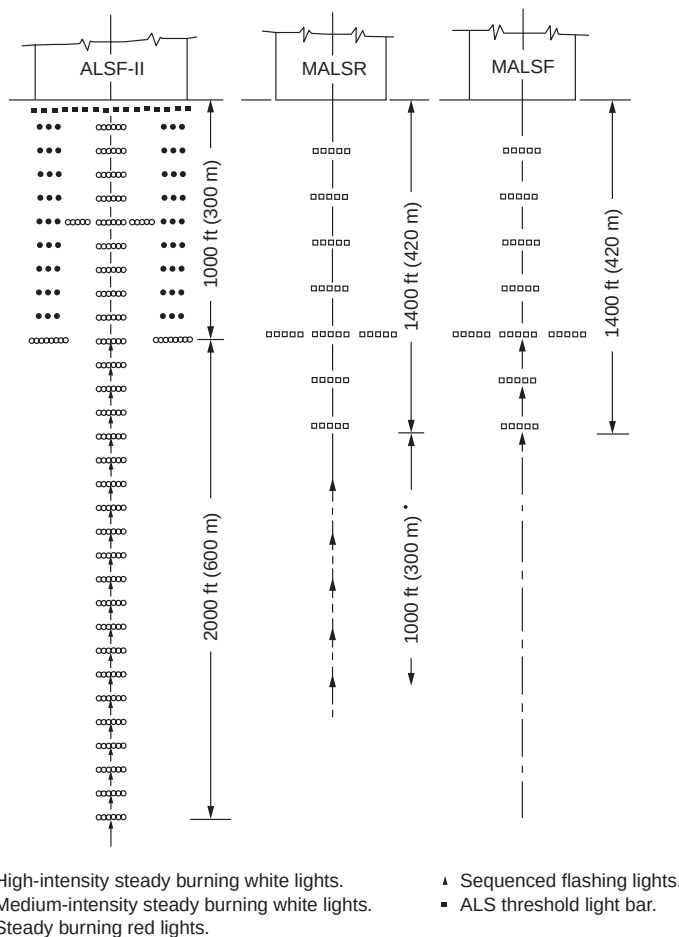


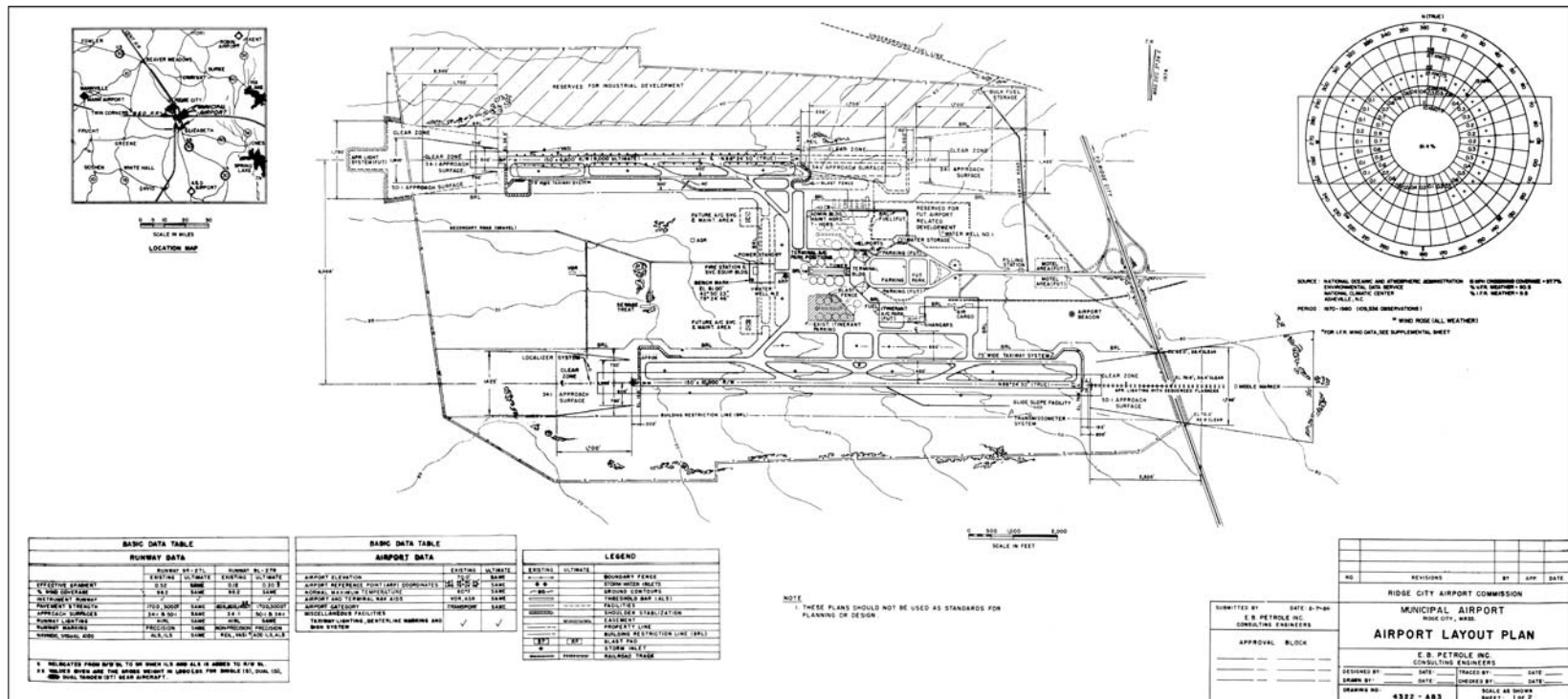
FIGURE 59.47 FAA approach light systems. (From FAA, *Standards for Airport Markings*, Advisory Circular AC150/5340-IG, 1993c.)

