

An aerial photograph of a large airport terminal complex with multiple circular concourses, runways, taxiways, and parking lots. The image is used as a background for the book cover.

FOURTH EDITION

# AIRPORT ENGINEERING

PLANNING, DESIGN, AND DEVELOPMENT OF 21ST-CENTURY AIRPORTS

NORMAN J. ASHFORD, SALEH A. MUMAYIZ, and PAUL H. WRIGHT



# **Airport Engineering**



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## **Planning, Design, and Development of 21st Century Airports**

**Fourth Edition**

**Norman J. Ashford**  
**Saleh Mumayiz**  
**Paul H. Wright**



**WILEY**

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## *To Joan, Lubna, and Joyce*

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# Preface

This book has been rewritten in its fourth edition to continue to serve as a basic text for courses in airport planning and design. In the past it has been of value as reference to airport designers, planners, and administrators worldwide as well as to consultants in airport infrastructure development. The fourth edition is a complete update of the third edition, published in 1992, taking into account major revisions to Federal Aviation Administration (FAA), International Civil Aviation Organization (ICAO), and International Air Transport Association (IATA) standards and recommended practices. Furthermore, the revisions reflect the experiences of the authors in teaching, consulting, and research in this field. The authors have teaching experience in postgraduate and post-experience courses throughout the world and extensive consultancy experience, having in the last 20 years participated in the planning and design of many airports around the world, both large and small.

This fourth edition of *Airport Engineering* appears 18 years after its predecessor and in the interim very big and far-reaching changes have occurred in civil aviation. Security has been dramatically and irrecoverably tightened throughout the world, especially in the United States, since the 9/11 terrorist atrocities in the northeastern United States in 2001. Passenger facilitation has been revolutionized with the introduction of almost universal electronic ticketing and check-in procedures. The introduction of the A380 aircraft into service has heralded the arrival of what had, up to then, been termed the New Large Aircraft. The information technology (IT) revolution had profound influence on air travel and the air transport industry. The widespread usage of the Internet has also permitted the rapid and broad publication of standards and recommended practices by the FAA and other regulatory bodies. The nature of civil aviation itself has changed with the evolution and proliferation of the low-cost carriers and growth of this market. Moreover, air freight has grown considerably and now has a significant proportion of its traffic carried by the door-to-door service of the integrated carriers. The general availability of desktop computers and low-cost software allows designers and operators to use computerized techniques [e.g., modeling, simulation, and geographic information system (GIS)] more widely and effectively as a day-to-day tool of airport design and operation. In the area of the environmental impact of aviation, the aircraft of the twenty-first century are an order-of-magnitude quieter than their predecessors: The importance of noise impact has decreased as the industry faces increased scrutiny and regulation in areas of water and air pollution, carbon footprint, renewable energy, and sustainable development. In this edition, the authors have addressed these changes and have restructured the shape of the text to reflect conditions as they are a decade into the twenty-first century.

Chapters 6, 7, and 8 have seen major restructuring to cover airport–airspace interaction, airport capacity (both airside and landside), and airside geometric design, respectively. These three areas of airport planning and design have come to the forefront in a major and comprehensive way. In particular, airport capacity has become

the basis of evaluating airport performance and as the primary determinant of airport improvement, expansion, and development. Chapters 10 and 12 incorporate the recently published procedures and practices relating to spreadsheet design using new Transportation Research Board (TRB-Airport Cooperative Research Program and FAA methods for passenger terminal planning and pavement design. New Chapters 15 and 16 have been included to cover matters relating to the increasingly important subjects of simulation and the developments of the airport city concepts. Chapter 17 has been totally revamped and updated to describe current thinking and regulations in the area of environmental impact. Elsewhere, all chapters have been updated to 2010 standards and practices to reflect industry structure, operational and market practices, and modern technology.

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Transportation Research Board, United States





# The Structure and Organization of Air Transport

## 1.1 THE NEED FOR NATIONAL AND INTERNATIONAL ORGANIZATIONS (1)

For those who have matured in an age marked by the noise, bustle, and efficiency of jet aircraft travel, it is difficult to realize that it is just over 100 years since the first brief flight of the Wright brothers at Kitty Hawk, North Carolina, and Bleriot's later historic crossing of the English Channel. Before the early years of the last century, except for the infrequent use of nonpowered balloons, man had been restricted to the earth's surface. In 2010 civil aviation was a major international industry that carried approximately 3 billion passengers each year in aircraft which fly an aggregate of close to 4.5 trillion kilometers. Since aviation is largely international, problems are created that individual nations cannot solve unilaterally; consequently, from the earliest days of civil aviation, there has been an attempt to find international solutions through the creation of international bodies. Typically, civil aviation requires the building of airports to accepted international standards, the establishment of standard navigational aids, the setting up of a worldwide weather-reporting system, and the standardization of operational practices to minimize the possibility of error or misunderstanding.

