



SAAD DAHLAB UNIVERSITY OF BLIDA 1
Institute of Aeronautics and Space Studies



Master II / Aeronautical Exploitation

Course Material

Airport Management

by

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Objectives of this course: The objective of this course is to provide students with the knowledge and skills to effectively manage airport operations, infrastructure, and services while ensuring safety, efficiency, profitability, and sustainability in compliance with international standards.

By the end of this course, students should be able to:

- Explain the organizational structure and key functions of airports.
- Manage airside and landside operations to ensure safety and efficiency.
- Apply international aviation standards and regulatory requirements (ICAO, IATA, etc.).
- Analyze airport capacity, infrastructure planning, and development needs.
- Evaluate airport revenue sources.
- Assess environmental and sustainability challenges in airport operations.
- Use modern technologies and innovations to improve airport efficiency and passenger experience.

Key Words : Airport Operations, Airside / Landside Management, Passenger Flow, Runway & Terminal Capacity, Ground Handling.

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Introduction

Airport systems exist in the context of their major clients, the airlines. To build airport facilities that will perform effectively over the 30 to 50 years of their lifetime, it is necessary to appreciate this context. Understanding the state of the airport/airline industry in the early twenty-first century gives a perspective on its future. This is the starting point for a forward looking text on airport systems planning.

Three trends dominate the airport/airline industry in the early twenty-first century:

1. **Long-term growth**, which has been about 4 percent per year worldwide. This implies a doubling of traffic about every 15 to 20 years and drives the demand for expansion and improvement. It also leads to the development of new airports, of multiple airport systems in metropolitan areas, and of niche airports serving leisure traffic or cargo.
2. **Organizational change**, as economic and political deregulation continues to spread worldwide. Economic deregulation creates opportunities for low-cost and integrated cargo airlines to grow, impels governments to privatize their airlines and airports, and leads traditional airlines to consolidate. Political deregulation, such as open-skies agreements, enables new markets, changes in traffic patterns, and increases competition. These ongoing changes in airport clients and their needs make for an uncertain, instable future. Airports will consequently have to plan flexibly so that they can adapt easily as required.
3. **Technical change**, most obviously in aircraft and air traffic control, but also contextually, particularly as regards information technology that continues to redefine the way we do business. These developments increase the efficiency and the capacity of airport facilities and processes. Airports need to adapt to these new opportunities as they occur.

Taken together, these trends are substantially changing the context, objectives, and criteria of excellence and efficiency for airport systems planning and design.

Airport management as a career

There are many career paths within the field of airport management as evidenced by the wide variety of job descriptions under the previous section. Even the job of airport manager varies greatly. At one extreme is the manager of a large metropolitan airport, an appointee or civil service employee of the city government or airport authority, who heads a large staff of assistants and specialists through which he or she manages a highly complex organization. At the other extreme is the owner-manager of a small private field near a rural community. The latter might combine activities as airport manager with work in some other business.

Between these two extremes is the manager of a municipally owned or privately owned airport where there are a limited number of scheduled airline flights each day. Based at the airport are several fixed-base operators (FBOs) and a number of aircraft owned by individuals and corporations. The typical manager of a medium-size airport deals with all segments of the aviation community including the airlines, general aviation, and federal and state agencies.

In the early days of aviation, an individual could become an airport manager if he or she was a pilot and had several years of experience in some segment of the industry. Although the individual had to be able to manage the operation for the owner, his or her experience was likely to be in some area of flying rather than in business management.

Today an airport manager must be primarily a skilled and experienced executive with a broad background in all facets of aviation and management in general. It is no longer necessary that the manager be a pilot. Almost every airport manager's job situation is unique in some major respects because of the wide variety of size of airport and type of ownership and operation. There are also wide variations in government procedures in different communities. This sometimes causes the responsibilities, salaries, and authority of airport managers to be completely different from one city to the next. Even the job title varies. Director of aviation, airport superintendent, executive director, airport director, general manager, and other titles are often used instead of airport manager.

Duties of an airport manager

An airport manager is often part landlord and part business executive. As a landlord, the safe condition and operation of the airport is the manager's greatest responsibility. The maintenance of the airport buildings and land is also important. As a business executive, the manager is in charge of public relations; financial planning; profitable and efficient day-to-day operation; and coordination of airline, concession, and airport facilities to best serve the tenants and flying public.

The airport manager's primary duty is the safe and efficient operation of the airport and all its facilities regardless of its size. However, at least in the larger commercial airports, the manager does not have direct control over most flying activities. He or she must deal with all groups and individuals who use the airport facilities. These include representatives of the airlines that schedule flights, maintain and service their aircraft, and process passengers; all segments of the general aviation community, including FBOs and individual and corporate owners and operators of aircraft; and the government-employed staffs of the air traffic control facilities, customs, and so forth.

All of these groups can be regarded as tenants of the airport, carrying on their independent activities. Besides dealing with the companies and individuals directly concerned with flying, the manager is in contact with concessionaires who operate restaurants, shops, and parking facilities, and with the traveling public.

The size of the airport and the services it offers its tenants and the public play an important part in determining the airport manager's specific duties. Some of these duties were enumerated earlier in this chapter under job descriptions. A manager must formulate fiscal policy, secure new business, recommend and enforce field rules and regulations, make provisions for handling spectator and passengers, oversee construction projects, see that the airport is adequately policed and that airplane and automobile traffic is regulated.

The manager interprets the functions and activities of the airport to the city or other local government and to the public; he or she is a public relations expert as well as a business manager. This public relations function is extremely important .

Not all of these duties are required of all managers of airports. Many airports are too small to have control towers; others have no scheduled airline flights. In these airports the job is simpler, but the manager must usually do all of the work personally. In large airports, the manager has many assistants and supervises the work

The job of airport manager is obviously not completed between 9 and 5. The hours are often irregular and most managers have some weekend and holiday work. They will often have to work at night. In emergency situations they will usually work additional hours. Difficult weather conditions, labor problems, personnel irregularities, and flight schedule changes are only some of the things that will affect job hours. Even when not actually working, most airport managers are on call.

Education and training

The major requirement for the job of airport manager is business and administrative ability; this means the ability to make decisions, to coordinate details, to direct the work of others, and to work smoothly with many kinds of people. Perhaps the best college program to follow is one that leads to a degree in aviation management. College courses in engineering; management; accounting; finance and economics; business and aviation law; and airline, general aviation, and airport management are good preparation for a career in airport management.

Because the position of airport manager is the top job in most airports, advancement generally comes by changing jobs usually by working for a larger airport. In a large metropolitan airport, an individual usually works up from managing various departments to become an assistant manager or director and finally manager or director.

Because the job of managing a medium-to-large commercial airport is a fascinating one that requires high qualifications, there will be tough competition for jobs; however, the motivated individual with a solid educational background and varied experience in the fields of aviation and management will find openings in a field of work that is and will remain comparatively small but one that provides an interesting and challenging profession.

CHAPTER I

Airport Classification and Design Standards

Introduction

The geometric design of an airfield critically affects every aspect of airport operations. This includes landside facilities and services, as the layout of the runway system largely dictates the general placement of the passenger, cargo, and other buildings, as well as the interfacing of airside and landside operations. Because of the overwhelming importance of safety for aviation operations, airfield design must comply with a voluminous set of detailed standards and recommended practices developed over the years by national and international civil aviation authorities and organizations. The ICAO plays a central role in this respect. Its Annex 14 to the International Convention on Civil Aviation specifies the *standards* and *recommended practices* that have been adopted by its nearly 200 Member States (formally “Contracting States”) over the years. An ICAO standard is:

any specification for physical characteristics, configuration, material, performance, personnel or procedure, the uniform application of which is recognized as necessary for the safety or regularity of international air navigation and to which Contracting States will conform (ICAO, 2009).

By comparison, a recommended practice is

any specification ... the uniform application of which is recognized as desirable ... and to which Contracting States will endeavor to conform.

Note that a standard is “necessary” for safety, while a recommended practice is “desirable” (“endeavor to conform”). In practice, the design standards and practices of national civil aviation agencies everywhere are largely based on or, in most cases, identical to those specified in the ICAO’s Annex 14. Member States that, for any reason, are unable to comply with an Annex 14 standard—and adopt a different one—must notify promptly the ICAO to this effect.

The two most influential sets of design standards are those of the International Civil Aviation Organization (ICAO) and the U.S. Federal Aviation Administration (FAA). They are based on similar, but not identical, coding systems that classify airfields according to the most demanding type of aircraft they are designed to serve. Once the reference code of an airfield or runway has been specified, design standards can be obtained from the relevant manuals and other supporting documents.

Airfields typically account for 80 to 95 percent of the total land area occupied by an air-port and affect in critical ways every facet of airport operations. The principal determinants of the size of the airfield include the number and orientation of the runways; the geometric configuration of the runway system; the dimensional standards to which the airfield has been designed; and the land area set aside to provide for future growth and/or environmental mitigation. Several airports use complex, multirunway layouts to serve very large volumes of nonhomogeneous traffic.

Four common mistakes in planning and designing airfields are the following:

- Failure to provide flexibility for future expansion.
- Overbuilding the airfield in its initial phases.
- Lack of integration and coordination of the planning process.
- Insufficient appreciation of the economic consequences of some design choices.

The implications of these mistakes for the capital and operating costs of airports and their users can be serious.

I.1 Airport Classification Codes and Design Standards

I.1.a Reference Codes for Aircraft Classification

Both the ICAO and the FAA use simple classification schemes to develop a two-element *reference code* for each type of aircraft. The ICAO reference code (ICAO, 2009) consists of two “elements,” a code number and a code letter (Table I.1). The *code number* of any type of aircraft is determined by the *airplane reference field length*, the minimum field length that aircraft requires for takeoff at maximum takeoff weight (MTOW), sea level, standard atmospheric conditions, no wind, and level runway. The *code letter* is determined by two physical characteristics of the aircraft: its *wingspan* and the *distance* (“*span*”) *between the outside edges of the wheels of the aircraft’s main gear*. When the aircraft’s wingspan and outer main gear wheel span (OMG) correspond to different code letters, the aircraft is assigned the more demanding code letter. For example, the Boeing 747-800 has an airplane reference field length of approximately 3000 m, which gives it code number 4, a wingspan of 68.5 m (code letter F), and OMG of 12.7 m (code letter E). Thus, the ICAO reference code for the Boeing 747-800 is 4-F.

ICAO Code Element 1		ICAO Code Element 2		
Code Number	Airplane Reference Field Length (RFL)	Code Letter	Wingspan (WS)	Outer Main Gear Wheel Span (OMG)
1	$RFL < 800 \text{ m}$	A	$WS < 15 \text{ m}$	$OMG < 4.5 \text{ m}$
2	$800 \text{ m} < RFL < 1200 \text{ m}$	B	$15 \text{ m} < WS < 24 \text{ m}$	$4.5 \text{ m} < OMG < 6 \text{ m}$
3	$1200 \text{ m} \leq RFL < 1800 \text{ m}$	C	$24 \text{ m} \leq WS < 36 \text{ m}$	$6 \text{ m} \leq OMG < 9 \text{ m}$
4	$1800 \text{ m} \leq RFL$	D	$36 \text{ m} \leq WS < 52 \text{ m}$	$9 \text{ m} \leq OMG < 14 \text{ m}$
		E	$52 \text{ m} \leq WS < 65 \text{ m}$	$9 \text{ m} \leq OMG < 14 \text{ m}$
		F	$65 \text{ m} \leq WS < 80 \text{ m}$	$14 \text{ m} \leq OMG < 16 \text{ m}$

Table I.1: ICAO Airport Reference Code

Analogously, the FAA uses aircraft *approach speed* to determine the first element of its reference code, the aircraft *approach category*, designated by a letter between A and E (Table I.2). The aircraft approach speed is defined as 1.3 times the stall speed in the aircraft’s landing configuration at maximum landing weight (MLW). The second element is a Roman numeral (I through VI) that specifies the *design group* to which the aircraft belongs. The design group is determined by the most demanding of two of the physical characteristics of the aircraft: its *wingspan* and its *tail height*. For example, in the case of the Boeing 737-800, the aircraft’s approach speed is 142 knots (FAA approach category D); its wingspan of 34.3 m and tail height of 12.6 m, both place it in design group III. Thus, the FAA reference code for the Boeing 737-800 is D-III.

FAA Code Element 1		FAA Code Element 2		
Aircraft Approach Category	Aircraft Approach Speed (AS) (knots)	Airplane Design Group	Aircraft Wingspan (WS)	Tail Height (TH) Wheel Span (OMG)
A	AS < 91	I	WS < 49 ft (WS < 15 m)	TH < 20 ft (TH < 6 m)
B	91 ≤ AS < 121	II	49 ft ≤ WS < 79 ft (15 m ≤ WS < 24 m)	20 ft ≤ TH < 30 ft (6 m ≤ TH < 9 m)
C	121 ≤ AS < 141	III	79 ft ≤ WS < 118 ft (24 m ≤ WS < 36 m)	30 ft ≤ OMG < 45 ft (9 m ≤ OMG < 13.5 m)
D	141 ≤ AS < 166	IV	118 ft ≤ WS < 171 ft (36 m ≤ WS < 52 m)	45 ft ≤ OMG < 60 ft (13.5 m ≤ OMG < 18.5 m)
E	166 ≤ AS	V	171 ft ≤ WS < 214 ft (52 m ≤ WS < 65 m)	60 ft ≤ OMG < 66 ft (18.5 m ≤ OMG < 20 m)
		VI	214 ft ≤ WS < 262 ft (65 m ≤ WS < 80 m)	66 ft ≤ OMG < 80 ft (20 m ≤ OMG < 24.5 m)

Table I.2: FAA Airport Reference Code

I.1.b Airport Reference Code

The *airport reference code* (ARC) of an airfield is determined by the code of the *most demanding* type of aircraft (“critical aeroplane” in ICAO terminology) that the airport is designed to serve. For instance, if the most demanding aircraft for some airport is the Airbus 340-600, classified as a 4-E aircraft in the ICAO’s scheme and as a D-V in the FAA’s, the airport’s ARC would be 4-E or D-V according to the ICAO’s or the FAA’s reference codes, respectively.

It is important to note that an airport’s “most demanding aircraft” the type that determines an airport’s ARC need not be an aircraft that is currently using the airport. In other words, an airport can be designed to accommodate in the future aircraft types that are more demanding than the ones that have been served there in the past.

At multirunway airports, individual runways may differ in their ability to serve different types of aircraft. For example, one runway may be too short for handling takeoffs by longrange aircraft, whereas another may be sufficiently long for this purpose. In such cases, different *runway design codes* (RDCs) will be associated with different runways. For ex-ample, the long runway may have an FAA RDC of D-V, and the shorter runway an RDC of C-III. In such situations, the runway with the “highest” RDC determines the overall ARC. Thus, in our example the ARC will be D-V the most demanding of D-V and C-III.

I.1.c Practical Implications

When it comes to the first element of the ICAO reference code, note that the most common narrow-body commercial aircraft, such as the Airbus 320 and the Boeing 737, has a reference field length greater than 1800 m (Table I.3b). This means that the ARC of virtually all major commercial airports has an ICAO code number of 4. At the same time, for all practical purposes the wingspan of the most demanding aircraft determines the second element of the ICAO reference code. This is because, for the existing types of important commercial jets, the OMG almost never places these aircraft in a code letter category higher than

the one to which they would be assigned based on their wingspan. For example, no airplane assigned code letter D on the basis of its wingspan would be assigned code letter E or F on the basis of its OMG. It follows from these two observations that the ICAO reference code for major airports can only be 4-C (in the rather unusual case where aircraft like the Airbus 320 or the Boeing 737 are the most demanding that the airport can serve) or, far more often, 4-D, 4-E, or 4-F.