59.9 Airport Plans

Upon completion of the inventory, forecasting, requirements analysis, and site evaluation, the master planning proceeds to the synthesis of airside and landside concepts and plans. These include an airport layout plan and an approach and clear zone plan. Other plans could include the site plan, the access plan, and the environmental plan.

Airport Layout Plan

The airport layout plan is a graphic representation to scale of existing and future airport facilities on the airport. An example is presented in Fig. 59.48. It will serve as the airport's public document, giving aeronautical requirements as well as pertinent clearance and dimensional data and relationships with the external area. The airfield configuration of runways, taxiways, aprons, and the terminal are shown schematically. The airport layout plan (usually a 24- by 36-in. plate with minimum lettering of 120 in.) should include, as a minimum, the following:



- Airport layout details
 - Runways, taxiways, blast pads, stabilized shoulders, runway safety areas, buildings, NAVAIDs, parking areas, road lighting, runway marking, pipelines, fences, major drainage facilities, wind indicators, and beacon
 - Prominent features such as trees, streams, ponds, ditches, railroads, power lines, and towers
 - Revenue-producing nonaviation property
 - Areas reserved for future development, such as FBO facilities and fuel farms
 - Areas reserved for nonaviation development
 - Existing ground contours
 - Fueling facilities and tie-down areas
 - Airport boundaries
 - Clear zones and associated approach surfaces
 - Airport reference point
 - Latitude, longitude, and elevation of existing and ultimate runway ends and thresholds
 - True azimuth of the runways (measured from true north)
 - Pertinent dimensional data
- Location map depicting the airport with surrounding cities, railroads, major roads, and tall towers within 25 to 50 miles of the airport
- Vicinity map
- Basic data table on existing and future airport features, including elevation, reference point coordinates, magnetic variations, maximum daily temperature for the hottest month, airport and terminal navigational aids, runway identification, longitudinal gradients, percent wind coverage, instrument runways, pavement type, pavement strength in gross weight, type of main gear (single, dual, or dual tandem), approach surfaces, runway lighting, runway marking, electronic and visual approach aids, and weather facilities
- Wind rose with runway orientation superimposed
- Designated instrumented runway [FAA, 1985]

Approach and Runway Clear Zone Plan

The approach and clear zone drawing permits the planner to determine how the airport will interface with the surrounding area in terms of safe flight. An example is presented in [Fig. 59.49](#). It includes:

- Area under the imaginary surfaces defined in U.S. Code FAR, Part 77 [1975]
- Existing and ultimate approach slopes or slope protection established by local ordinance
- Runway clear zones and approach zones showing controlling objects in the airspace
- Obstructions that exceed the criteria
- Tall smokestacks, television towers, garbage dumps, landfills, or other bird habitats that could pose a hazard to flight

Other Plans

Terminal Area Plan

The terminal area plan usually consists of a conceptual drawing showing the general plan for the terminal, including its possible expansion. Under some changes the terminal modification will have a major impact on the taxiway and apron and will be reflected in an altered ALP.

Noise Compatibility Plan

Using future airport traffic, noise contours should be generated to identify future impacts of noise in the community. The plan would include alternative takeoff tracks and operational constraints. It would also identify buildings and other facilities that might potentially need to be moved or soundproofed.