National institutions can assist in the general aims of providing safe and reliable civil air transport. Their role is to furnish procedures for the inspection and licensing of aircraft and the training and licensing of pilots and to provide the necessary infrastructure—that is, navigation aids and airports. Although the establishment of an infrastructure for a country's civil air transport is a national concern that cannot realistically be assumed by an international body, it is clear that there is a need for the standardization of procedures, regulations, and equipment, as well as infrastructure, on a worldwide basis.

## 1.2 THE INTERNATIONAL CIVIL AVIATION ORGANIZATION

The first attempt to reach an international consensus was unsuccessful; in 1910, representatives of 19 European nations met to develop an international agreement. Another attempt was made to internationalize civil aviation standards after World War I, when the Versailles Peace Conference set up the International Conference for Air Navigation

(ICAN). Although this organization lasted from 1919 until World War II, its effectiveness was extremely limited because of the regionality of air transport even up to the early 1940s.

World War II provided a huge impetus to civil aviation. New types of fast monoplane aircraft had been developed, and the jet engine was in its infancy; navigational aids that had been developed for military purposes were easily adapted to civilian use, and many countries had built numerous military airports that were to be converted to civilian use after the war. A generation of peacetime development had been crammed into the period of the European war from 1939 to 1945. In early 1944, the United States sought out its allies and a number of neutral nations—55 in all—to discuss postwar civil aviation. The result of these exploratory discussions was the Chicago Convention on Civil Aviation in November 1944, attended by 52 countries. Its purposes are best described by the preamble to the convention (1):

WHEREAS the future development of international civil aviation can greatly help to create and preserve friendship and understanding among the nations and peoples of the world, yet its abuse can become a threat to the general security; and

WHEREAS it is desirable to avoid friction and to promote that cooperation between nations and peoples upon which the peace of the world depends;

THEREFORE the undersigned governments, having agreed on certain principles and arrangements in order that international civil aviation may be developed in a safe and orderly manner and that international air transport services may be established on the basis of equality of opportunity and operated soundly and economically;

HAVE accordingly concluded this Convention to that end.

The Chicago Convention established 96 articles which outlined the privileges of contracting states, provided for the establishment of international recommended practices, and recommended that air transport be facilitated by the reduction of formalities of customs and immigration. After ratification by the legislatures of 26 national states, the International Civil Aviation Organization (ICAO) came into existence on April 4, 1947. By 2008, the original 26 ratifying states had grown to 190 member states. The modus operandi of the ICAO is stated in Article 44 of the Convention:

ICAO has a sovereign body, the Assembly, and a governing body, the Council. The Assembly meets at least once in three years and is convened by the Council. Each Contracting State is entitled to one vote and decisions of the Assembly are taken by a majority of the votes cast except when otherwise provided in the Convention. At this session the complete work of the Organization in the technical, economic, legal and technical assistance fields is reviewed in detail and guidance given to the other bodies of ICAO for their future work.

Although the sovereign body of the ICAO is the Assembly, in which each contracting state has one vote, the governing body of the organization is the 36-member Council, which emphasizes in its makeup the states of chief importance to air transport, with a provision for geographical balance. One of the principal functions and duties of the Council is to adopt international standards and recommended practices. Once adopted, these are incorporated as annexes to the Convention on International Civil Aviation (Table 1.1).

**Table 1.1** Annexes to the ICAO Convention on International Civil Aviation

Annex <sup>a</sup>	Covers
1. Personnel Licensing	Licensing of flight crews, air traffic control officers, and aircraft maintenance personnel
2. Rules of the Air	Rules relating to the conduct of visual and instrument flights
3. Meteorological Service for International Air Navigation	Provision of meteorological services for international air navigation and reporting of meteorological observations from aircraft
4. Aeronautical Charts	Specifications for aeronautical charts for use in international aviation
5. Units of Measurement to Be Used in Air and Ground Operations	Dimensional systems to be used in air and ground operations
6. Operation of Aircraft Part I—International Commercial Air Transport Part II—International General Aviation	Specifications that will ensure in similar operations throughout the world a level of safety above a prescribed minimum
7. Aircraft Nationality and Registration Marks	Requirements for registration and identification of aircraft
8. Airworthiness of Aircraft	Certification and inspection of aircraft according to uniform procedures
9. Facilitation	Removal of obstacles and impediments to movement of passengers, freight, and mail across international boundaries
10. Aeronautical Telecommunications	Standardization of communications equipment and systems (Vol. 1) and of communications procedures (Vol. 2)
11. Air Traffic Services	Establishment and operation of air traffic control, flight information, and alerting services
12. Search and Rescue	Organization and operation of facilities and services necessary for search and rescue
13. Aircraft Accident Investigation	Uniformity in the notification, investigation, and reporting of aircraft accidents
14. Aerodromes	Specifications for the design and equipment of aerodromes
15. Aeronautical Information Services	Methods for the collection and dissemination of aeronautical information required for flight operations
16. Environmental Protection	Specifications for aircraft noise certification, noise monitoring, and noise exposure units for land use planning
17. Security	Specifications for safeguarding international civil aviation against acts of unlawful interference
18. Safe Carriage of Dangerous Goods by Air	The storage, handling, and carriage of dangerous and hazardous cargo

<sup>a</sup>All annexes, except 9, are the responsibility of the Air Navigation Commission. Annex 9 is the responsibility of the Air Transport Committee.