Turning to the FAA ARC, it is again true that the wingspan of the most demanding aircraft determines the airplane design group for all practical purposes (see Table I.3) This is because the tail height never places an aircraft in a design category higher than the one to which it would have been assigned based solely on its wingspan. Note also that the wingspan thresholds that separate FAA airplane Groups I through VI from one another are exactly the same as the ICAO thresholds. For example, FAA Group IV aircraft have wing spans between 36 and 52 m, exactly the same as ICAO code letter D aircraft. This means that the second elements of the FAA and the ICAO reference codes for all types of aircraft correspond perfectly. The only difference is that the FAA uses Roman numerals and the ICAO uses capital letters to designate that second element. An airport with an ARC in Group V per the FAA will have code letter E per the ICAO and vice versa certainly a desirable circumstance for airfield designers. This is pointed out in Fig I.1, which plots the length and wingspan of many of the most common types of current commercial jet air-planes and identifies on the right vertical axis the second code element to which they belong.

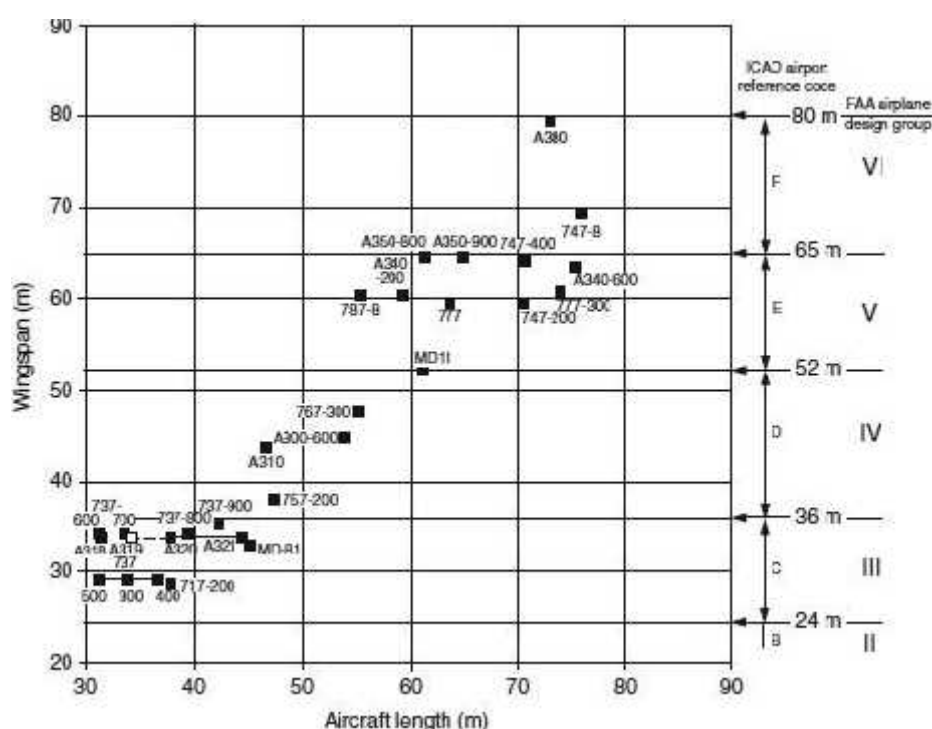


Figure I.1: Length and wingspan of current types of commercial jet transport airplanes. The corresponding ICAO and FAA reference codes are indicated along the vertical axis on the right.

The second code element largely determines many of the geometric design standards at airports, such as the required separation between a runway and a parallel taxiway or between two parallel taxiways. This is because wingspan reflects well the physical size of aircraft, especially when it comes to selecting airfield dimensions that will ensure safe operations. It follows that it makes little difference, in most instances, whether an airport is designed to FAA or ICAO standards because these agencies will classify any airport in the same way, on the basis of wingspan, and their dimensional standards for different wingspan

categories are usually either identical or very similar. There are, however, a few significant exceptions to this statement.

The choice of ARC is obviously a critical decision for airport planners and operators. Building for a more demanding aircraft than necessary means incurring unnecessary capital and maintenance costs: the dimensions of runways, taxiways, and aprons and the separations between them will be larger than necessary. On the other hand, it may be even costlier to “under-design” the airport. If, at some future time, an airline wishes to initiate service with a type of aircraft that the airport is not designed to handle, this service must either be denied, or arrangements must be made to accept the aircraft under some special handling provisions, or the airport’s facilities must be modified to make them compatible with the aircraft. The first two choices are unattractive in the long run, especially if the popularity of the aircraft in question increases over time. The third choice can be very expensive and disruptive if adequate provisions were not made at the outset for the possibility of future redimensioning of airfield facilities, as Examples I.1 and I.2 suggest.

Example I.1 The Airbus 380, with a wingspan of 79.8 m, was the first nonmilitary airplane with an ICAO reference letter F (or FAA Group VI) designation to be widely introduced at commercial airports. Before its entry into service, Airbus Industry surveyed 81 leading airports around the world, considered the top candidates to receive A380 service, in order to identify potential airport/aircraft compatibility problems. The survey found that the three principal problems were runway and taxiway dimensions and separations, weight effect on taxiway bridges, and the impacts of aircraft size and capacity on passenger buildings. An Airports Council International survey of 30 of these airports found an average cost of about \$100 million per airport for the adjustments needed to accept the A380 at these airports, or a total of \$3 billion for just these 30 airports.

Example I.2 The FAA, anticipating the future development of aircraft larger than the Boeing 747, published as early as 1983 design standards for aircraft in Group VI with a wingspan of up to 80 m (FAA, 1983). The ICAO did not officially publish its corresponding standards (code letter F) until 1999. Prudent planners at airports that might be used in the future by new airplanes in Group VI or Code Letter F, such as the Airbus 380, consulted the FAA standards between 1983 and 1999 in designing new airports or planning for the expansion of existing ones.

The message is clear: *design for flexibility and build in stages*. Whenever the land area available makes this feasible, the geometric design should make possible the future adjustment of the geometric characteristics of the airfield so it can serve larger aircraft than it was originally built for. To follow such a strategy, airport designers and planners should be aware of the full foreseeable range of potential aircraft sizes and associated design standards.

Table I.3 lists some of the characteristics of many common types of commercial jet air-planes and a few turboprops. It is subdivided into parts for wide-body aircraft (see Table I.3a), narrow-body aircraft (see Table I.3b), and regional jets and turboprops (see Table I.3c). The information provided includes the following:

	WS (m)	Length (m)	TH (m)	OMG (m)	MTOW (tons)	Passenger Seats	Range (km)	TO Field Length (m)	ICAO RC	FAA RC	FAA TDG
Airbus											
A300-600R	44.9	54.1	16.6	10.9	171.7	220-266	7,540	2320	4-D	C-IV	5
A310-300	43.9	46.7	15.8	10.9	164.0	218-240	9,600	2260	4-D	C-IV	5
A330-200	60.3	58.8	17.4	12.6	233.0	253-293	13,430	2220	4-E	C-V	6
A340-300	60.3	63.6	16.9	12.6	276.5	295-375	13,700	3000	4-E	D-V	6
A340-600	63.5	75.3	17.3	12.6	368.0	380-440	14,350	3100	4-E	D-V	6
A350-900	64.8	66.9	17.1	12.9	268.0	315-366	15,000	n.a.	4-E	D-V	6
A380	79.8	72.7	24.5	14.3	560.0	525-644	15,400	2900	4-F	D-VI	7
Boeing											
747-200B	59.6	70.6	19.3	12.4	377.8	366-452	12,700	3190	4-E	D-V	6
747-400	64.4	70.6	19.4	12.6	396.9	416-524	13,450	3200	4-E	D-V	6
747-8	68.5	76.3	19.4	12.7	448.0	467-605	14,800	3000	4-F	D-VI	6
767-200ER	47.6	48.5	16.1	10.9	179.2	181-224	11,825	2740	4-D	D-IV	5
767-300ER	47.6	54.9	16.0	10.9	186.9	218-269	11,065	2540	4-D	D-IV	5
777-200ER	60.9	63.7	18.5	12.9	297.6	301-400	14,300	3570	4-E	C-V	6
777-300ER	64.8	73.1	18.5	12.9	351.5	365-451	14,690	3200	4-E	D-V	6
787-8	60.2	56.7	16.9	11.7	228.0	242-264	15,200	2850	4-E	D-V	6
787-9	60.2	62.8	17.0	11.7	251.0	250-290	15,700	n.a.	4-E	D-V	6

Table I.3a: Characteristics of Common Wide-Body Turbofans

	WS (m)	Length (m)	TH (m)	OMG (m)	MTOW (tons)	Passenger Seats	Range (km)	TO Field Length (m)	ICAO RC	FAA RC	FAA TDG
Airbus											
A318	34.1	31.4	12.6	8.7	68.0	107-117	5700	1828	4-C	C-III	3
A319-100	34.1	33.8	11.8	8.7	75.5	124-134	6700	2164	4-C	C-III	3
A320-200	34.1	37.6	12.1	8.7	77.0	150-164	5900	2090	4-C	C-III	3
A321-200	35.8	44.5	11.8	9.1	93.0	185-199	5950	2560	4-C	C-III	5
Boeing											
717-200	28.5	37.8	8.9	5.4	54.9	106-117	3800	1800	4-C	C-III	3
737-200	28.4	30.5	11.2	6.4	58.1	102-136	4300	2090	4-C	C-III	5
737-300	28.9	33.4	11.1	6.4	62.8	128-140	4200	2300	4-C	C-III	3
737-400	28.9	36.5	11.1	6.4	68.0	146-159	4200	2540	4-C	C-III	3
737-500	28.9	31	11.1	6.4	60.6	108-122	4450	2470	4-C	C-III	3
737-600	34.3	31.2	12.6	7.0	66.0	108-123	5650	1750	4-C	C-III	3
737-700	34.3	33.6	12.5	7.0	70.1	128-140	6230	2100	4-C	C-III	3
737-800	34.3	39.5	12.5	7.0	79.0	160-175	5670	2400	4-C	D-III	3
737-900	35.7	42.1	12.5	7.0	85.1	174-204	5000	3000	4-C	D-III	3
757-200	38.1	47.3	13.6	8.6	115.7	200-239	7200	2910	4-D	C-IV	5
MD-81*	32.8	45.0	9.0	6.2	63.5	155-172	2910	1870	4-C	C-III	3
MD-87*	32.8	39.7	9.3	6.2	63.5	130-139	4400	1860	4-C	C-III	3

Table I.3b: Characteristics of Common Narrow-Body Turbofans

	WS (m)	Length (m)	TH (m)	OMG (m)	MTOW (tons)	Passenger Seats	Range (km)	TO Field Length (m)	ICAO RC	FAA RC	FAA TDG
Bombardier											
CRJ 200ER	21.2	26.8	6.2	4.0	23.1	50	3045	1770	3-B	C-II	3
CRJ 700ER	23.2	32.5	7.6	5.7	34.0	70	3208	1676	3-B	C-II	3
CRJ 900ER	24.9	36.4	7.5	6.8	37.4	86	2950	1861	4-C	C-III	3
CRJ 1000ER	26.2	39.1	7.5	7.0	41.6	100	2843	2079	4-C	C-III	3
Dash8 (Series Q400)*	28.4	32.8	8.3	6.1	29.3	78	2522	1402	3-C	B-III	3
Embraer											
ERJ 135ER	20.0	26.3	6.8	4.1	19.0	37	2300	1610	3-B	C-II	3
ERJ 145ER	20.0	28.5	6.8	4.1	22.0	50	1900	1970	4-B	C-II	3
ERJ 170-200 (ERJ 175)	26.0	31.7	9.7	6.2	38.8	78-88	3839	2244	4-C	C-III	3
ERJ 190-100	28.7	36.2	10.3	6.9	50.3	94-114	4250	2056	4-C	C-III	3
ATR											
ATR 42-500*	24.6	22.7	7.6	4.9	18.6	42-50	1555	1100	2-B	B-III	3
ATR 72-500*	27.1	27.2	7.7	7.3	22.5	68-74	1324	1165	2-C	B-III	3

Table I.3c: Characteristics of Common “Regional Jets” (Narrow-Body Turboprops and Turboprops (indicated with*))

- Wingspan (WS), length, tail height (TH), and outer main gear wheel span (OMG).
- Maximum certificated structural takeoff weight (MTOW).
- Number of passenger seats.
- Maximum range of the aircraft at full payload.
- Takeoff field length at MTOW, sea level, standard atmospheric conditions, no wind, and level runway.
- ICAO and FAA reference codes (RC).
- FAA taxiway design group (TDG), a recent grouping of aircraft types for taxiway design purposes.

The MTOW, range, and takeoff field length shown are only indicative and may vary for the same aircraft model depending on many factors, such as engine type, or modifications and improvements that may become available over time. The number of passenger seats shown indicates a typical range for standard three-class (first, business, and economy) seating or two-or single-class configurations. The number of seats may be increased in some cases beyond the ranges shown in Table I.3, depending on intended use of the aircraft (e.g., short hops), the seat pitch desired by the airline, and the class configuration of the airplane cabin.

Note that the ranges and takeoff field lengths in Table I.3 apply under a set of nominal conditions (e.g., takeoff field length at MTOW from a level runway at sea level under standard atmospheric conditions and no wind). They may vary greatly on a day-to-day basis and the specific circumstances involved, such as the selected tradeoff between payload and the amount of fuel carried, the weather conditions (temperature and winds at takeoff airport, winds aloft), and the physical characteristics of the takeoff runway.

I.1.d Runway Designation and Classification

Every runway is identified by a two-digit number, which indicates its magnetic azimuth in the direction of operations to the nearest 10° (see the exception for four or more parallel runways below). For example, a runway with a magnetic azimuth of 224° is designated and marked as “Runway 22” (for 220°). Obviously, the identification numbers at the two ends of any runway will differ by 18. For instance, the opposite end of Runway 22 is designated as Runway 04, and the runway is referred to as “Runway 04/22.” In the case of two parallel runways, the letters R, for right, and L, for left, are added to distinguish between the runways.

Thus, Boston/ Logan has a pair of close parallel runways designated as 04R and 04L when the runways are operated to the northeast and, respectively, as 22L and 22R when operated to the southwest. The letters R, C (for center), and L are often used with three parallel runways. If an airport has four parallel runways, one pair is typically marked to the nearest 10°, with the additional indications R and L, and the other to the next nearest 10°, with the additional indications R and L. For example, Los Angeles/International has four parallel runways arranged in two close pairs, the pair 6L/24R and 6R/24L to the north of the terminal complex and the pair 07L/25R and 07R/25L to the south. This also indicates that, with operations to the east, the magnetic azimuth of the four Los Angeles runways is between 60° and 70°.

There may be deviations from these practices, if this is deemed advisable to avoid confusion and ensure safety. For instance, Seoul/Incheon opened with two close parallel runways, designated 15R/33L and 15L/33R. When a third parallel runway was later added to the west and at some distance from the two existing ones, it was designated 16/34, in preference to changing the designation of the existing runway 15R/33L to 15C/33C and calling the new runway 15R/33L. Similarly, when Atlanta opened a fifth parallel runway (see Fig. I.7) in 2006, it was called 10/28, to avoid renaming any of the already existing runways 8L/26R and 8R/26L, to the north of the terminal complex, and 9L/27R and 9R/27L to the south. In contrast, at Dallas/Fort Worth (Fig. I.8), the five parallel runways in the principal direction of operations are designated as 17L/35R, 17C/35C, and 17R/35L (three runways on one side of the terminal complex) and 18L/36R and 18R/36L (a close pair on the other side). For the purpose of specifying design standards, runways are also classified as noninstrument and instrument. A *noninstrument* (or *visual*) *runway* is intended for the operation of aircraft using visual approach procedures. Instrument runways are further subdivided into nonprecision and precision. A *nonprecision approach runway* has some visual aids and, at a minimum, a navigation aid that provides directional guidance adequate for a straight-in approach, but no vertical guidance. A *precision approach runway* allows operations with a decision height and visibility corresponding to at least Category I limits.

I.2 Wind Coverage

The construction of runways in more than one direction is usually motivated by the requirement to provide adequate coverage for crosswinds. Landings and takeoffs are typically conducted into the wind. For instance, when the wind is from the north, runways with a northerly direction, if available, will be preferred over others, and landings and takeoffs will be performed in a generally south-to-north direction. When any given runway is in use, the crosswind is the component of the surface wind velocity vector perpendicular to the runway centerline. Its magnitude can be computed by simply multiplying the speed of the prevailing wind by the sine of the angle between the wind direction and the runway centerline.

