

An aerial photograph of a large airport terminal and runways. The terminal is a long, curved structure with multiple levels and a central tower. The runways are wide and paved, with taxiways and parking areas. The surrounding landscape is a mix of green fields and brown earth.

FOURTH EDITION

AIRPORT ENGINEERING

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

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

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Airport Engineering

Planning, Design, and Development of 21st Century Airports

Fourth Edition

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WILEY

JOHN WILEY & SONS, INC.

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Published by John Wiley & Sons, Inc., Hoboken, New Jersey

Published simultaneously in Canada

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Library of Congress Cataloging-in-Publication Data:

Ashford, Norman.

Airport engineering : planning, design, and development of 21st century airports / Norman J. Ashford, Saleh Mumayiz, Paul H. Wright.—4th ed.

p. cm.

Includes bibliographical references and index.

ISBN 978-0-470-39855-5 (cloth); 978-1-118-00529-3 (ebk); 978-1-118-00546-0 (ebk); 978-1-118-00547-7 (ebk); 978-1-118-04822-1 (ebk); 978-1-118-04824-5 (ebk)

1. Airports—Planning. I. Mumayiz, Saleh A. II. Wright, Paul H. III. Title.

TL725.3.P5A83 2011

387.7'36—dc22

2010054177

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.

Acknowledgments

Steve Culberson, Director, Ricondo & Associates, United States, authored Chapter 17, which is a complete rewrite of the environmental impact chapters of earlier editions

Michael Makariou, Makariou Associates, United Kingdom, updated the text, tables, and figures in Chapter 3 and assisted in the updating of Chapter 12 in the area of pavement design.

Acknowledgement is also due to the assistance of the following professionals and organizations in the preparation of an updated text:

Andrew Bell, Vice-President, Planning, Dallas Fort Worth International Airport, United States

James Crites, Executive Vice-President, Dallas Fort Worth International Airport and past Director, TRB-ACP, United States

Frank Elder, Forecast Director, Feather Consulting, United Kingdom

Edward L. Gervais, Boeing Airplane Company, United States

Richard Golaszewski, GRA, Inc., United States

Doug Goldberg, President, Landrum and Brown, United States

Graham Greaves, Aviation Consultant, formerly Director, Cardiff Wales International Airport, United Kingdom

Paul Hanley, Director, Ricondo & Associates, United States

Mike Hirst, Senior Associate, Airport Planning and Development Ltd., United Kingdom

Christopher W. Jenks, Director, Cooperative Research Programs, Transportation Research Board, United States

Bill Millington, Director, Halcrow Airports Group, United Kingdom

John Oakshott, Director of Aviation, Parsons Brinckerhoff Ltd, United Kingdom

Inna Ratieva, President, SRA Aviation, The Netherlands

Dr. Mario Luiz Ferreira de Mello Santos, President, AEROSERVICE, Brazil

Maurits Schaafsma, Urban Planner, Schiphol Group, The Netherlands

Peter Trautmann, President, Bavarian Air Group, Munich, Germany

Aeroports de Paris, France

Agusta Westland, United Kingdom

Airbus Industrie, France

Airports Council International

Boeing Airplane Company, United States

Federal Aviation Administration, United States

Fraport Frankfurt Airport, Germany

International Air Transport Association, Canada

International Civil Aviation Organization, Canada

Munich International Airport, Munich, Germany

PathPlan, Simtra AeroTech, Sweden

Transportation Research Board, United States

Chapter 1

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^a		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

^a 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.

[Figure 1.1](#) The aviation function within state DOTs.