Source: *Memorandum on ICAO*, Montreal: International Civil Aviation Organization, July 1975 as updated.

### 1.3 NONGOVERNMENTAL ORGANIZATIONS

There are a number of industrial organizations active in the area of air transportation, both at the international and the national levels. The most important of the international organizations are as follows:

1. *International Air Transport Association (IATA)*. An organization with more than 100 scheduled international carrier members. Its role is to foster the interests of civil aviation, provide a forum for industry views, and establish industry practices.
2. *Airports Council International (ACI)*. This organization was founded in 1991 as *Airports Association Council International (AACI)* to serve as a forum and a focus for the views and interests of civil airport operators. The ACI came about from a merger of the mainly U.S. Airport Operators Council International (AOCI), a mainly North-American association, and the International Civil Airports Association (ICAA), which had been dominated by European operators.

In the United States, the more important domestic organizations with views and policies affecting the civil aviation industry are the Air Line Pilots Association, the Aircraft Owners and Pilots Association, the Air Transport Association of America, the National Association of State Aviation Officials, and the American Association of Airport Executives.

### 1.4 U.S. GOVERNMENTAL ORGANIZATIONS (2)

The administration, promotion, and regulation of aviation in the United States are carried out at the federal level by three administrative bodies:

1. The Federal Aviation Administration
2. The National Transportation Safety Board

After the calamitous terrorist incidents of September 2001, security aspects of the aviation were assumed by the newly created:

3. Department of Homeland Security, which set up the Transportation Security Administration within its structure

#### **The Federal Aviation Administration (FAA)**

The FAA has prime responsibility for civil aviation. Formerly called the Federal Aviation Agency, it was absorbed into the Department of Transportation under the terms of the reorganization contained in the Department of Transportation Act of 1967 (80 Stat. 932). It is charged with:

- Regulating air commerce in ways that best promote its development and safety and fulfil the requirements of national defense
- Controlling the use of the navigable airspace of the United States and regulating both civil and military operations in such airspace
- Promoting, encouraging, and developing civil aeronautics

- Consolidating research and development with respect to air navigation facilities
- Installing and operating air navigation facilities
- Developing and operating a common system of air traffic control and navigation for both civil and military aircraft
- Developing and implementing programs and regulation to control aircraft noise, sonic boom, and other environmental effects of civil aviation

The administration discharges these responsibilities with programs in nine principal areas:

1. *Safety and Regulation.* Issuance and enforcement of regulations relating to the manufacture, operation, and maintenance of aircraft; rating and certification of airmen and certification of airports serving air carriers; flight inspection of air navigation facilities in the United States and, as required, abroad.
2. *Airspace and Air Traffic Management.* The operation of a network of air traffic control towers, air route traffic control centers, and flight service stations. The development and promulgation of air traffic rules and regulation and the allocation of the use of airspace. Provision for the security control of air traffic to meet national defense requirements.
3. *Air Navigation Facilities.* The location, construction or installation, maintenance, and operation of federal visual and electronic aids to air navigation.
4. *Research, Engineering, and Development.* Research, engineering, and development activities directed toward providing systems, procedures, facilities, and devices for safe and efficient air navigation and air traffic control for both civil aviation and air defense. Aeromedical research to promote health and safety in aviation. Support for the development and testing of new aircraft, engines, propellers, and other aircraft technology.
5. *Test and Evaluation.* The agency conducts tests and evaluations on items such as aviation systems and subsystems, equipment, devices, materials, concept, and procedures at any phase in the cycle of design and development.
6. *Airport Programs.* Maintenance of a national plan of airport requirements; administration of a grant program for development of public use airports to assure and improve safety and to meet current and future needs; evaluation of environmental impacts of airport development; administration of airport noise compatibility program; developing standards and technical guidance on airport planning, design, safety, and operations; provision of grants to assist public agencies in airport system and master planning, airport improvement and development.
7. *Registration and Recording.* Provision of a system for the registration of aircraft and recording of documents affecting title or interest in aircraft, aircraft engines, and spare parts.
8. *Civil Aviation Abroad.* Under the Federal Aviation Act of 1958 and the International Aviation Facilities Act (49 U.S.C. app 1151), the agency promotes aviation safety and civil aviation abroad by information exchange with foreign aviation authorities; certification of foreign repair stations, airmen, and mechanics; negotiating bilateral airworthiness agreements; technical assistance

and training; technical representation at international conferences and participation in ICAO and other international organizations.