The ICAO specifies that a runway should not be used if the crosswind component exceeds the following:

- 19 km/h (10.5 knots) for airplanes whose reference field length is less than 1200 m
- 24 km/h (13 knots) for airplanes whose reference field length is between 1200 and 1499 m
- 37 km/h (20 knots) for airplanes whose reference field length is 1500 m or greater, except that with poor braking action (e.g., when the runway surface is wet) the limit is 24 km/h (13 knots)

The corresponding FAA requirements (FAA, 2012) call for crosswinds not exceeding the following:

- 10.5 knots (19 km/h) for ARCs A-I and B-I
- 13 knots (24 km/h) for A-II and B-II
- 16 knots (30 km/h) for A-III, B-III, C-I through C-III, and D-I through D-III
- 20 knots (37 km/h) for all other ARCs

Naturally, these limits are conservative. For example, aircraft in FAA Groups IV, V, or VI (or with ICAO code letter D, E, or F) can maneuver with crosswinds as high as 25 to 30 knots (46–55 km/h). The actual selection of the runway(s) to be used at any given time at an airport is made by the provider of ATM services (the FAA in the United States), not the airport operator, taking into consideration prevailing winds. A pilot may request reassignment to a different runway on account of crosswinds.

Both the ICAO and the FAA recommend that the number and orientation of runways should be such that *crosswind coverage* (or the *airport usability factor* in ICAO terminology) is at least 95 percent. In other words, the percentage of time during which the use of a runway system is restricted because of crosswinds should be less than 5 percent. Note that the 95 percent target may still leave approximately 18 days per year without crosswind coverage. For many major airports this may not be acceptable. In practice, these airports usually provide runways in a sufficient number of directions, when needed, to ensure usability factors higher than 95 percent. National civil aviation authorities, in fact, may impose far more stringent crosswind coverage requirements than 95 percent at the principal air-ports of their countries.

Airport designers use historical wind statistics from an airport's site to determine the orientation of the runways that should be provided to achieve adequate crosswind coverage. A *wind rose* conveniently summarizes these statistics graphically. It consists of a series of concentric circles, representing wind speed groupings from 0 to 10 knots, 10 to 16 knots, 16 to 21 knots, etc., and a set of radial lines, usually drawn at intervals of 10°, that cut through the circles (Fig.I.2). The figure within each resulting “box” indicates the percent-age of time during which winds observed at the site are within the corresponding orientation limits and speed limits.

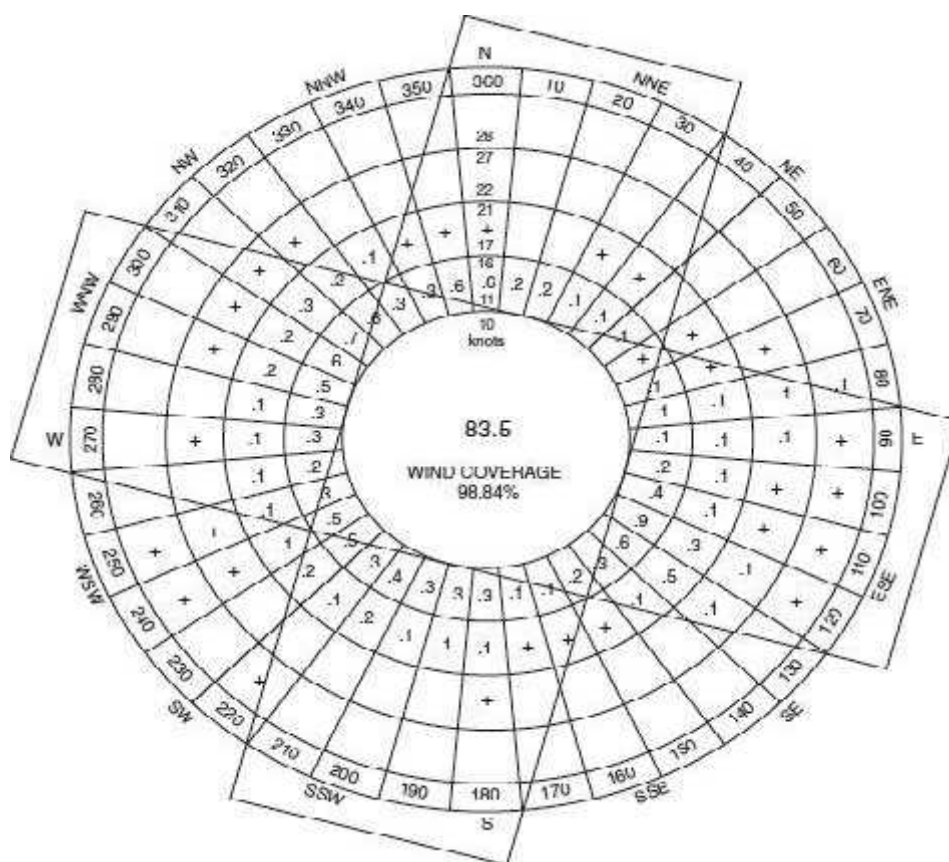


Figure I.2 : A wind rose and the wind coverage of two runways. The numbers indicate percent of time and a “+” indicates “nonzero, but less than 0.1 percent.” The total coverage achieved by the two runways in this example is 98.84 percent.

In a manual wind analysis, two parallel lines are drawn for each runway orientation examined. These lines are tangent to the circle corresponding to the allowable crosswind limit. For example, one of the runway orientations of interest in Fig.I.2 is, in opposite directions, 105° and 285° (true) and the allowable crosswind limit is 10 knots. All winds within the rectangle drawn in this way are “covered” for crosswinds of 10 knots or less by a runway with that orientation; those outside the rectangle are not. In Fig.I.2, two bidirectional runways, one with a 105° and 285° orientation and the other with 15° and 195°, together provide 98.84 percent crosswind coverage when the crosswind limit is 10 knots. In practice, a simple computer program performs this procedure. Wind analyses are important in the design of new airports and in any study of the effects of weather on existing airports. For this reason, the FAA and the ICAO recommend that extensive historical wind records be compiled at each actual or potential airport site, preferably covering up to 10 consecutive years.

I.3 Airport Layouts

This section provides a brief descriptive review of airport layouts, with emphasis on the configuration of the airfield and of systems of runways. It makes several general observations concerning the range of land areas that airports occupy and the principal factors that influence this parameter. It concludes with a survey of commonly used generic types of air-port layouts and a summary of some of their properties and characteristics.

I.3.a Land Area Requirements and Related Observations

Airfields largely determine the total land area occupied by an airport and play a critical role in determining the airport’s functionality and capacity. How much land area is actually occupied by an airfield depends on many factors. Principal among them are the following:

- The number, layout, and geometry of the runways, including runway length, separations between parallel runways, angles between nonparallel runways, ARCs selected for the purposes of airfield design, etc.
- The location of the landside facilities relative to the airside facilities.
- The additional land area held in reserve for future expansion or to provide a “buffer” area for mitigation of noise and other environmental effects.

The land areas that airports occupy span an enormous range, while the correlation between land area and the amount of traffic processed is rather weak. For example, the land area of New York/LaGuardia, which covers 2.6 million m² is equal to less than 2 percent of Denver/International’s, which covers 136 million m² (54 sq. miles). However, in 2011, LaGuardia processed almost half as many passengers as Denver (24 vs. 52.7 million). Atlanta at 89.3 million passengers had nearly 80 percent more passengers than Denver, while occupying only 25 percent as much space. There is, however, a strong correlation between an airport’s land area and its potential capacity to handle passengers and aircraft.

The airfield takes up most of the land area occupied by an airport. All the landside facilities (passenger buildings, cargo areas, on-site access roads, car parking, etc.) typically occupy only between 5 and 20 percent of the total land area, with the larger percentages applying to airports with small land areas, such as New York/LaGuardia and Washington/ Reagan (3.8 million m²). The other 80 to 95 percent is dedicated to the complex of runways, taxiways, and aprons.

The number of runways needed to serve air traffic demand is a critical factor in determining land area requirements for airfields. In this respect, there exists an interesting systemic difference among regions of

the world. This is suggested by Table I.4, which lists the 30 busiest airports in the world in 2010, ranked by number of passengers. Of those, 13 were in North America, 10 in Asia⁷ and Oceania (Sydney), and 7 in Europe.⁸ The table also shows the number of aircraft movements at these airports and the number of passengers per movement. A distinct characteristic of North American (the United States and Canada) airports is that they process very large numbers of aircraft movements. Note, for example, that Chicago/O'Hare, London/Heathrow, and Tokyo/Haneda had similar numbers of passengers in 2010, but Tokyo/Haneda handled only 75 percent as many movements as London/Heathrow and 39 percent as many as Chicago/O'Hare. This also meant a relatively small number of passengers per movement at North American airports, compared to European and especially to Asian airports. These observations are further borne out by Table I.5, which provides relevant statistics for the 15 busiest airports in Asia, Europe, and North America in 2010. It shows that the average number of passengers per airport was about 9 percent smaller in the 15 busiest airports in Asia/Oceania than in North America, while the average number of movements per airport was 45 percent smaller, resulting in 67 percent more passengers per movement (145 vs. 87) in Asian airports. The 15 busiest European airports averaged 110 passengers per movement or 26 percent more than the ones in North America.

	Passengers (millions)	Movements (thousands)	Passengers/ Movement
Atlanta	89.3	950	94
Beijing	73.9	518	143
Chicago/O'Hare	66.8	883	76
London/Heathrow	65.9	455	145
Tokyo/Haneda	64.2	343	187
Los Angeles/International	59.1	667	89
Paris/de Gaulle	58.2	500	116
Dallas/Ft. Worth	56.9	652	87
Frankfurt/International	53.0	464	114
Denver	52.2	630	83
Hong Kong/Chek Lap Kok	50.3	307	164
Madrid	49.8	434	115
Dubai	47.2	293	161
New York/Kennedy	46.5	400	116
Amsterdam	45.2	402	112
Jakarta	44.4	339	131
Bangkok/Suvarnabhumi	42.8	267	160
Singapore	42.0	264	159
Guangzhou	41.0	329	125
Shanghai/Pudong	40.6	332	122
Houston/Intercontinental	40.5	531	76
Las Vegas	39.8	506	79
San Francisco/International	39.3	387	102
Phoenix	38.6	449	86
Charlotte	38.3	529	72
Rome/Fiumicino	36.2	329	110
Sydney	36.0	303	119
Miami/International	35.7	376	95
Orlando/International	34.9	308	113
Munich	34.7	390	89

Table I.4 : Traffic at the World's 30 Busiest Airports in 2010.

15 Busiest Airports In...	Average Annual Passengers (millions)	Average Annual Aircraft Movements (thousands)	Average Passengers per Movement
North America	46.9	541	87
Europe	35.7 (-24%)	325 (-40%)	110 (+26%)
Asia	42.9 (-9%)	296 (-45%)	145 (+67%)

Table I.5 : Comparison of 15 Busiest Airports in North America, Asia/Oceania, and Europe

The explanation for these large regional differences lies in the fact that the aircraft mix at the busiest airports in Asia includes a large percentage, often in excess of 40 percent of the total, of large, wide-body jets, performing long-range often intercontinental flights. By contrast, the aircraft mix at North American airports is dominated (roughly 90 percent of the total movements at the 15 busiest airports) by a combination of narrow-body jets, regional jets, and nonjets flown by regional airlines. A large fraction of the passengers on the latter two types of aircraft connect to flights on the larger airplanes. Europe is in the middle: following the 1993 deregulation of the airline industry in the European Union, there has been a sharp increase in regional flights at European airports, including “feeder” flights with smaller aircraft. Thus, the busiest North American and, to a lesser extent, European airports need more runways than their Asian counterparts to serve the same number of passengers. The 34 busiest airports in the United States had an average of 4.1 runways in 2010 and the 34 busiest in Europe 2.5, whereas only one major airport in Asia had four runways (Tokyo/Haneda) and only a handful had three.

However, a major change has been taking place at the busiest Asian airports, as a result of the very rapid growth in: domestic air travel in China, India, Indonesia, and several other countries; regional services, especially in Southeast Asia; and low-cost carriers. Because narrow-body jets primarily provide these domestic, regional, and low-cost services, the large increase in the numbers of passengers at Asian airports has had to be absorbed through a roughly equally large increase in the number of aircraft movements. As of 2012, Asian airports were experiencing a runway capacity crisis: practically every major airport in the region had either constructed recently one or more new runways or was in the process of planning for such expansion.

The need for additional runway capacity, either by adding new runways to existing airports or by building new airports, is therefore global. The need will persist for as long as air traffic growth outpaces gains in runway capacity obtained through improvements in the ATM system. Building new runways is, however, an extremely difficult proposition politically in many countries. In addition, when expansion is feasible, it is typically a time consuming and expensive process. Recent runway addition projects at Atlanta, Seattle/Tacoma, and St. Louis/Lambert all cost upward of \$1 billion, whereas the Chicago/O’Hare modernization plan that emphasizes runway modifications and additions has an estimated cost in the order of \$10 billion. The new second runway on a landfill at Osaka/Kansai that opened in 2007 cost around \$10 billion, while in early 2012 Hong Kong/Chek Lap Kok announced plans to build a third runway on landfill (and expand landside facilities) at an anticipated cost of approximately \$17 billion.

I.3.b Case Studies of Airport Layouts

The geometric characteristics of the runway system and of the airfield are very important in determining land area requirements. The length of the runways is a simple example. At major airports they can be as short as 1500 m (roughly 5000 ft) and as long as 4000 m (13,000 ft) or even longer at high elevations. Obviously, the longer the runways, the more land area is needed, especially if the airport property is to have a regular and compact shape, such as a rectangle. When parallel runways are present, the separation between

their centerlines is another parameter critical to determining how much space the airport will occupy and where the landside facilities will be placed. Finally, the physical dimensions of runways, taxiways, and aprons (width, separations between runways and neighboring taxiways, taxilanes, aprons and buildings, separations between parallel taxiways, etc.) depend on the ARC selected for design purposes.

Several major and many secondary airports have only a single runway. Because of limited land availability at their sites, it is also unlikely that many of these airports will ever add second runways. Their geometric layout is quite simple, as illustrated by Fig.I.3, which sketches London/Gatwick. Although the airport seems to have a pair of close parallel runways, it actually operates with a single runway at all times because of the proximity of 08L/26R and 08R/26L: the former is normally used as a taxiway for the latter, except at times when 08R/26L is closed down for maintenance and repairs. At single-runway air-ports, the landside facilities are to the side of the runway, with passenger buildings and cargo buildings possibly on opposite sides. However, because of site limitations, the buildings may sometimes be inconveniently located relative to the runway. Note that at London/Gatwick, the location of the main passenger building necessitates taxiing distances of about 3500 m (2.2 miles) for aircraft taking off from 08R, which is the case much of the time. The nature of the traffic that single-runway airports handle is dictated in large part by the length of the runway. Milan/Linate, with a 2700-m (8860-ft) runway, is limited to shortand medium-range flights. London/Gatwick and Geneva both have long runways and can accommodate intercontinental, long-range flights. Single-runway airports may be able to handle surprisingly large numbers of passengers, especially if the mix of aircraft includes a high fraction of wide-body aircraft. London/Gatwick handled 33.7 million passengers in 2011 and ranked 36th in the world. San Diego, heavily utilized by medium-size and smaller aircraft, processed 200,000 aircraft movements and 16.8 million passengers that year.