59.10 Summary

The total airport system is the effective integration of both airside and landside systems to handle traveler requirements for airplane travel to and from distant points, usually beyond the convenient range of automobile traffic or when time constraints require much higher speed movement. The users of the airport include the traveler, the airlines (and their aircraft), flying enthusiasts, air freight forwarders, and air traffic controllers and other federal government representatives. The critical issues in airport design are:

- Complexities in design caused by the unique interaction of the aircraft performance and size with the engineering aspects of airport design
- Airport growth (terminal and runway) to account for the continued expansion of air travel demand, which is not expected to diminish in the next 50 years
- Integration of air traffic requirements into the design of the airport, particularly its operational capability in poor weather conditions
- Criteria for new or expanded sites for airports to increase capacity (minimize delay) while at the same time operating within the constraints imposed by noise and obstruction within the airways

The controlling document of any airport is the master plan, the outline of which was followed in this chapter.

There are other subjects that might have been treated here, such as:

- Design of an air cargo terminal
- Design of a heliport or vertiport
- Design of fuel farms and water supply
- Design of firefighting and rescue systems
- Design of snow and ice control

The FAA has provided definitive design guidelines for each of these items and many more. See FAA Advisory Circular AC00-2.7 for a list of all available circulars.

Defining Terms

Aircraft approach category — A grouping of aircraft based on 1.3 times their stall speed in their landing configuration at their maximum certificated landing weight. The categories are as follows:

- A: Speed less than 91 knots
- B: Speed 91 knots or more, but less than 121 knots
- C: Speed 121 knots or more, but less than 141 knots
- D: Speed 141 knots or more, but less than 166
- E: Speed 166 knots or more

Aircraft design group (ADG) — A grouping of aircraft based on wingspan. The groups are as follows:

- I: Up to but not including 49 ft (15 m)
- II: 49 ft (15 m) up to but not including 79 ft (24 m)
- III: 79 ft (24 m) up to but not including 118 ft (36 m)
- IV: 118 ft (36 m) up to but not including 171 ft (52 m)
- V: 171 ft (52 m) up to but not including 214 ft (65 m)
- VI: 214 ft (65 m) up to but not including 262 feet (80 m)

Airport elevation — The highest point on an airport's usable runway expressed in feet above mean sea level.

Airport layout plan (ALP) — The plan of an airport showing the layout of existing and proposed airport facilities.

Airport reference point (ARP) — The latitude and longitude of the approximate center of the airport.

Blast fence — A barrier used to divert or dissipate jet blast or propeller wash.

Building restriction line (BRL) — A line that identifies suitable building area locations on airports.

Clearway (WY) — A defined rectangular area beyond the end of a runway cleared or suitable for use in lieu of runway to satisfy takeoff distance requirements.

Declared distances — The distances the airport owner declares available and suitable for satisfying the airplane's takeoff distance, accelerate-stop distance, and landing distance requirements.

Displaced threshold — The portion of pavement behind a displaced threshold may be available for takeoffs in either direction and landings from the opposite direction.

Hazard to air navigation — An object that, as a result of an aeronautical study, the FAA determines will have a substantial adverse effect upon the safe and efficient use of navigable airspace by aircraft, operation of air navigation facilities, or existing or potential airport capacity.

Inner-approach OFZ — The airspace above a surface centered on the extended runway centerline. It applies to runways with an approach lighting system.

Inner-transitional OFZ — The airspace above the surfaces located on the outer edges of the runway OFZ and the inner-approach OFZ. It applies to precision instrument runways.

Large airplane — An airplane of more than 12,500 lb (5700 kg) maximum certificated takeoff weight.

Nonprecision instrument runway — A runway with an approved or planned straight-in instrument approach procedure that has no existing or planned precision instrument approach procedure.

Object — Includes, but is not limited to, aboveground structures, NAVAIDs, people, equipment, vehicles, natural growth, terrain, and parked aircraft.

Object-free area (OFA) — A two-dimensional ground area surrounding runways, taxiways, and taxilanes that is clear of objects except for those whose location is fixed by function.

Obstacle-free zone (OFZ) — The airspace defined by the runway OFZ and, as appropriate, the inner-transitional OFZ, which is clear of object penetrations other than frangible NAVAIDs.

Obstruction to air navigation — An object of greater height than any of the heights or surfaces presented in subpart C or U.S. Code FAR, Part 77. (Obstructions to air navigation are presumed to be hazards to air navigation until an FAA study has determined otherwise.)

Precision instrument runway — A runway with an existing or planned precision instrument approach procedure.

Relocated threshold — The area behind which the pavement is not available for taking off or landing. It may be available for taxiing of aircraft.

Runway (RW) — A defined rectangular surface at an airport prepared or suitable for the landing or takeoff of airplanes.

Runway blast pad — A surface adjacent to the ends of runways provided to reduce the erosive effect of jet blast and propeller wash.

Runway OFZ — The airspace above a surface centered on the runway centerline.

Runway protection zone (RPZ) — An area off the runway end (formerly the clear zone) used to enhance the protection of people and property on the ground.