9. *Other Programs.* Aviation insurance, aircraft loan guarantee programs, allotting priorities to civil aircraft and civil aviation operations, publication of current information on airways and airport service, issuing technical publications for the improvement of safety in flight, airport planning and design, and other aeronautical services.

### **The National Transportation Safety Board (NTSB)**

The NTSB was established as an independent agency of the federal government in April 1975 under the terms of the Independent Safety Board Act of 1974 (88 Stat. 2156; 49 U.S.C. 1901). Its five members are appointed by the president. Its function is to ensure that transportation in the United States is conducted safely. The NTSB assumed responsibility for the investigation of aviation accidents, which previously had been carried out by the Civil Aeronautics Board, the economic regulatory organization which became defunct in the early 1980s as part of domestic deregulation of civil aviation. The Bureau of Accident Investigation, the section within the agency responsible for investigating aviation accidents, reports directly to the five-member board through the Office of the Managing Director.

### **Department of Homeland Security (Transportation Security Administration)**

Part of the Department of Homeland Security is the Transportation Security Administration, which is responsible nationally for transportation security and in particular that of aviation. Federal staff is responsible for, among other matters, air passenger screening, baggage screening, air cargo inspection and screening, federal air marshals and federal flight deck officers, and canine explosive detection.

## **1.5 AVIATION PLANNING AND REGULATION AT STATE LEVEL**

In the early days of civil aviation, the federal government saw no role for itself in the provision of airports. This was stated to be a local responsibility that should be financed principally by the municipalities or by private sources (3). The Air Commerce Act of 1926 gave the secretary of commerce authority “to designate and establish civil airways and, within the limits of available appropriations hereafter made by Congress, to establish, operate and maintain along such airways all necessary air navigation facilities except airports.”

In that municipalities draw all their power from the authority delegated by the sovereign states, government at the state level necessarily became involved in aviation. Consequently, state aviation departments and bureaus and, in some cases, state aeronautical commissions were established. Most states have some form of user taxation on aviation, which is channeled back into airport development in the form of matching-fund grants.

The planning and financing of airports vary from state to state, and the practice of a particular state depends greatly on the organizational structure of the overall administration of transportation within the state. All states now have state Departments

of Transportation (DOTs), which act as intermediaries in federal–local negotiations. A number of different organizational forms of state DOTs have evolved. In extreme forms, they vary from *functional* structures, in which individual departments are multimodal, to *modal* structures, which strongly reflect the single-mode agencies prior to the formation of state DOTs. Frequently, the structure is of a *hybrid* form that is somewhere between these two extremes. Figure 1.1 illustrates the forms of functional, modal, and hybrid state DOTs.

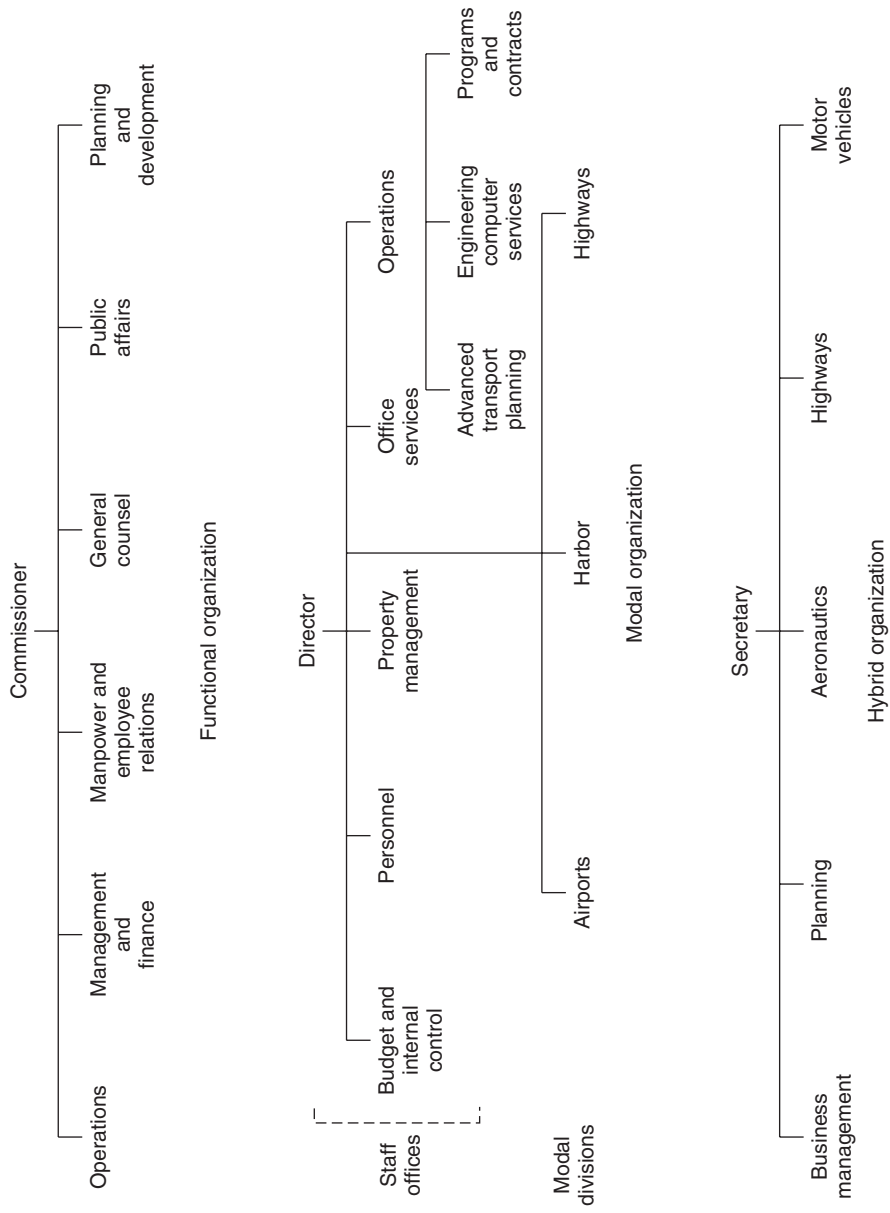
## 1.6 PATTERNS OF AIRPORT OWNERSHIP (4, 5)