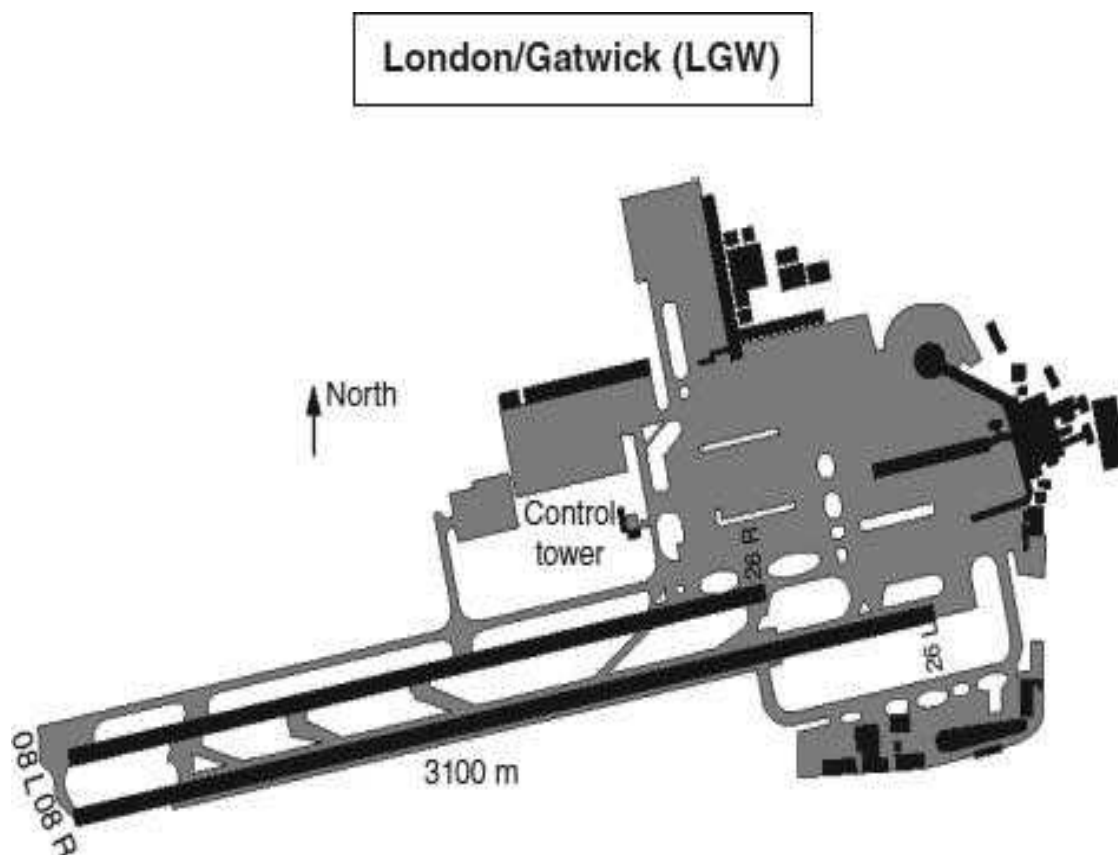


Figure I.3 Layout sketch of London/Gatwick.

The runway systems of many major airports consist of two parallel runways. Depending on the separation between the runway centerlines, these airports are said to have “close,” “medium-spaced,” or “independent” parallel runways. Although standards differ somewhat from country to country, close parallel runways are generally those with centerline separations of less than 2500 ft (762 m). Under instrument flight rules (IFR), movements of aircraft on the two close parallel runways must be coordinated.

Independent parallel runways, on the other hand, are those whose centerlines are separated by distances greater than 4300 ft (1310 m) or 5000 ft (1525 m), depending on runway instrumentation and the ATM rules in different countries. As the name suggests, any pair of aircraft movements on the two independent parallel runways need not be coordinated, as long as a number of ATM and terminal airspace conditions are satisfied. Independence allows simultaneous parallel approaches to the two runways.

Medium-spaced parallel runways lie between the two extremes of close parallel and independent parallel. They permit independent departures from the two runways or independent “segregated” parallel operations, meaning that one runway can be used for arrivals and the other, independently, for departures. However, arrivals on two medium-spaced runways are not independent.

The capacity of the runway system obviously generally increases as one moves from a close to a medium-spaced to an independent pair of parallel runways.

However, close and medium-spaced parallel runways may be able to generate capacities close to those of an independent pair when operated under visual flight rules (VFR) in good weather, as they often are in the United States. Parallel runway operations under VFR can be conducted on pairs separated by as little as 700 ft (214 m) according to the FAA and the ICAO, although the FAA recommends 1200 ft (366 m) for runways serving Group V and VI aircraft.

Close parallel and medium-spaced parallel runways do not provide sufficient space for the development of a landside complex between them. Thus, landside facilities at these airports are generally located to one or both sides of the runway pair. Layouts based on two close parallel runways or on two medium-spaced parallel runways (rather than two independent ones) are necessitated by such reasons as limited land availability, environmental restrictions and irregular shape of the airport site. Important examples include Philadelphia, New York/Newark, Frankfurt/International, and Milan/Malpensa.

Fig.I.4 shows a sketch of Frankfurt/International, where a third runway supplements the close pair of parallel runways. This third runway usually serves only takeoffs (and only to the south), primarily because of environmental restrictions. Note that all four of the airports mentioned above are on older sites. Because of their local and regional importance, they have all undergone (or are undergoing) major infrastructure improvements and, in some cases, limited expansion of the available land area.

All these airports share an important disadvantage: aircraft operating on the runway farther from the passenger building and main apron area must usually cross an active runway or its extension. This increases surface traffic delays and taxi times, as well as air traffic controller workload.

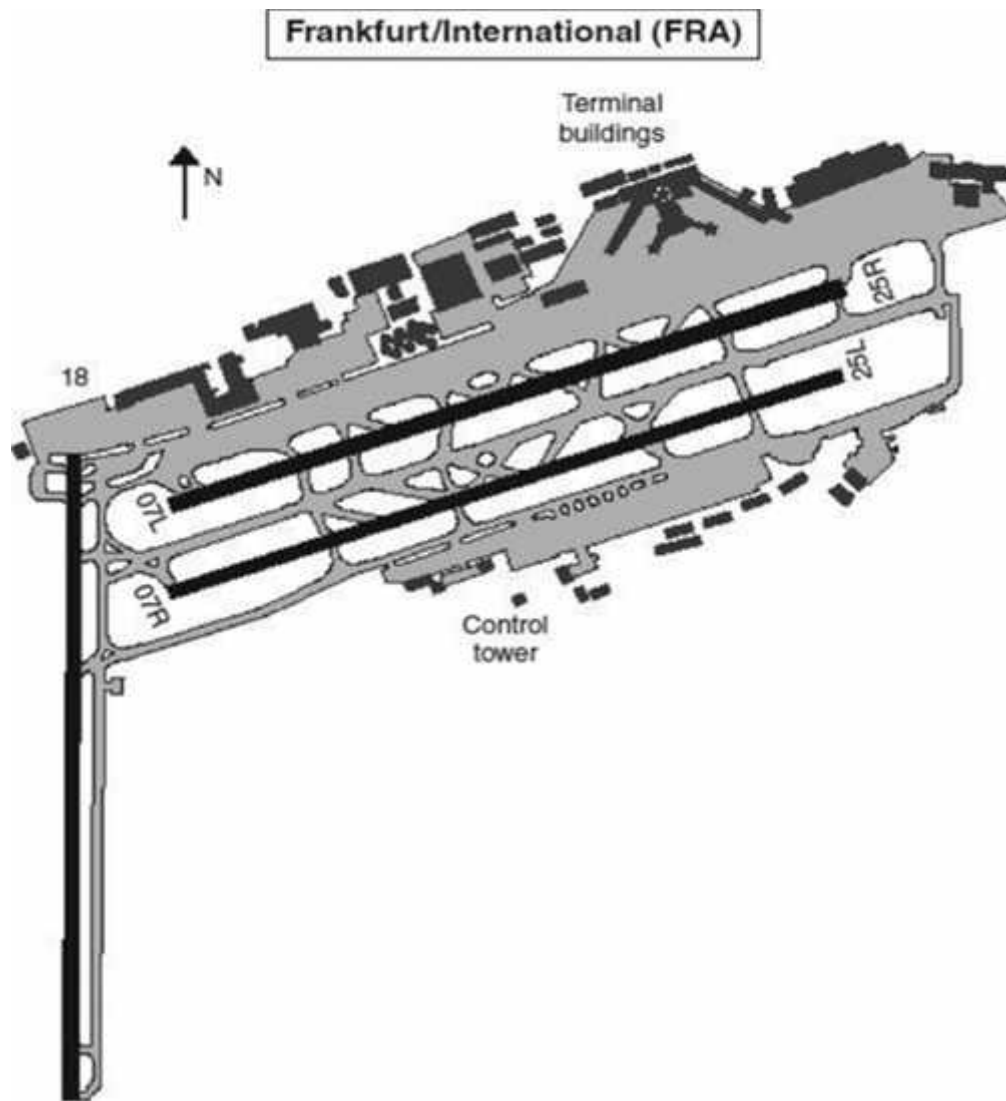


Figure I.4 : Layout sketch of Frankfurt/International.

When runway system occupies the central part of an airport's site, as in the cases of single and close or medium-spaced parallel runways, it is important to have all passenger buildings on the same side of the runways. A number of airports, such as Manila/Aquino, Moscow/Sheremetyevo, Sydney (and other major Australian airports), and (in the future) Frankfurt/International, have passenger buildings on both sides of the runway system. Transfers of passengers and bags between buildings are then difficult, expensive, and time consuming. There is also wasteful duplication of services and facilities on the two sides of the airport and limited opportunity to achieve economies of scale through sharing of common areas. Airlines and connecting passengers generally dislike using air-ports with these split landside arrangements.

Independent parallel runways provide sufficient space between them to accommodate the bulk of an airport's landside facilities, especially when spaced by 5000 ft (1525 m) or more, as is usually the case. The landside facilities are built mostly along the central axis of the airport. Some of the busiest airports in the world and, especially, many new airports that have started operations since 1990 belong to this category. London/Heathrow, Singapore, Hong Kong/Chek Lap Kok, Guangzhou, Jakarta, Kuala Lumpur, Athens, Oslo/Gardermoen, and Munich (Fig.I.5) are examples. Some of the main advantages of this popular family of airport designs include the following:

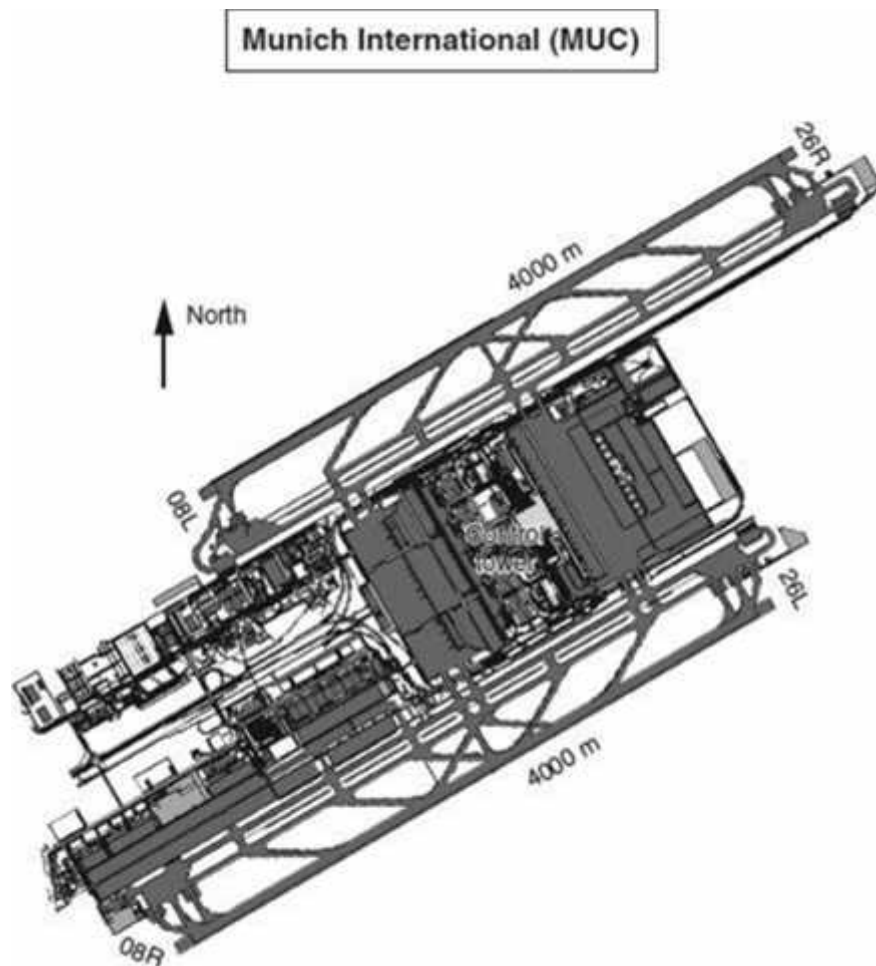


Figure I.5 : Layout sketch of Munich Airport.

- Efficient utilization of the vast land area between the independent runways, which would otherwise be greatly underutilized.
- Reasonable proximity of passenger and cargo buildings to both runways, assuming that the landside configuration and apron and taxiway systems are well designed.
- Better airfield traffic circulation, as aircraft can reach either runway without having to cross another active runway.
- Ability to isolate the airport's landside from the airport's surroundings and thus better control the landside's development, as well as ground access to the airport.

There are disadvantages, as well. One stems from the fact that these layouts typically feature multilane access roads that provide ground connection to the local highway system and may also have rail access to the passenger buildings. Such transportation links may cut across the entire length or at least a major part of the airport. To ensure good circulation of aircraft on the airport's surface, this necessitates the construction of an extensive taxiway system that includes expensive taxiway bridges passing over the access roads. Munich (see Fig I.5) has eight such bridges. A second disadvantage is that the placement of landside facilities along the central axis of the airport restricts somewhat the flexibility for expansion of these facilities when traffic grows. London/Heathrow is an extreme case in point: the space between its two parallel runways is completely saturated by now with various kinds of terminal buildings and other landside facilities.

A site of at least 11 million m², or roughly 5 km by 2.2 km, is needed to accommodate an airport with two independent long parallel runways of 3.5 to 4 km length, separated by at least 1525 m between their centerlines.

At several of the airports that operate with two independent parallel runways, the runways are “staggered.” This is shown in Fig I.5 for Munich: the threshold of runway 08L is displaced relative to the threshold of runway 08R, and the same is true for the thresholds of runways 26R and 26L. One of the benefits of staggered runways is that they provide additional vertical separation between aircraft operating on the two runways.

For example, when two aircraft are performing simultaneous parallel approaches to the two runways (e.g., 08R and 08L at Munich, (see Fig.I.5), the aircraft landing on the “farthest” runway (08L in this case) is at a higher altitude than the aircraft aiming for the “closer” one (08R). Another advantage of staggered runways is the reduced taxiing distances when one runway is used for arrivals only and the other for departures only, as often done in practice.

For instance, when Munich is operating in an eastern orientation, the use of runway 08R for arrivals and 08L for departures reduces the taxiing distances for both landing and departing aircraft between their runway and the terminal area.

Conversely, when operations are to the west, assigning arrivals to 26R and departures to 26L accomplishes the same objective. Munich indeed obtains tangible taxiing distance benefits in this way.

However, to increase runway capacity as traffic increases, airports are often forced to mix arrivals and departures on both runways. In such cases, the reduced taxiing advantage of staggered runways may be largely lost.

A possible disadvantage of staggered runways is that they increase the land area required if the airport property is to retain a rectangular or nearly rectangular shape. Land acquisition is almost always a problem in airport development.

Airports often have runways whose orientations differ. The runways intersect in such cases, either physically or along their projected centerlines.¹² New York/LaGuardia is an example where the runways intersect physically (Fig I.6).

Airfield geometries with intersecting runways may be necessary at sites that often experience strong winds from several different directions. The different orientations of the runways make it possible to operate the airport under most weather conditions and provide the 95 percent or greater crosswind coverage recommended by the ICAO, the FAA, or other civil aviation authorities.