Runway safety area (RSA) — A defined surface surrounding the runway prepared or suitable for reducing the risk of damage to airplanes in the event of an undershoot, overshoot, or excursion from the runway.

Runway type — A runway-use classification related to its associated aircraft approach procedure.

Shoulder — An area adjacent to the edge of paved runways, taxiways, or aprons providing a transition between the pavement and the adjacent surface: support for aircraft running off the pavement, enhanced drainage, and blast protection.

Small airplane — An airplane of 12,500 lb (5700 kg) or less maximum certificated takeoff weight.

Stopway (SWY) — A defined rectangular surface beyond the end of a runway prepared or suitable for use in lieu of runway to support an airplane, without causing structural damage to the airplane, during an aborted takeoff.

Taxilane (TL) — The portion of the aircraft parking area used for access between taxiways and aircraft parking positions.

Taxiway (TW) — A defined path established for the taxing of aircraft from one part of an airport to another.

Taxiway safety area (TSA) — A defined surface alongside the taxiway prepared or suitable for reducing the risk of damage to an airplane unintentionally departing the taxiway.

Threshold (TH) — The beginning of that portion of the runway available for landing. When the threshold is located at a point other than at the beginning of the pavement, it is referred to as either a displaced or a relocated threshold, depending on how the pavement behind the threshold may be used.

Visual runway — A runway without an existing or planned straight-in instrument approach procedure.

Acronyms

AC	Advisory circular published by the FAA
AGL	Above ground level
AIP	Federal Aviation Administration Airport Improvement Program
ALSF	Approach lighting system with sequenced flashing lights
ALSF-1	Level 1 high-intensity approach lighting system
ASOS	Automated Surface Observation System
ASR	Airport surveillance radar
ATCT	Air traffic control tower
AWOS	Automated Weather Observation System
CAT I ILS	Category I instrument landing system
CAT II ILS	Category II instrument landing system
CAT III ILS	Category III instrument landing system
DH	Decision height
DME	Distance measuring equipment
FAA	Federal Aviation Administration
FAF	Final approach fix
FAR	Federal Aviation Regulation
FBO	Fixed-base operator
GPS	Global Positioning System
HAA	Height above airport elevation
HAT	Height above touchdown
HIRL	High-intensity runway light
IAP	Instrument approach procedure
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
ILS	Instrument landing system
LIRL	Low-intensity runway light

LOC	Localizer
MALS	Medium-intensity approach lighting system
MALSF	Medium-intensity approach lighting system with sequenced flashing lights
MALSR	Medium-intensity approach lighting system with runway alignment indicator lights
MAP	Missed approach point
MDA	Minimum descent altitude
MEA	Minimum en route altitude
MIRL	Medium-intensity runway light
MLS	Microwave landing system
MSL	Mean sea level
NAVAID	Navigational aid
NDB	Nondirectional radio beacon
NDB-A	Circling approach utilizing NDB facility
NOAA	National Oceanic and Atmospheric Administration
NOTAM	Notice to airmen
NPIAS	National Plan of Integrated Airport Systems
NWS	National Weather Service
ODALS	Omnidirectional approach lighting system
PAPI	Precision approach path indicator
PFC	Passenger facility charge
RAP	Remote altimetry penalty
RNAV	Area navigation
RPM	Revenue passenger mile
SASP	State aviation system plan
SASL	Simplified short approach lighting system
SSALR	Simplified short approach lighting system with runway alignment indicator lights
TERPS	Federal Aviation Administration's terminal instrument procedures
TVOR	Terminal VOR
VAPI	Visual approach path indicator
VASI	Visual approach slope indicator
VFR	Visual flight rules
VHF	Very high frequency
VOR	Very-high-frequency omnidirectional range
VOR-A	Circling approach utilizing VOR facility
VORTAC	VOR and ultra-high-frequency tactical air navigation aid

References

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Further Information

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For further information about site design, FAA Advisory Circular AC150/5000, *Airport Design*, September 1989, is available from the Superintendent of Documents (SN 050-007-853-8 plus change 1, SN-050-007-929-1). Information on noise is found in FAA Advisory Circular AC150/5020-1, *Noise Control and Compatibility Planning for Airports*, August 1983, available at no cost from the U.S. Department of Transportation, Washington, D.C.

Section 59.8 augments the airport design computer program available from the FAA discussed in Advisory Circular AC150/5360-13, *Airport Design*. A diskette for PCs containing the airport design programs is available from your nearest FAA airport office.

For further design information about runway length for various aircraft, consult FAA Advisory Circular AC150/5325-4A, *Runway Length Requirements for Airport Design*, January 1990, available at no cost from the U.S. Department of Transportation, Washington, D.C.