In the early days of civil aviation in the United States, airports typically were owned by local authorities or private organizations. Massive increases in passenger volume, however, required building an extensive infrastructure in the passenger terminal area; at the same time, the increasing weight and sophistication in aircraft necessitated greater investment in extensive pavements for runways, taxiways, and aprons; equally necessary were navigational and landing aid systems. These requirements were generally beyond the capability of private finance, and the private airport operator tended to disappear, except at the smallest airports.

Until the late 1980s, public ownership of a nation’s large airports was a worldwide model that was generally upheld as being the natural state of things. However, by the late 1980s, it became apparent that some airports had grown to be both large generators of revenues and profits and the centers of activities which required very large infusions of capital financing. In the wake of de jure deregulation of U.S. domestic civil aviation and progress toward de facto deregulation of European airlines, strong moves were made in a number of countries to “privatize” or denationalize the nation’s airports. The United Kingdom took a lead in this direction with the Airports Act (1986), which required all its medium and large airports to become private companies by 1987, placing them in the private sector. In 1987, the BAA plc, which had formerly been the British Airports Authority, handling three-quarters of all British air passengers, became the first airport company to be quoted on the public stock exchange.

Since the late 1980s, except in the United States, the international tendency has been to move from public to private ownership, but the form of public or private ownership varies from country to country. The principal forms of ownership are the following:

1. Ownership by a governmental agency or department whereby airports are centrally owned and operated either by a division of the overall Ministry of Transport or by the more specialized Ministry of Civil Aviation
2. Quasi-governmental organizations—public corporations set up by government for the specific purpose of airport ownership and operation, where the governmental unit may be national or regional (including state or provincial governments)
3. Authorities for individual airports or for groups of airports authorized by a consortium of state, provincial, or local governmental units
4. Individual authorities that run one airport on behalf of one local authority
5. Departments of a local authority
6. Single private companies or private consortia owning one or more airports



**Figure 1.1** The aviation function within state DOTs.



An examination of international patterns of ownership indicates no special trends. In 2010, France, Italy, Germany, Holland, and the United States had the majority of their airports in public ownership, run by individual airport authorities. In a number of developing countries, as well as the United Kingdom, South Africa, Australia, Canada, Mexico, Chile, and Argentina, airports have been sold to private companies. In many cases, the largest airports in a country are owned and operated by private companies or consortia from foreign countries. In 2010 countries such as Holland, Ireland, Nigeria, and Brazil still owned and operated their airports through centralized organizations that are owned by or are part of the national government.

## 1.7 REVENUES AND EXPENDITURES AT U.S. AIRPORTS

Since the feasibility of developing and building an airport rests heavily on the anticipated revenue and expenditure, the financial aspects of airport planning must take into consideration both *revenues* and *expenses*. These two principal divisions may be further grouped into operating and nonoperating areas.