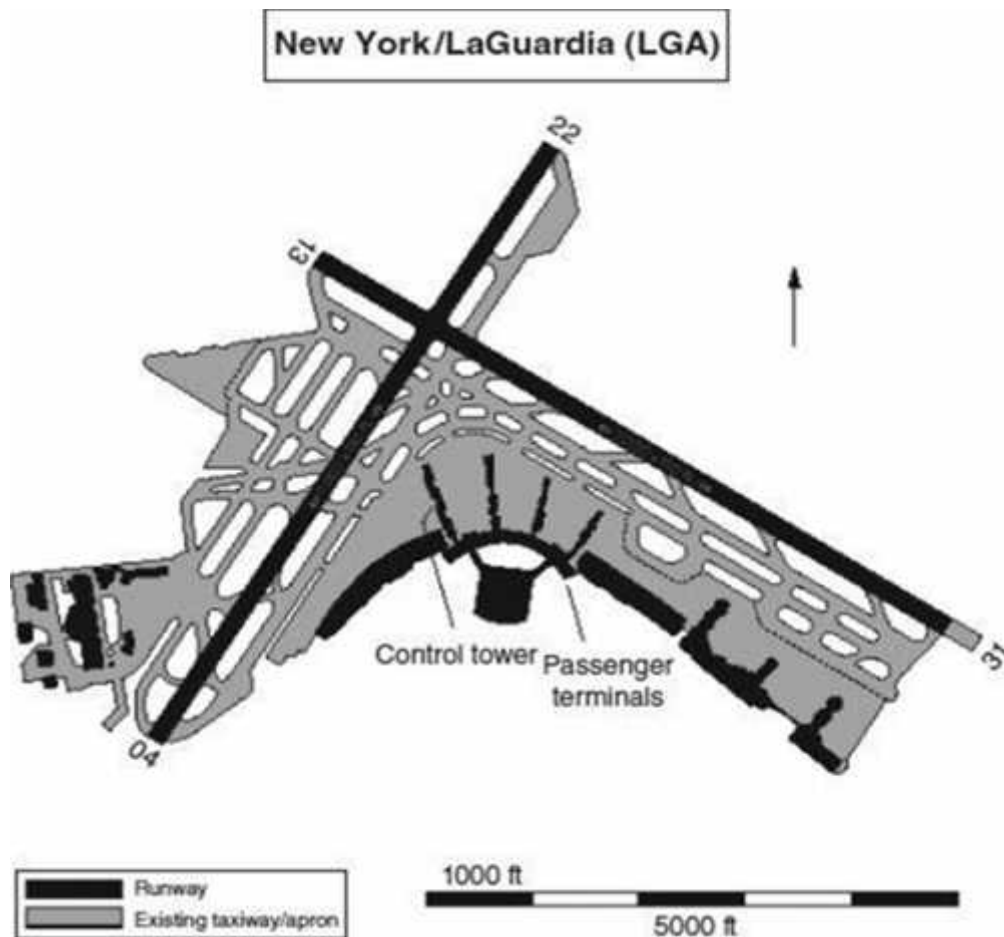


Figure I.6 Layout sketch of New York/LaGuardia.

Airports with intersecting runways are more difficult to operate from the ATM point of view. From Fig.I.6 it is clear that when both runways are active, aircraft movements on each must be carefully coordinated with those on the other runway. Moreover, the capacity of the runway pair will vary depending on the direction in which the operations take place and the location of the intersection point. When strong winds in one direction force one of the two runways to close down, the airfield capacity is also affected in a major way. Thus, airports with intersecting runways are often challenging operationally, especially when local weather conditions are highly variable. The simplest way to increase the capacity of airports with two independent parallel runways is by adding a close parallel runway next to one of the two existing ones. Examples include Seoul/Incheon, Shanghai/Pudong, and, in the near future, Bangkok/Suvarnabhumi. The airport thus ends up with a pair of close parallel runways and a third independent runway. In such situations, one of the close parallels is used solely for arrivals, the other solely for departures, and the third independent runway for mixed operations (arrivals and departures).

Airports with two independent pairs of close parallel runways, one pair on each side of the landside complex, represent the next stage of capacity evolution. Examples include Paris/Charles de Gaulle, Los Angeles/International, Delhi/Indira Gandhi (in the near future), and, until 2006, Atlanta (Fig I.7). These airports typically operate each close pair of runways by having departures on the inner runways (08R/26L and 09L/27R in Atlanta) and arrivals on the outer (08L/26R and 09R/27L). The distance between the two runways used for arrivals is sufficient to operate these two runways independently. This runway layout is well suited for airports processing 50 million or more passengers per year. The complex of the four runways can provide a total capacity of 140 or more movements per hour, even under IFR. Airports with a land area of 15 million m² and preferably more may be able to accommodate this type of layout.

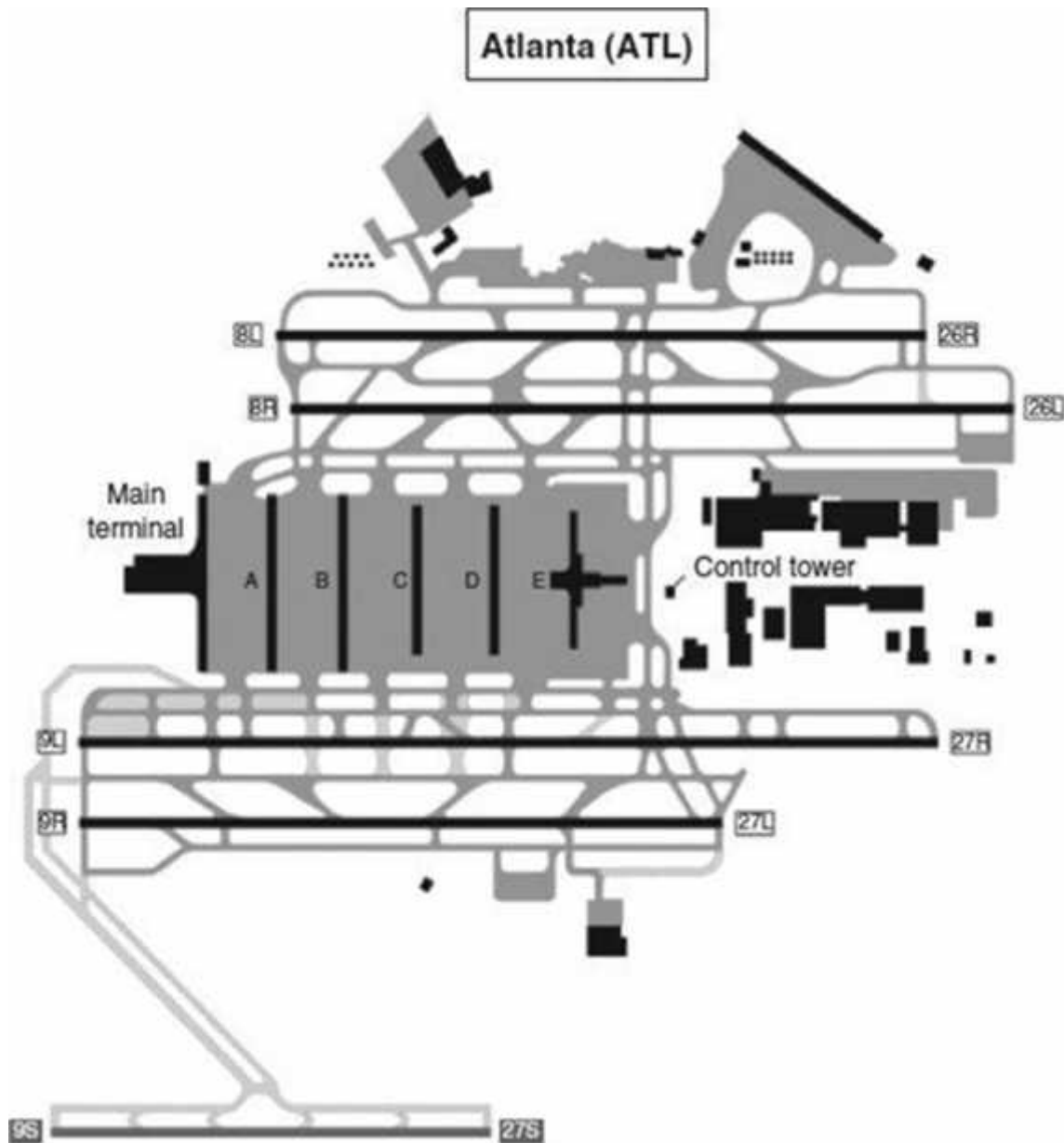


Figure I.7: Layout sketch of Atlanta Airport.

Airports that occupy 30 million m² or more have enormous capacity potential, as they can accommodate six or more parallel (or nearly parallel) runways in the primary orientation of operations, if necessary. Moreover, at least three of these runways can be separated by more than approximately 5000 ft (1525 m) from one another, as required by the FAA in order for all three to be used for approaches simultaneously. This means a capacity of 100 or more arrivals per hour or 200 or more movements per hour when all six runways are active. The United States has several such potential “mega-airports” at Denver/International, Dallas/Ft. Worth (Fig I.8), Chicago/O’Hare, Atlanta, and Orlando/ International.

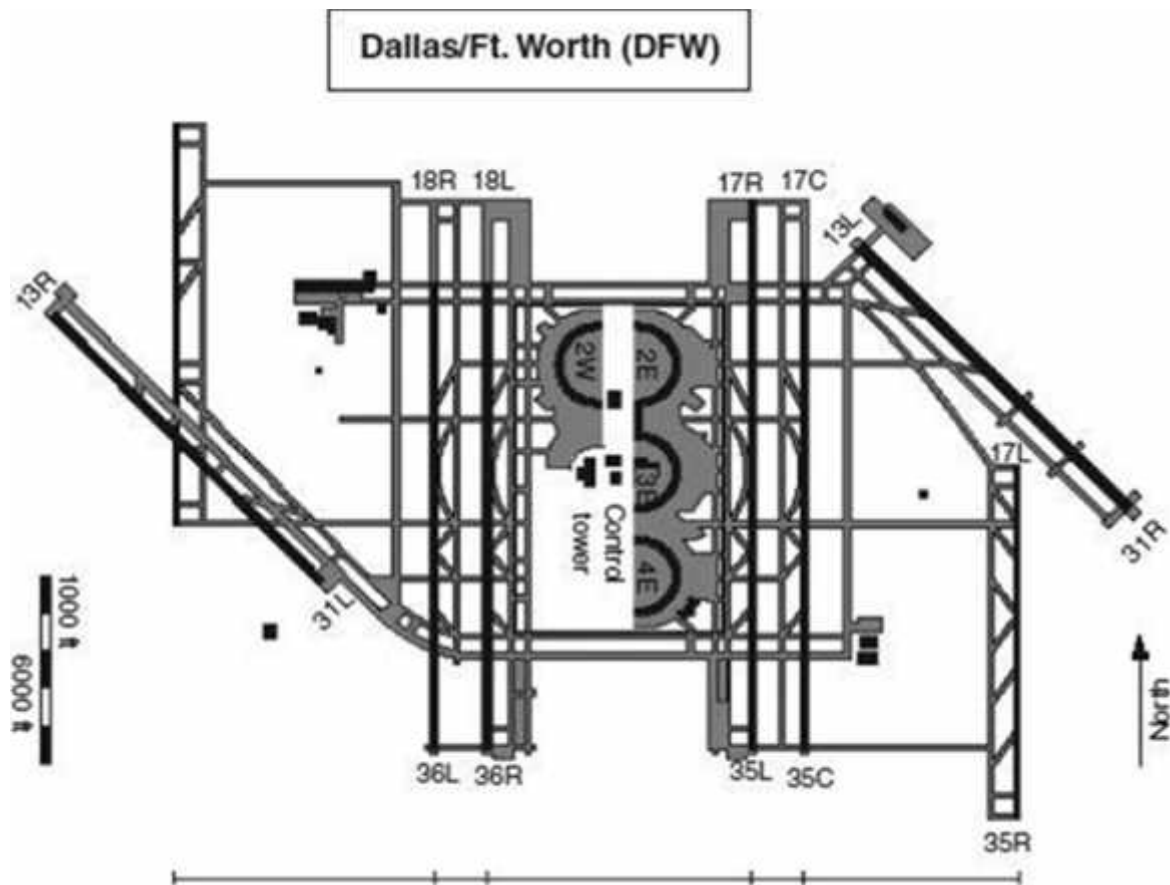


Figure.I.8 : Layout sketch of Dallas/Ft. Worth; the north–south runway at the upper left (without a runway number) has not been constructed.

Allowing for local variations, the airfield layouts discussed previously are typical of those encountered at most major airports around the world. However, they do not exhaust the range of possibilities. Several multi runway airports have layouts that do not fit any of the models described so far. San Francisco/International, Toronto/Pearson, Amsterdam/ Schiphol, and Zürich are examples of airports with four, five, six, and three runways, respectively, that fall in this category. Boston/Logan has six runways with three different orientations. Chicago/O’Hare has had seven runways with three different orientations, but its modernization program is transforming it to a configuration of six parallel and two crosswind runways.

CHAPTER II

The Airport as an Operational System /Case Studies

II.1 The Airport as a System

The airport forms an essential part of the air transport system because it is the physical site at which a modal transfer is made from the air mode to the land modes or vice versa. Therefore, it is the point of interaction of the three major components of the air transport system:

- The airport, including its commercial and operational concessionaires, tenants, and partners, plus, for these discussion purposes, the airways control system.
- The airline.
- The user.

The planning and operation of airports must, if they are to be successful, take into account the interactions among these three major components or system actors. For the system to operate well, each of the actors must reach some form of equilibrium with the other two. Failure to do so will result in suboptimal conditions, exemplified by a number of undesirable phenomena that are indicators of inadequate operation. Each phenomenon can, in a state of unrestrained competition, lead to an eventual decline in the scale of operation at the airport facility or at least a loss of traffic total share as traffic is attracted elsewhere. In the absence of a competitive option, total demand levels will be depressed below levels achievable in the optimal state. Suboptimality can become manifest in a number of ways:

- Deficit operations at the airport.
- Deficit operations by the airline(s) at the airport.
- Unsatisfactory working conditions for airline and airport employees.
- Inadequate passenger accommodation (low levels of service [LOS]).
- Insufficient flight supply.
- Unsafe operations.
- High operational costs to users.
- Inadequate support facilities for airlines.
- High delay levels for airlines and passengers.
- Inadequate access facilities.
- Sluggish passenger demand.

Figure II.1 displays a simple hierarchical system diagram of the primary interactions among the airport, the airline, and the user.