### Revenues

***Operating Revenues.*** The operating revenues at airports may be categorized into five major groupings (5).

1. ***Landing Area.*** Revenues are produced directly from the operation of aircraft in the form of landing fees and parking ramp fees.
2. ***Terminal Area Concessions.*** Nonairline uses in the terminal areas produce income from a varied range of activities, including *specialty areas* (e.g., duty-free stores, souvenir vendors, bookshops, newsstands, banks), *food and drink areas* (e.g., restaurants, cafeterias, bars), *leisure areas* (e.g., television, movie, and observation areas), *travel services* (e.g., lockers, wash-rooms, nurseries, insurance desks, car rentals, rest areas, telephones), *personal service areas* (e.g., barber shops, beauty salons, valet service), and *off-terminal facilities* (e.g., office rentals, advertising).
3. ***Car Parking and Ground Transportation.*** Especially at large airports, car parking is a very substantial contribution to airport revenues. In conjunction with ground transportation, this area of revenue generation is both large and profitable.
4. ***Airline Leased Areas.*** Within the terminal itself or in the general airport site, substantial revenues can be generated by leasing facilities to the airlines. Airlines normally rent offices, hangars, ticket and check-in counters, operations and maintenance areas, and cargo terminals. Ground rents are paid when the facility is provided by the airline.
5. ***Other Leased Areas.*** Many larger airports function as industrial and transport complexes incorporating a number of nonairline operations. These operations, which constitute another source of revenue, typically include industrial areas, fuel and servicing facilities, fixed-base operators, freight forwarders, and warehousing.

6. *Other Operating Revenue.* Sources of revenue in this category include equipment rental, resale of utilities, and, at some airports, services such as baggage handling.

**Nonoperating Revenues.** All income that accrues from sources that are not directly connected to airport functions is nonoperating revenue. Such income may derive, for example, from the rental of nonairport land or from interest on accumulated surpluses.

## Expenditures

**Operating Expenses.** Numerous operating expenses are associated with the provision of airport services. These can be categorized into maintenance costs and operations costs:

1. *Maintenance Costs.* Expenditures are required for the upkeep of facilities; these are largely independent of traffic volume. Maintenance must be provided to the landing area (runways, taxiways, aprons, lighting equipment, etc.), the terminal area (buildings, utilities, baggage handling, access routes, grounds, etc.), and hangars, cargo terminals, and other airport facilities.
2. *Operations Costs.* This category, which includes administration and staffing, utilities, and to some extent security, reflects to a greater degree the amount of traffic. To some degree, these costs are escapable when demand is low.

**Nonoperating Expenses.** The inescapable costs that would have to be met even if the airport ceased operation are said to be nonoperating expenses. Typically, they include the interest payments on outstanding capital debt and amortization charges on such fixed assets as runways, aprons, buildings, and other infrastructure.

Table 1.2 shows the effect of the magnitude of passenger operations on the sources of income and expenditure for 43 airports in the United States. The data reveal a moderate tendency for nonoperating income and expenses to increase as airports

**Table 1.2** Average Income and Expense Breakdown for U.S. Airports with Different Levels of Operational Activity

Income or expense	Average percentage breakdown of airport income and expenses by hub type		
	Large hubs (1% or more of U.S. enplanements)	Medium hubs (at least 0.25%, but less than 1% of U.S. enplanements)	Small hubs (at least 0.05%, but less than 0.25% of U.S. enplanements)
<b>Income</b>			
Operating income, %	48.4	42.3	46.4
Nonoperating income, %	51.6	57.7	53.6
<b>Expenses</b>			
Operating expenses, %	31.7	32.1	40.4
Nonoperating expenses, %	68.3	67.9	59.6

Sources: FAA Form 127 download and R. Golaszewski, GRA, Inc.

become larger. The overwhelming source of both revenue and expenditure remains in the operating category. The low level of nonoperating expense at U.S. airports reflects high levels of FAA funding for infrastructure. In fundamentally differently financed systems, nonoperating costs could rise substantially higher.

When the expense and revenue structure of non-U.S. airports is examined, it is found that the aeronautical income covers aeronautical expenditure only at the largest airports. At small airports, the aeronautical operations cause substantial losses. Non-aeronautical income which includes commercial income usually covers nonaeronautical expenditure at all but the smallest airports. At large airports, the intense commercialization of the passenger terminals generate large profits from nonaeronautical sources. These profits have proved to be highly incentive for commercial enterprises to buy into the airport industry. Investment in airports has come from banks, construction companies, and a variety of nonairport sources.

### Structure of Revenues

Operating revenues vary considerably from airport to airport, in structure and in size. Their structure depends greatly on operating volume. (Since nonoperating revenues are, by their nature, not dependent on the operating characteristics of the airport, they tend to be peculiar to the individual airport.) As the number of airport operations increases across the range of airport sizes, the busier airports attract a higher proportion of commercial air carrier operations. The larger passenger capacity of commercial carrier aircraft ensures a disproportionate increase in passenger traffic, in comparison with the increase in aircraft movements. Consequently, air terminal income increases rapidly in importance in the overall revenue structure with growing operational activity.

Operational growth that accompanies increasing air carrier traffic requires substantial investment in terminal infrastructure to provide for the rapid increase in passenger movements. Table 1.3 indicates, for U.S. airports across a range of operational volumes, a historic estimate of the declining relative importance of the landing area as a source of revenue and the increasing dominance of terminal income. Table 1.4 shows the average figures for large, medium, and small U.S. facilities. The financial stability of the operation of large airports is strongly related to the income generated by the terminal area. More than half of this income relates to surface access in the form of parking charges and leases to car rental firms, but more than one-quarter of terminal income is almost discretionary, coming from restaurants, bars, shopping concessions, and similar sources. Careful design can optimize this income relative to expenditure.