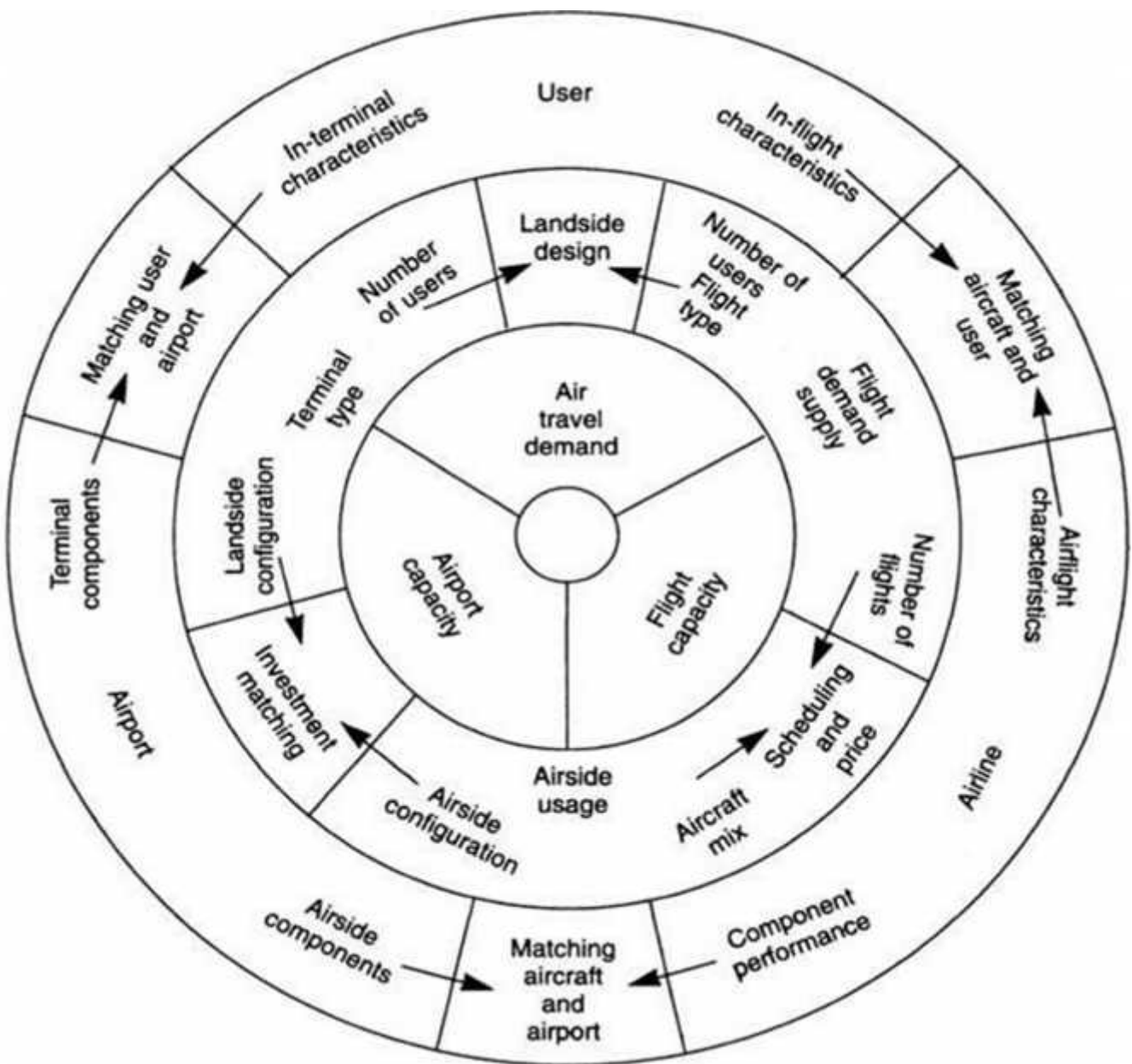


Figure II.1: A hierarchical system of airport relationships

The figure attempts to show how these interactions produce the prime parameters of operational scale, passenger demand, airport capacity, and flight capacity. Although the simplified diagram helps with conceptualization of the main factors of airport operation, large airports are in fact very complex organizational structures. This is not surprising because a large airport might well be one of the largest generators of employment in a metropolitan region. The very largest hub airports, such as Chicago O'Hare, Los Angeles, and London Heathrow may well have a total site employment in the region of 100,000 workers (TRB 2008). To place this in some context of urban scale, the number employed at a large airport can more than equal the number of workers in a city of over half a million population. Large systems such as this are necessarily more complex than the simple trichotomy expressed in Figure II.1. A more complete listing of involvement for a large airport is contained in Table II.1. This table includes an important fourth actor, the nonuser, who can have an important impact on airport operation and who is greatly affected by large-scale operations.

Principal Actor	Associated Organizations
Airport operator	Local authorities and municipalities Central government Concessionaires Suppliers Utilities Police Fire service Ambulance and medical services Air traffic control Meteorology
Airline	Fuel supplies Engineering Catering/duty-free Sanitary services Other airlines and operators
Users	Visitors Meeters and senders
Nonusers	Airport neighbor organizations Local community groups Local chambers of commerce Environmental activist groups Antinoise groups Neighborhood residents

Table II.1 : Organizations Affected by the Operation of a Large Airport

II.2 National Airport Systems

Modern airports, with their long runways and taxiways, extensive apron and terminal areas, and expensive ground handling and flight navigation equipment, constitute substantial infrastructure investments. All over the world, airports have been seen as facilities requiring public investment, and as such, they are frequently part of a national airport system designed and financed to produce maximum benefit from public funding. Each country, with its own particular geography, economic structure, and political philosophy, has developed a national airport system peculiar to its own needs. This overall national system is important to the individual airport in that the national framework determines the nature of current and future traffic handled at the facility in terms of such parameters as volume, international/domestic split, number of airlines served, and growth rates. Since 1987, outside the United States, a very large number of the larger airports have been privatized and, to a large degree, have become deregulated in matters relating to competition and services offered. Those which were rigidly controlled within a central government structure have necessarily become more open to adaptation to a deregulated aviation industry. Two different national systems will be discussed here briefly: those of the United States and those in the United Kingdom.

The United States is a very large industrialized nation with just over 19,800 airports (including heliports, STOLports, seaplane bases, and joint-use civil-military airports), of which approximately 14,600 are closed to the public or of limited public use (Figure II.2). Of the remainder, over 550 facilities provide primary or other commercial services for passenger transport aircraft (Table II.2). Of the more than 2,800 reliever and general-aviation airports not served by air carriers, some have more flight operations than a number of the airports served by major or commuter airlines; for example, Phoenix Deer Valley has over 480,000 operations per year, and Los Angeles Van Nuys has over 400,000 operations per year. Publicly owned airports in the National Plan of Integrated Airport Systems (NPIAS) are eligible for federal aid in the construction of most facilities required at the airport, other than those related to commercial activities. Ownership of the large and mediumsized airports is almost entirely in the hands of local communities. The two large airports in the Washington, DC, area were formerly operated directly by the federal government, but since June 1987, they have been operated by the Metropolitan Washington Airports Authority. In the U.S. system, privately owned commercial transport airports are few in number and are barely significant to the national system. In 2013, there was still some pressure for some of the largest facilities to be privatized, but there is little political support for such action. The scale of monies paid to each publicly owned airport from the Airport and Airways Trust Fund is related to the functional role of the facility. The system consists of geographically widely separated hub, regional, and municipal airports that have an opportunity to expand as traffic increases. As a consequence, the functional classification system of the U.S. National Airport System plan is a relatively free structure related to passenger throughput and aviation activity. Airports are free to move their classification, which is a de facto demand classification.

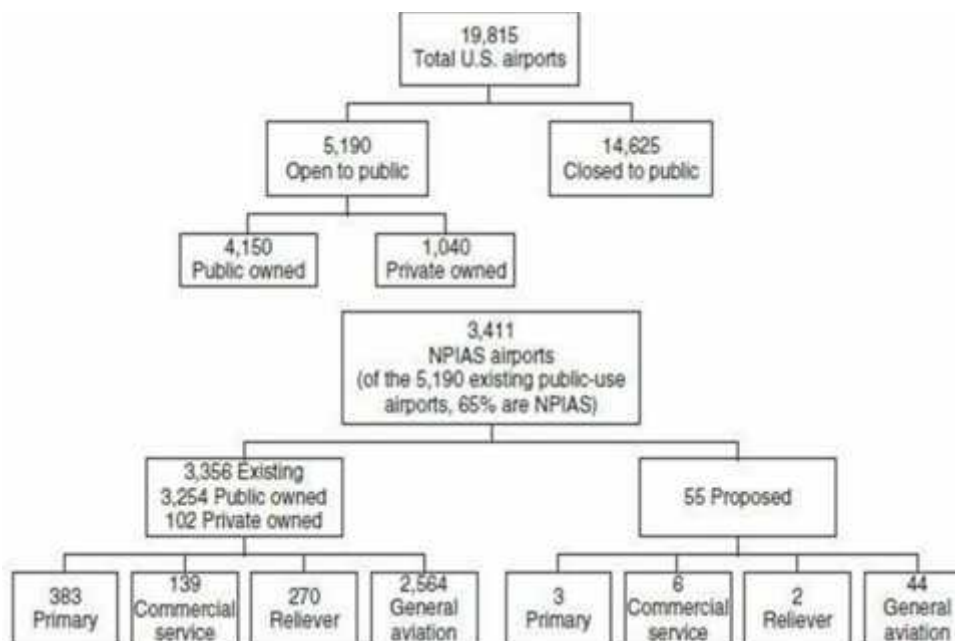


Figure II.2 : classification of the U.S. airport system. (Source: FAA, NPIAS.)

Airport	Hub Type Classification	Percentage of Annual Passenger Boardings	Common Name
Commercial Service Publicly owned airports that have at least 2,500 passenger boardings each calendar year and receive scheduled passenger service	Primary Have more than 10,000 passenger boardings each year	Large 1% or more	Large hub
		Medium At least 0.25% but less than 1%	Medium hub
		Small At least 0.05% but less than 0.25%	Small hub
		Nonhub More than 10,000 but less than 0.05%*	Nonhub primary
	Nonprimary	Nonhub At least 2,500 and no more than 10,000	Nonprimary Commercial service
Nonprimary (except commercial service)			Reliever
			General aviation
Other than passenger classification			Cargo service

*Nonhub airports—Locations having less than 0.05 percent of the total U.S. passengers, including any nonprimary commercial airport, are statutorily defined as nonhub airports. For some classification purposes, primary locations are separated within this type, although more than 100 nonhub airports are currently classified as nonprimary commercial service airports.

Table II.2 : Definitions of U.S. Airport Categories

The United Kingdom presents an entirely different conceived system that has developed for a relatively small country that has, in addition to a few major airports, a large number of regional facilities spread throughout the country. By the early 1970s, the smaller airports, which had been turned back to civilian use after the war, were owned by local municipal governments. Economic appraisal of the performance of the British airport system indicated that most of the airports were loss-making facilities that were unlikely to be able to recoup past investments made in the hope of attracting traffic (Doganis and Thompson 1973; Doganis and Pearson 1977). To encourage the development of a national airport system in which a few major hubs would cater to international traffic and the rest of the airports would assume a subsidiary role, the British government developed an airports policy to guide central-government investment in the airport system (HMSO 1978). The policy recognized four distinct categories of airports and indicated that government approval in the form of finance and planning permission to develop facilities would be based on this categorization. These categories are gateway international airports, which supported a wide range of international and intercontinental services; regional airports, which provided shorthaul international and domestic services; local airports, which provided third-level services (e.g., scheduled passenger services with aircraft having fewer than 25 seats); and general-aviation airports (Table II.3). This four-tier system worked for a number of years, coming under increasing pressure as more and more passengers wished to fly direct into European and North African destinations in two-engine aircraft without having to transit through the hub airports. Also, the development of aircraft technology in the early 1980s brought North

American destinations within the range of two-engine extended-range (ER) aircraft such as those available from Airbus and Boeing. Following deregulation of the aviation industry in the United States and abolition of the Civil Aeronautics Board, in 1987 Britain went a step further by privatizing all publicly owned airports having annual revenue in excess of £1 million. This meant that the British Airports Authority (BAA), which had more than three-quarters of all British airport traffic and whose seven airports included Heathrow and Gatwick, was floated on the London stock market in that year as BAA plc. All other airports at that time became private companies, but with all shares entirely owned by local governmental authorities. One by one the airports were sold to the private sector, and since the general privatization, most other airports have been transferred into private hands. By 2013, only a few, notably including Manchester, remain in the public sector. Newcastle airport was owned 51 percent by seven local authorities and 49 percent by the Copenhagen Airport. BAA plc, still carrying approximately 70 percent of all passengers uplifted in Britain, was bought by the Spanish company Grupo Ferrovial in July 2006, changed its name to BAA Airports Ltd., and ceased to be traded on the London Stock Exchange, where it had been part of the FTSE Index. By 2013, airports that were nominally regional facilities, such as Birmingham, Bristol, and Newcastle, were offering scheduled flights to destinations as widespread as Pakistan, the United States, the Caribbean, Dubai, and Mexico.

The neat classifications of 1978 had been allowed to blur into a laissez-faire system where airport capacity and ability to generate traffic were the prime determinants of function. Also by this time, the general growth in air passenger traffic had greatly reduced the number of loss-making British regional airports. The pragmatic approach to the national plan for airports was recognized in a white paper (Department of Transport 2003) that examined the potential for individual growth and development of the major British airports. It is apparent that the policy for regulated development of air services by declaring and promoting gateways had an enduring effect on the manner in which capacity supplied to the British airport system and the demand that it created. While probably not as strong as the policy of privatization, which promoted the path to airport profitability, the structure of the British Airports Authority is still very much influenced by the policy set out in 1978.

Gateway International Airports Airports supplying a wide range and frequency of international services, including intercontinental services and a full range of domestic services. Regional Airports Airports catering to the main air traffic demand of individual regions. They are concerned with the provision of a network of short-haul international services (mainly to Scandinavia and other parts of Europe) and a range of charter services and domestic services, including the links with gateway airports. Local Airports Airports providing third-level services (e.g., scheduled passenger services operated by aircraft with fewer than 25 seats), catering privately for local needs, concentrating on general aviation with some feeder services and some charter flights. General Aviation Airports Airports concerned primarily with the provision of general aviation facilities.

Table II.3 : The British National Airport System (as of 1978)

II.3 The Function of the Airport

An airport is either an intermediate or terminal point for an aircraft on the air portion of a trip. In simple functional terms, the facility must be designed to enable an aircraft to land and take off. In between these two operations, the aircraft may, if required, unload and load payload and crew and be serviced. It is customary to divide the airport's operation between the airside and landside functions shown in the simplified system diagram in Figure II.3.

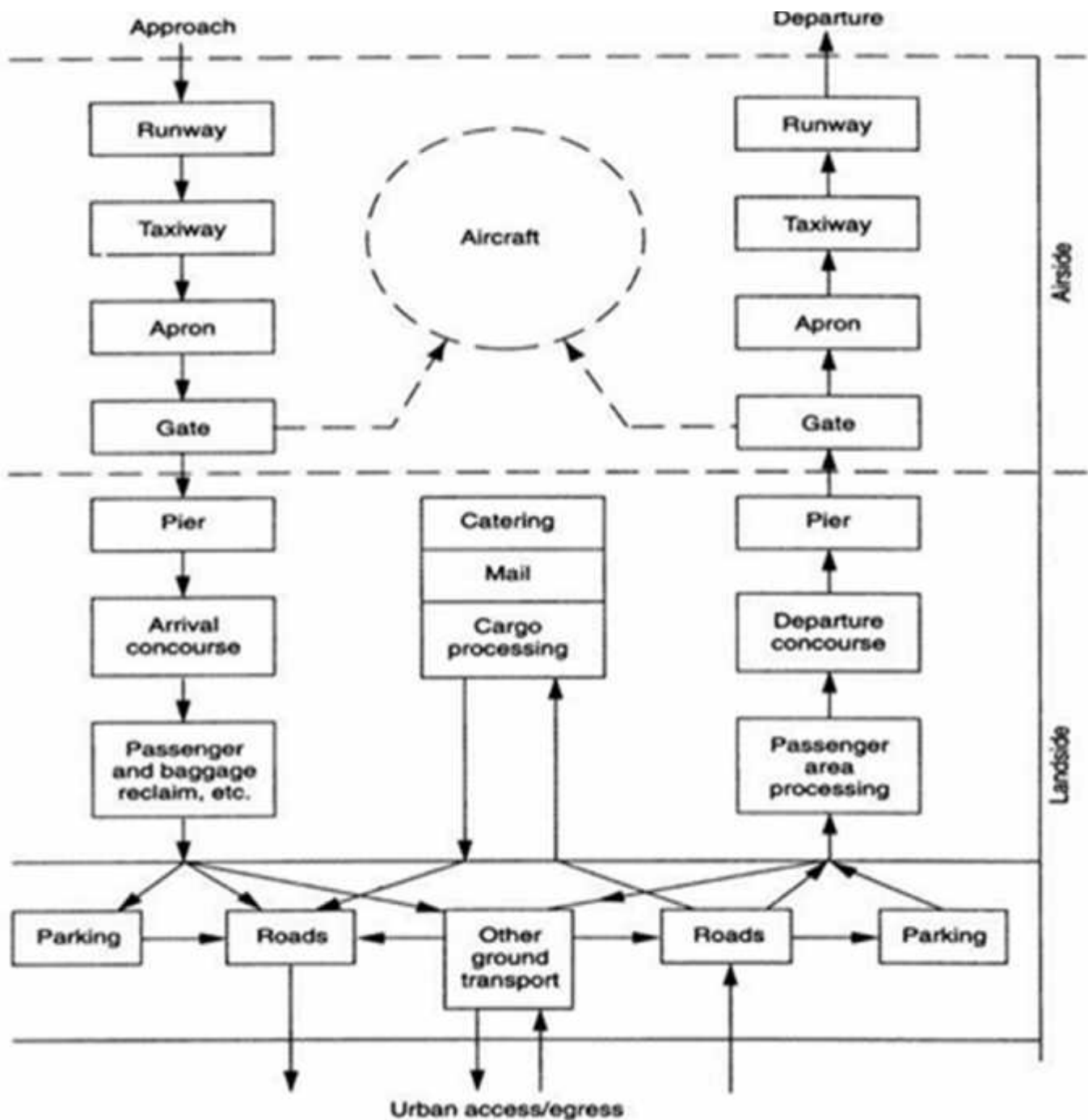


Figure II.3 The airport system.

The airport passenger and freight terminals are themselves facilities that have three distinct functions: Change of mode. To provide a physical linkage between the air vehicle and the surface vehicle designed to accommodate the operating characteristics of the vehicles on landside and airside, respectively. Processing. To provide the necessary facilities for ticketing, documentation, and control of passengers and freight. Change of movement type. To convert continual shipments of freight by trucks and of departing passengers by car, bus, taxi, and train to aircraft-sized batches that generally depart according to a preplanned schedule and to reverse this process for arriving aircraft.

Many small airports that provide little more than a simple passenger terminal for low-volume passenger operations provide very little more than a passenger terminal facility. The operation of the airport is not significantly more complex than that of a railroad station or an interurban bus station. Medium-or large-scale airports are very much more complex and require an organization that can cope with such complexity.

Airports of a significant size must have an organization that can either supply or administer the following facilities:

- Handling of passengers.
- Servicing, maintaining, and engineering of aircraft.
- Airline operations, including aircrew, cabin attendants, ground crew, and terminal and office staff.
- Businesses that provide services to passengers and are necessary for the economic stability of the airport (e.g., concessionaires, leasing companies, etc.).
- Aviation support facilities (e.g., air traffic control, meteorology, etc.).
- Government functions (e.g., agricultural inspection, customs, immigration, health).

Large international hubs are complex entities that have all the problems of any large organization with many employees. In some cases, the airport itself is a large employer. In other cases, the authority acts more as a broker of services, resulting in a low level of direct authority employment. Regardless of the chosen modus operandi, overall staffing levels at airports will be high, and there will be complex interactions among the various employing organizations. Inefficient operations and operational failures in such large systems, whether through incompetence, disorganization, or industrial action, involve huge expenses in terms of additional wages, lost passenger time, and the costs of delayed freight.

II.4 Centralized and Decentralized Passenger Terminal Systems

The way in which an airport terminal system is operated and the administrative structure of the operating company may be affected by the physical design of the airport itself. It is convenient to classify airports into two broad and very different operational types: centralized and decentralized. Most older terminals were designed using the centralized concept, where processing was carried out in the main terminal building, and access to the aircraft gates was attained by piers and satellites or by apron transport. Many airports still operate quite satisfactorily using centralized facilities (e.g., Tampa and Amsterdam Schiphol). Other airports started life as centralized facilities but became decentralized when additional terminals were added to cope with increased traffic (e.g., London Heathrow, Paris Orly, and Madrid Barajas). Some airports were designed ab initio as decentralized facilities operating with a number of unit terminals, each with a complete set of facilities (e.g., Dallas–Fort Worth, Paris Charles de Gaulle, Kansas City, and New York JFK). A hybrid form of centralization/decentralization occurs with extensive remote pier developments (e.g., Atlanta and Hong Kong) and remote satellites (e.g., Pittsburgh and Kuala Lumpur). Figure II.4 shows examples of centralized and decentralized layouts, respectively.

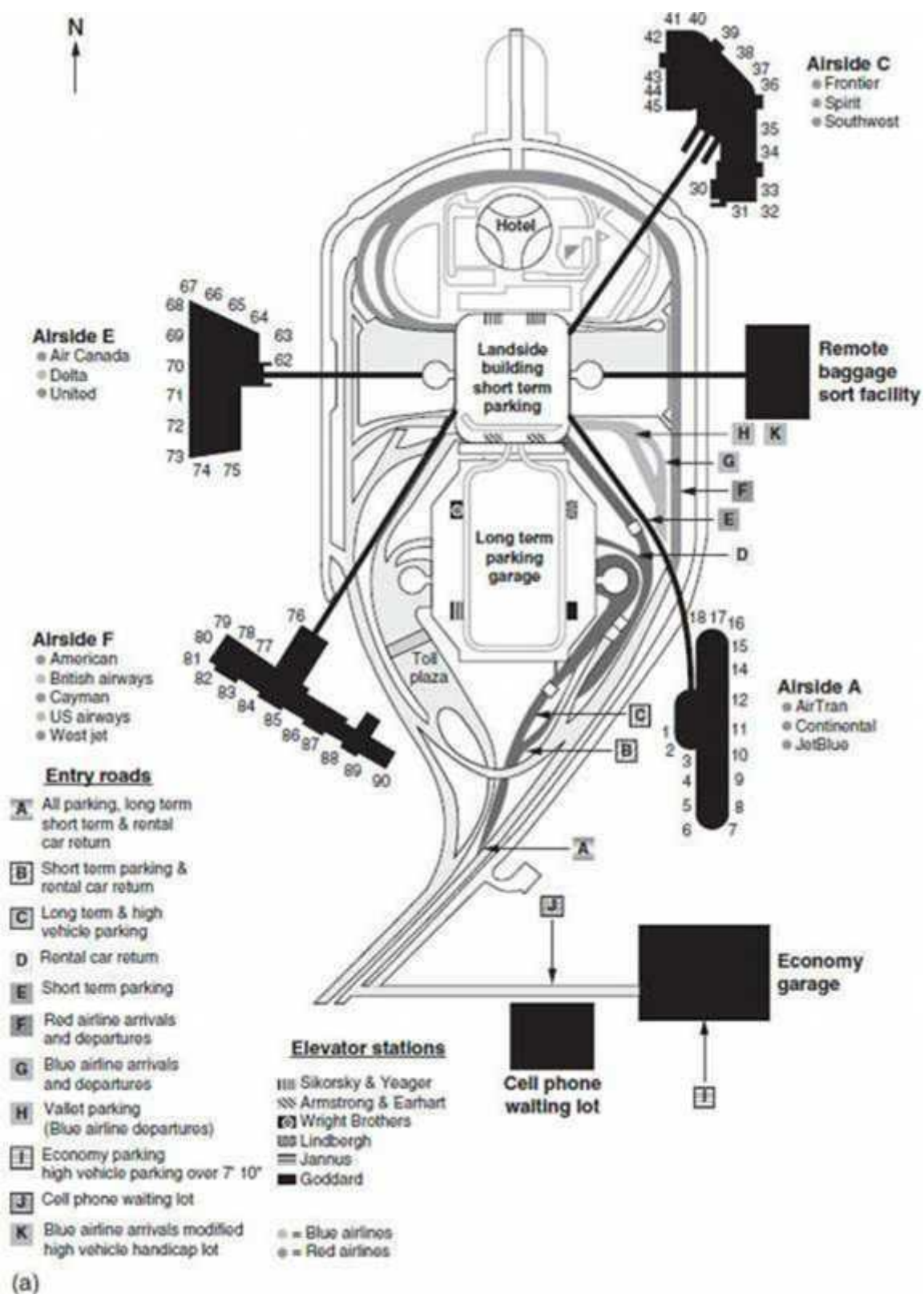


Figure II.4 (a) : Schematic of Tampa International Airport—a centralized terminal layout.

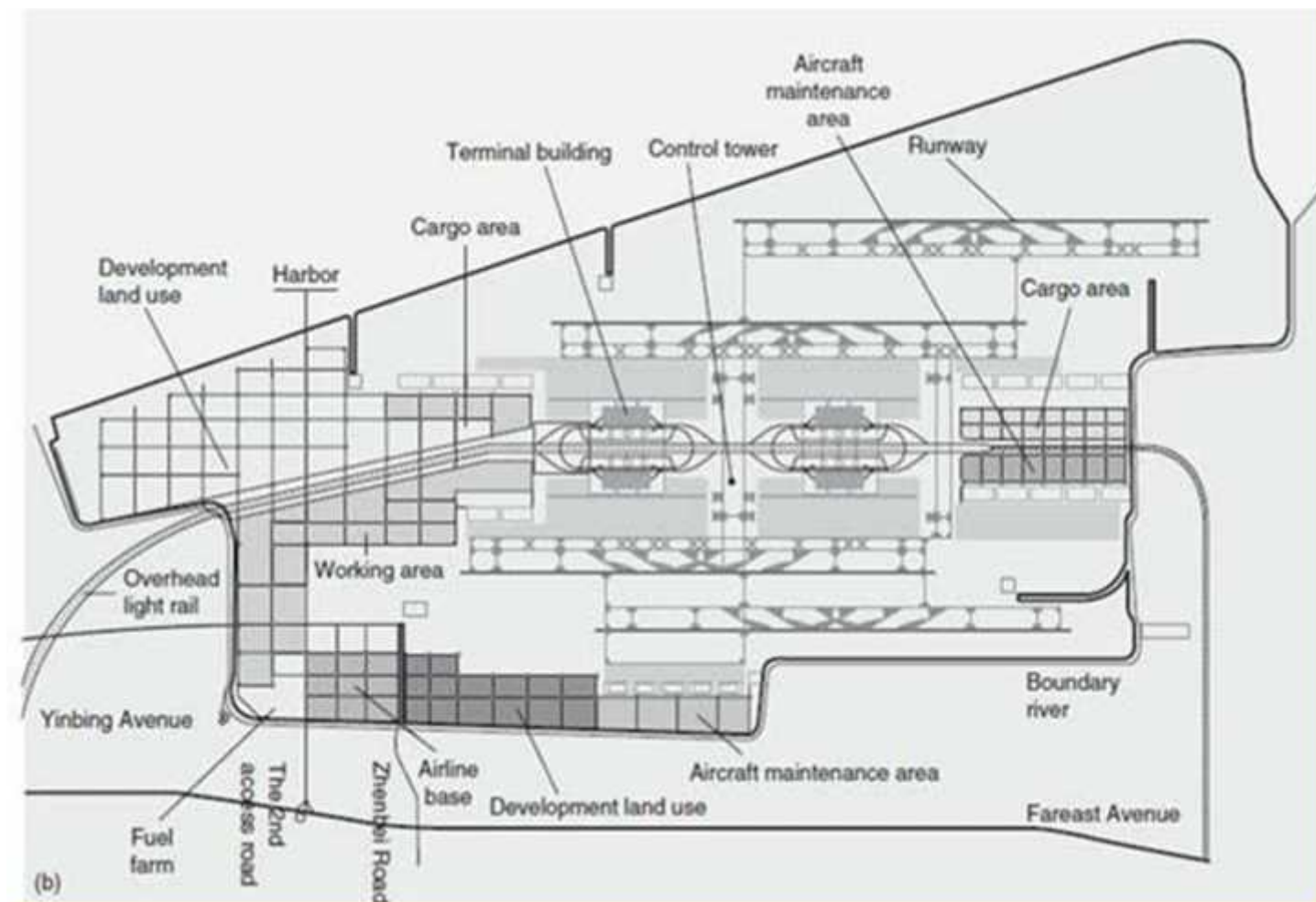


Figure II.4 (b) : Schematic of Shanghai International Airport—a decentralized terminal layout.

Until the early 1960s, passenger traffic through even the world's largest airports was so small that centralized operation was commonplace. There can be economies of scale on the use of fixed equipment such as baggage systems, check-in desks, and mobile apron equipment. Similar economies are found with the airport company, airline, and airport tenants' staff requirements. It also has been found that fewer security personnel are required in centralized designs. Where an airport company has chosen a centralized operation, there is a tendency for the administration to be very closely involved in the day-to-day operations of the terminal area.

As traffic grew at the major hubs, the physical size of some centralized facilities also grew as terminal additions were constructed. Some facilities became extraordinarily large in scale. For example, before the redevelopment of Chicago O'Hare, the distance between extreme gates in the single terminal was just under 1 mile (1.6 km). Parking facilities also grew in scale. Passengers could face very long walks, either when interlining or as originating or terminating passengers.

In order to overcome the problem of unsatisfactory walking distances, decentralized designs were developed to keep walking distances down to the region of 984 feet (300 m), as recommended by the International Air Transport Association (IATA), with a maximum distance between curb side and the further check-in counter set at 328 feet (100 m). Decentralization was carried as far as the gate arrival concept of Dallas–Fort Worth (DFW) and Kansas City, where the total walking distances from car to aircraft originally were set at 328 feet (100 m). The advantages of decentralization are significant. Terminals

are kept on a human scale, passenger volumes never become uncomfortably high, and walking distances are kept short. Parking lots are kept small and walking distances reasonable. Such areas are easier to supervise and thus safer from a crime viewpoint, and curb side drop-offs are simple to design. Operationally, however, decentralization can lead to higher airport staff requirements because some functions of administration and security must be carried out separately in each terminal. Because the scale of decentralized facilities is very large, each unit requires a full range of passenger and staff facilities. It is possible, therefore, to have poor economy of scale in terms of the fixed facilities, such as baggage rooms, baggage claims, and check-in areas. Similarly apron handling equipment must be duplicated.

For a large airport, the scale of separation between units can be very large. For example, if the 14-unit terminals at DFW had been constructed according to the original master plan, the distance between the two extreme unit terminals would have been 3 miles (5 km). Completely decentralized designs mean that interlining passengers must have some form of transit system to permit reasonable interterminal movement. At DFW, Frankfurt, and Singapore Changi, this is achieved by an automatic transit vehicle; at older terminals, such as London Heathrow and Paris Charles de Gaulle (CDG), this is achieved by a simple bus service. Neither method is particularly convenient if the number of terminals is large, such as at CDG. At decentralized airports, the administrative offices are frequently well separated from the day-to-day operations of the terminals.

An often ignored problem arising from decentralization is the loss of daily capacity when a given terminal area is broken up into a number of subareas that operate independently. Capacity is determined by peak-hour operations, and demand peaks are more easily smoothed for one large terminal than for four smaller terminals. Prior to the opening of Heathrow Terminal 5 in 2008, London Heathrow operated four terminals that were functionally different. With some exceptions, the traffic assignment to the four terminals was as follows:

Terminal 1: Domestic and shorthaul European routes (British Airways).

Terminal 2: Shorthaul European routes (foreign carriers).

Terminal 3: Long-haul routes (foreign carriers).

Terminal 4: Long-haul routes (British Airways) and some shorthaul European routes (foreign carriers).

An internal BAA study found that if all flights could have been assigned to one giant terminal, the required number of aircraft terminal gates would have been lowered significantly (Ashford, Stanton, and Moore 1997). Because of the different peaking characteristics observed in the four different terminals, when the airport is subdivided into four largely independent units, the demands on apron space and apron equipment were greater than those of a single terminal unit.

With the development of airline alliances, which began in the 1980s, at the large airports, the assignment of airlines among multiple-unit terminals became even more complicated. At Madrid Barajas, for example, prior to the commissioning of the new terminal in 2006, the airport management studied how best to use the huge new facility in conjunction with the existing three terminals on the site. Much consideration had to be given to the fact that the major-based airline, Iberia, was part of the One World airline alliance, which had 12 members, including American Airlines, British Airways, and Qantas.

Since the annual peak transfer rate at Madrid was 45 percent, with 41 percent of transfers being within the same alliance, the decision was made to locate One World in the new terminal and the other major alliances, Star Alliance and Sky Team, in the existing three terminals. The old and new terminal sites were separated by more than 2 miles (3 km). For interlining transferring passengers, a landside bus service was introduced. This allocation of airlines to the various terminals was calculated to minimize the overall inconvenience to Madrid's transfer passengers and was the principal rationale behind the final decision on terminal allocation. The complexity of the traffic mix to be dealt with is shown in Table II.4.