## 1.8 SOURCES OF CAPITAL FINANCING FOR U.S. AIRPORTS (5)

All airports are to some degree self-financing, and some large airports give a healthy return on invested capital. The initial capital requirement for the construction and development of airports is very large, and frequently the owning authority is unable to supply the necessary amount from its own resources. In the United States, ownership of airports rests almost entirely in the hands of local governmental units with slender capital resources. Airport development therefore proceeds on the basis of money aggregated from a variety of sources, such as general obligation bonds, self-liquidating general obligation bonds, revenue bonds, local taxes, and state and federal grants.

**Table 1.3** U.S. Airport<sup>a</sup> Sources of Total Annual Revenues/Types of Costs

Revenues	Year 2008 or 2007 (\$Millions)		
	Large hubs	Medium hubs	Small hubs
Landing fees	\$2,088.2	\$551.7	\$147.1
Terminal rental	\$2,620.5	\$582.1	\$216.5
Other aeronautical	\$965.8	\$296.0	\$155.9
<b>Total Aeronautical</b>	<b>\$5,674.6</b>	<b>\$1,429.8</b>	<b>\$519.4</b>
Rents, land, and other nonterminal	\$249.0	\$80.2	\$83.0
Rents, terminal	\$1,198.6	\$205.3	\$59.2
Car rental	\$799.9	\$369.6	\$178.6
Parking	\$1,763.8	\$773.5	\$302.0
Other nonaeronautical	\$651.0	\$76.0	\$42.7
<b>Total Nonaeronautical</b>	<b>\$4,662.4</b>	<b>\$1,504.5</b>	<b>\$665.5</b>
Bond proceeds and interest income	\$7,497.4	\$1,932.8	\$473.5
Grants	\$762.3	\$431.8	\$445.6
Passenger facility charges	\$1,918.5	\$501.3	\$173.7
Other	\$856.0	\$1,139.6	\$280.4
<b>Total Nonoperating</b>	<b>\$11,034.2</b>	<b>\$4,005.5</b>	<b>\$1,373.2</b>
<b>Total Revenue</b>	<b>\$21,371.1</b>	<b>\$6,939.8</b>	<b>\$2,558.1</b>
Expenses			
Personnel compensation	\$2,414.1	\$754.5	\$382.8
Communications	\$634.9	\$170.6	\$84.3
Supplies	\$550.3	\$87.3	\$51.0
Services	\$2,208.6	\$704.9	\$255.2
Insurance	\$159.9	\$44.6	\$26.7
Other operating	\$538.2	\$132.1	\$60.1
<b>Total Operating Expense</b>	<b>\$6,506.0</b>	<b>\$1,894.1</b>	<b>\$860.1</b>
Interest	\$2,235.7	\$500.1	\$137.4
Capital expenditures	\$7,095.3	\$2,256.1	\$881.1
Other nonoperating expense	\$174.3	\$78.7	\$24.2
Reporting year debt payments	\$4,542.1	\$1,174.7	\$221.9
<b>Total Nonoperating Expense</b>	<b>\$14,047.5</b>	<b>\$4,009.6</b>	<b>\$1,264.6</b>
<b>Total Expenses</b>	<b>\$20,553.5</b>	<b>\$5,903.6</b>	<b>\$2,124.6</b>
	<b>\$817.7</b>	<b>\$1,036.1</b>	<b>\$433.5</b>

<sup>a</sup>Number of reporting airports: large hub, 29; small hub, 36.

Excluded airports: large hub, FLL; small hub, TUS and SJU.

Note: DOT hub airport definitions:

The definitions and formulas used for designating primary airports by hub type and percentage of annual passenger boarding are: Large, 1% or more; Medium, at least 0.25% but less than 1%; Small, at least 0.05% but less than 0.25%; Nonhub, more than 10,000 but less than 0.05%.

Source: FAA Form 127 data download March 2009 and GRA Inc. USA.

## General Obligation Bonds

General obligation bonds are issued by a governmental unit. They are secured by the full faith, credit, and taxing power of the issuing governmental agency. Although the level of anticipated revenues is considered in the initial determination of the level of investment, the bonds themselves are guaranteed from the general resources of the issuing body,

**Table 1.4** U.S. Airport Annual Average Revenues and Costs

Revenues	Year 2008 or 2007 (\$Millions)		
	Large hubs	Medium hubs	Small hubs
Landing fees	\$72.0	\$15.3	\$2.2
Terminal rental	\$90.4	\$16.2	\$3.3
Other aeronautical	\$33.3	\$8.2	\$2.4
<b>Total Aeronautical</b>	<b>\$195.7</b>	<b>\$39.7</b>	<b>\$7.9</b>
Rents, land and other nonterminal	\$8.6	\$2.2	\$1.3
Rents, terminal	\$41.3	\$5.7	\$0.9
Car rental	\$27.6	\$10.3	\$2.7
Parking	\$60.8	\$21.5	\$4.6
Other nonaeronautical	\$22.4	\$2.1	\$0.6
<b>Total Nonaeronautical</b>	<b>\$160.8</b>	<b>\$41.8</b>	<b>\$10.1</b>
Bond proceeds and interest income	\$258.5	\$53.7	\$7.2
Grants	\$26.3	\$12.0	\$6.8
Passenger facility charges	\$66.2	\$13.9	\$2.6
Other	\$29.5	\$31.7	\$4.2
<b>Total Nonoperating</b>	<b>\$380.5</b>	<b>\$111.3</b>	<b>\$20.8</b>
<b>Total Revenue</b>	<b>\$736.9</b>	<b>\$192.8</b>	<b>\$38.8</b>
<b>Expenses</b>			
Personnel compensation	\$83.2	\$21.0	\$5.8
Communications	\$21.9	\$4.7	\$1.3
Supplies	\$19.0	\$2.4	\$0.8
Services	\$76.2	\$19.6	\$3.9
Insurance	\$5.5	\$1.2	\$0.4
Other operating	\$18.6	\$3.7	\$0.9
<b>Total Operating Expense</b>	<b>\$224.3</b>	<b>\$52.6</b>	<b>\$13.0</b>
Interest	\$77.1	\$13.9	\$2.1
Capital expenditures	\$244.7	\$62.7	\$13.3
Other nonoperating expense	\$6.0	\$2.2	\$0.4
Reporting year debt payments	\$156.6	\$32.6	\$3.4
<b>Total Nonoperating Expense</b>	<b>\$484.4</b>	<b>\$111.4</b>	<b>\$19.2</b>
<b>Total Expenses</b>	<b>\$708.7</b>	<b>\$164.0</b>	<b>\$32.2</b>
<b>Cash Surplus (Deficit)</b>	<b>\$28.2</b>	<b>\$28.8</b>	<b>\$6.6</b>
<b>Numbers of Airports</b>	<b>29</b>	<b>36</b>	<b>66</b>

Source: FAA Form 127 data download March 2009 and GRA Inc. USA.

not from the revenues themselves. With this degree of investment security, general obligation bonds can be sold at a relatively low interest rate, requiring a lower level of expenditure on debt servicing. Since local authorities are constitutionally limited in the total debt that can be secured by general obligation, the use of this type of bond reduces the available debt level. Because of the high demand on local authorities for capital investment, usually for facilities that produce no revenue, most government agencies consider it unwise to use general obligation bonds for such income-generating projects as airports.

### Self-Liquidating General Obligation Bonds

Self-liquidating general obligation bonds have been recognized by the courts of some states. These instruments are secured in exactly the same way as ordinary general obligation bonds; however, since it is recognized that the bonds are financing a revenue-producing project, the issue is not considered to contribute to the overall debt limitation set by the state. This type of financing is particularly desirable in that it bears low interest rates without limiting other general obligation debt.

### Revenue Bonds

Revenue bonds can be issued where the entire debt service is paid from project revenues. Although subject to the general debt limitation, these bonds bear substantially higher interest rates than general obligation bonds, the interest rate often being dependent on the anticipated level of coverage of revenues to debt service. Before issuing revenue bonds, it is normal practice to prepare a traffic-and-earnings report that includes the forecasting of revenues and expenses during the life of the bond issue. Revenue bonds are sold on the open market, but they suffer from the disadvantage that banks are forbidden to deal in revenue bond issues. Banks, on the other hand, are responsible for a large share of the underwriting of general obligation issues.

Some authorities have negotiated airport–airline agreements to provide a greater degree of security to revenue bond issues in order to assure a lower interest rate. Under these agreements, the airline guarantees to meet all airport obligations with respect to the issue. Usually, however, this sort of agreement requires that capital decisions be made by the airline—a restriction that few airports are prepared to accept.

In the past, almost all airports were financed by general obligation bonds, but the rapidly increasing sophistication of the required facilities has necessitated an increasing trend toward the use of revenue bonds, with an increasing level of commitment by the airlines in guaranteeing the revenues for debt service. As airports have become larger revenue generators and have been seen as capable of generating substantial operating surpluses if commercial development is encouraged, previously unconventional means of financing have become more important. These include:

*Nonprofit Corporation Bonds.* These bonds are issued by specially created nonprofit corporations and are backed by special-use taxes. The improvements financed in this way usually revert to the airport or municipality on bond retirement.

*Industrial Development Authority Bonds.* These bonds are issued and underwritten by a separate corporate entity located on the airport on leased land. Bonds of this nature permit nonaeronautical development without the involvement of the airport.

*Third-Party Private Finance.* This is now more frequently attracted into the airport, which is seen to be a high potential investment site because of the sustained growth of aviation.

For further discussion of this type of finance, reference should be made to Section 5.13 and texts on airport financing (5).