Traffic Type	Passengers
Domestic	19.6 million
European (Chengen)	14.7 million
International	12.3 million
Total	46.6 million
Alliance	Passengers
One World	31.2 million
Star	5.1 million
Wing	4.0 million
Sky Team	3.8 million
Other	2.5 million
Total	46.6 million
One World Alliance	12 airlines
Star Alliance	27 airlines
Sky Team	13 airlines
Annual transfer	21 million 45 percent
Transfer within same alliance	19 million 41 percent

Table II.4 : Breakdown of Traffic to Be Assigned to Existing and New Terminals at Madrid Barajas Airport, 2000

II.5 The Complexity of the Airport Operation

Until the deregulation and privatization of the air transport industry in the late 1970s and 1980s, it had been seen in many countries almost as a public-service industry that required support from the public purse. Subsidies to aviation were provided in a number of different ways by different countries. Early post–World War II airports had very little commercial activity, and the services provided by the airport were very basic. Airports such as Shannon in the Irish Republic, and Amsterdam Schiphol in the Netherlands, were among the first to develop income from commercial activities. By the 1970s, the commercial revenues had become very important in terms of total income and at many of the largest European airports provided virtually all the profit, aeronautical income barely covering covered by aeronautical expenditures.

The larger airports became complex businesses with functions that extended well beyond the airfield or “traffic” side of operations. As airports increase in size, in terms of passenger throughput, the nonaviation revenues become increasingly important. It is also clear that in most countries, airports maintain economic viability by developing a broadly based revenue capability. In general, the organizational structure of the airport company changes to reflect the increasing importance of commercial revenues with increasing passenger throughput. As the relative and absolute sizes of the nontraffic element of the airport’s revenue increase, much more attention must be paid to developing commercial expertise, and some of the largest airports have developed considerable in-house expertise in maximizing commercial revenues.

Among the nonaeronautical activities found at airports are :

- Aviation fuel suppliers.
- Food and beverage sales (i.e., restaurants, bars, cafeterias, vending machines, etc.).
- Banks/foreign exchange.
- Airline catering services.
- Taxi services.
- Car rentals.
- Car parking.
- Advertising.
- Airport/city transport services (i.e., buses, limousines, etc.).
- Duty-free shopping.
- Petrol/automobile service stations.
- Hairdressing/barber shop.
- Internet services.
- Cinema.
- Vending machines for other than food.
- Hotels/motels.
- Freight consolidators/forwarders/agents.
- Art exhibitions.

The degree to which airports go to develop nonaeronautical activities is likely to depend on the destination of the revenues generated from such activities. At most airports, these go directly to the airport and add to the airport's profitability. As such, the airport company has a great incentive to generate as much of this type of income as possible, and the energy of the company is directed in this direction.

There are a number of situations that can act as a disincentive to the airport company:

- Where income from nonaeronautical sources goes directly to the national treasury.
- Where the government gives the duty-free franchise to the government-owned airline.
- Where the U.S. airport is operated on a residual cost basis, and income from nonaeronautical sources is used to reduce landing fees for the airlines and does not accrue to the airport.

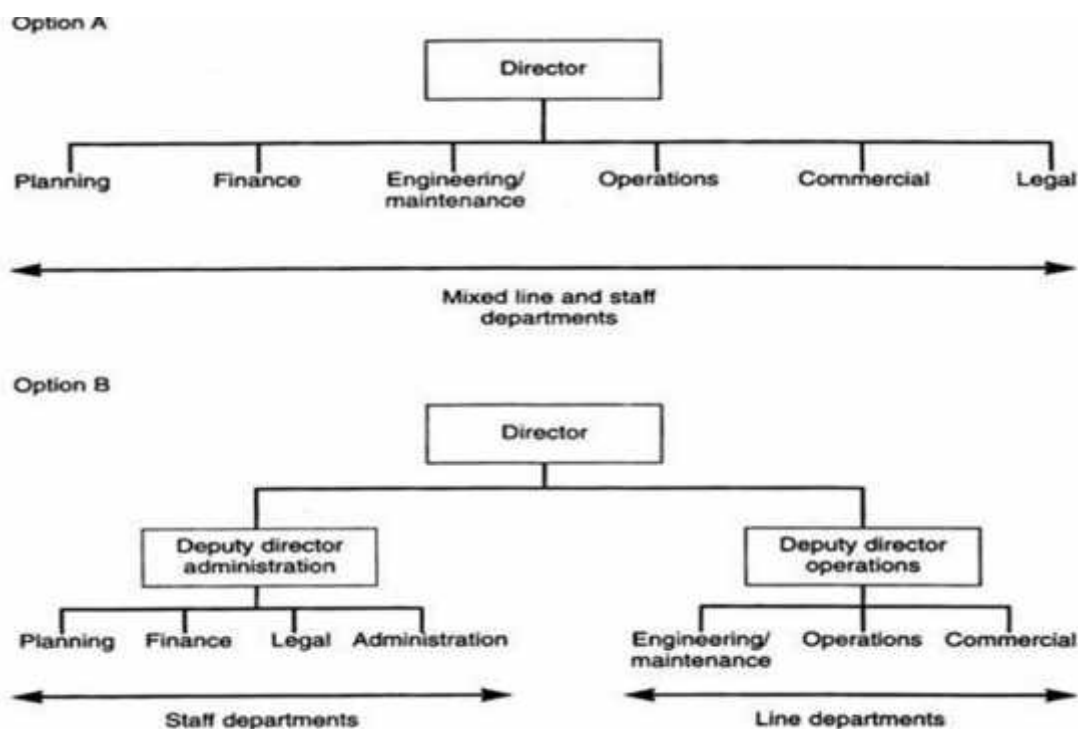
Under these circumstances, there is little incentive for the airport management to attempt to increase nonaeronautical income, and in the absence of outside efforts, this side of the business is likely to stagnate.

II.6 Management and Operational Structures

Prior to deregulation of the airlines, which started in 1979 in the United States, the widespread model for operation of a transport airport was to be run as a department of either the central government or the local government. After deregulation, most central governments divested themselves of the operation of airports wherever possible. By 2013, many central governments still were involved in the running of airports, but it had become less common in the economies of the developed world. Countries such as the Netherlands, Spain, and Germany still had mostly government-owned facilities.

There is no single form of administrative structure that is ideal for every airport. Airports differ in their type and scale of throughput, vary in their interrelationships with other governmental and quasi-governmental bodies, and also must fit within differing matrices of allied and associated organizations at central, regional, and local governmental levels. Organizational structures also must be recognized as evolutionary in nature, depending on the previously existing structure and on the pressures for change, some of which arise from the personalities and abilities of individuals with directorial responsibilities in the existing organization. In any event, organizational structure will undergo radical reform should an airport become privatized. After privatization, there are many models of airport administration.

The structure of an airport's organization depends on the role the airport company assumes in the operation of the facility. This may vary from a largely brokering function with minimal operational engagement in many on-airport activities (the U.S. model) to direct line involvement in many of the airport's functions (the European model). It also should be borne in mind that in common with other commercial and governmental organizations, the management structure may be divided into staff and line functions. The way these functions are accommodated also varies among airports. Staff departments are those which provide direct managerial support to the airport director or general manager. Often relatively small in size in terms of personnel, they are engaged in decision making that has an impact on the whole organization. Line departments, on the other hand, are the portions of the organization engaged in the day-to-day operation of the facility. In comparison with the staff departments, they usually require heavy staffing. The manner in which staff and line departments report to the airport director differs greatly among airports. Figure II.5 shows three different formalized structures that cover the range of what might occur at any particular airport.



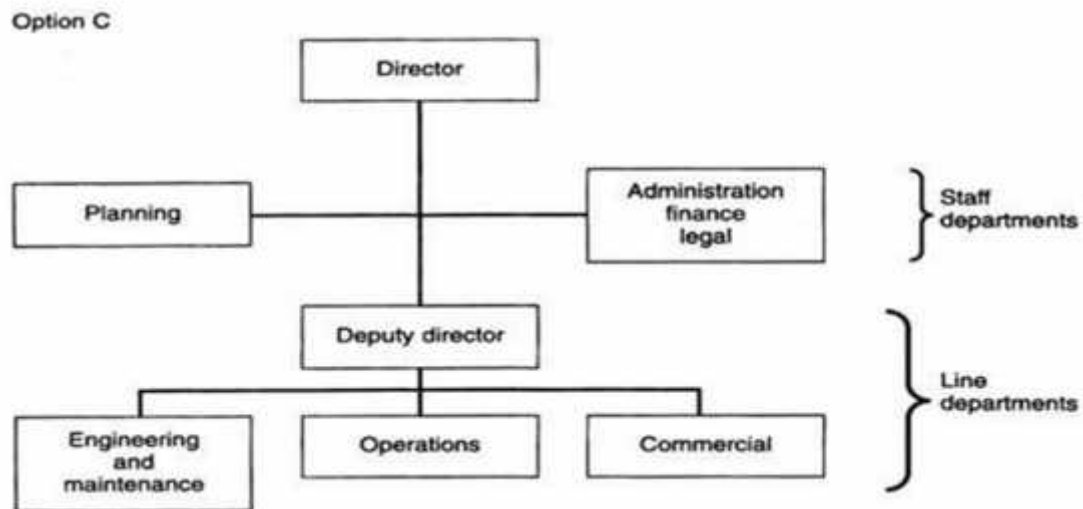


Figure II.5 : Schematic positions of line and staff departments in the structure of airport administrations.

Option A is the structure where staff and line departments all report directly to the airport director. This is the normal situation at a small airport where staff functions are not excessive, and the airport director, as a matter of course, is closely involved with day to day operations.

Option B is likely to occur at larger airports. The increasingly busy line departments report through a deputy director, while the staff departments are in a close supportive role to the director. At larger airports, option C is likely to occur, with line and staff departments reporting through two separate deputy directors.

Figures II.6 and II.7 show the organizational structures of two autonomous Western European airports. Both structures reflect the fact that the organization is involved with the operation of a single airport on the European model and that some of the ground handling is carried out by airport authority employees. Until the 1990s, almost all the ground handling at these airports was carried out by airport authority staff only.

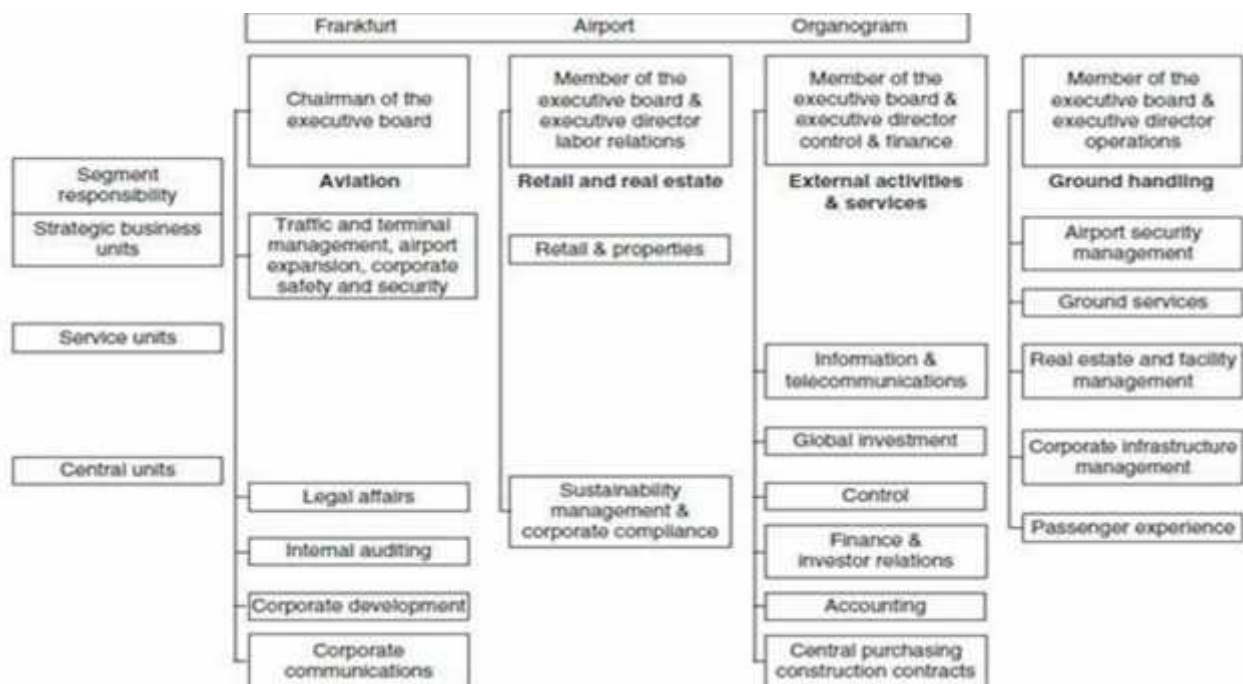


Figure II.6: Administrative and staff structure, Frankfurt Airport (FRAPORT), 2011.

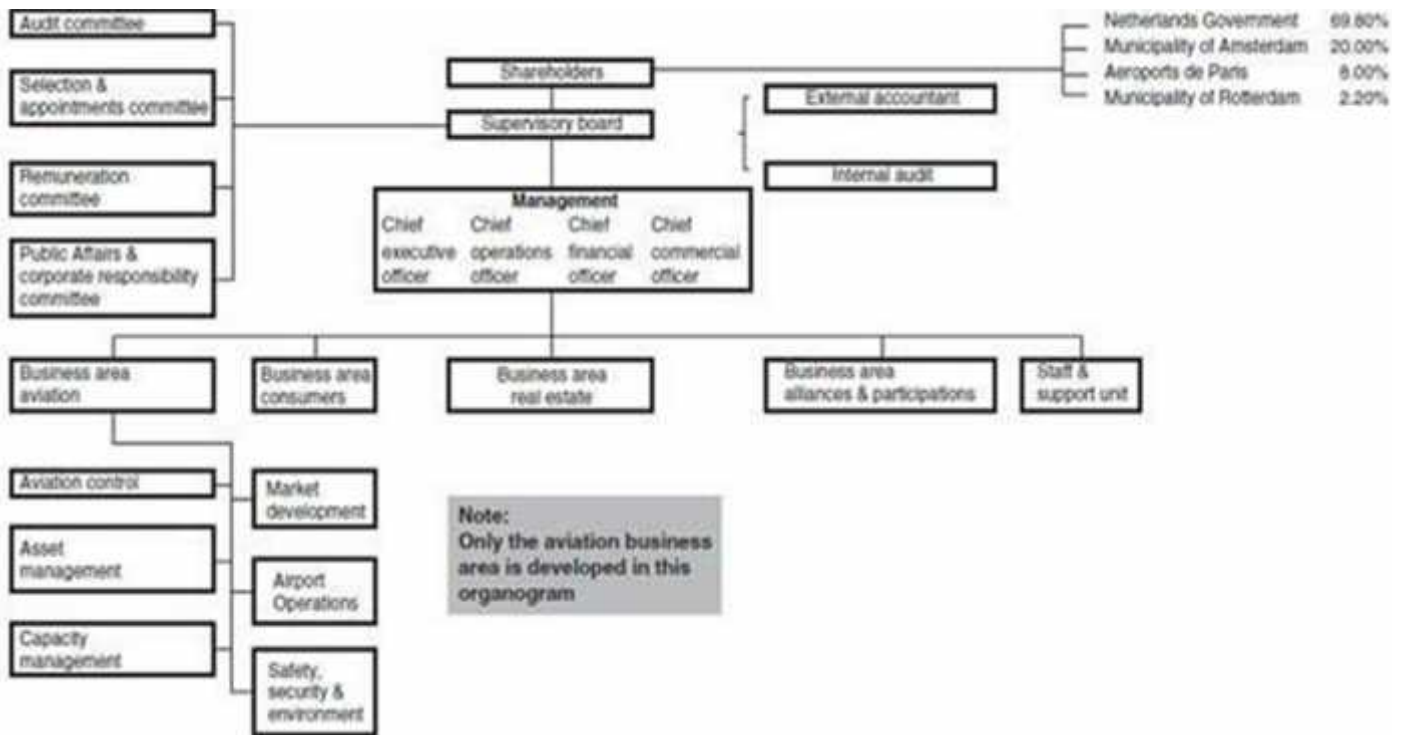


Figure II.7 Administrative and staff structure, Schiphol Amsterdam Airport, 2011.

A very different form of functional arrangement exists in U.S. airports, where the airport authority requires that all the operational aspects of passenger and freight handling are carried out by the airlines and handling companies. The organization of the Los Angeles World Airports organization shown in Figure II.8, and those of Sacramento and San Francisco airports are shown in Figures II.9 and II.10.

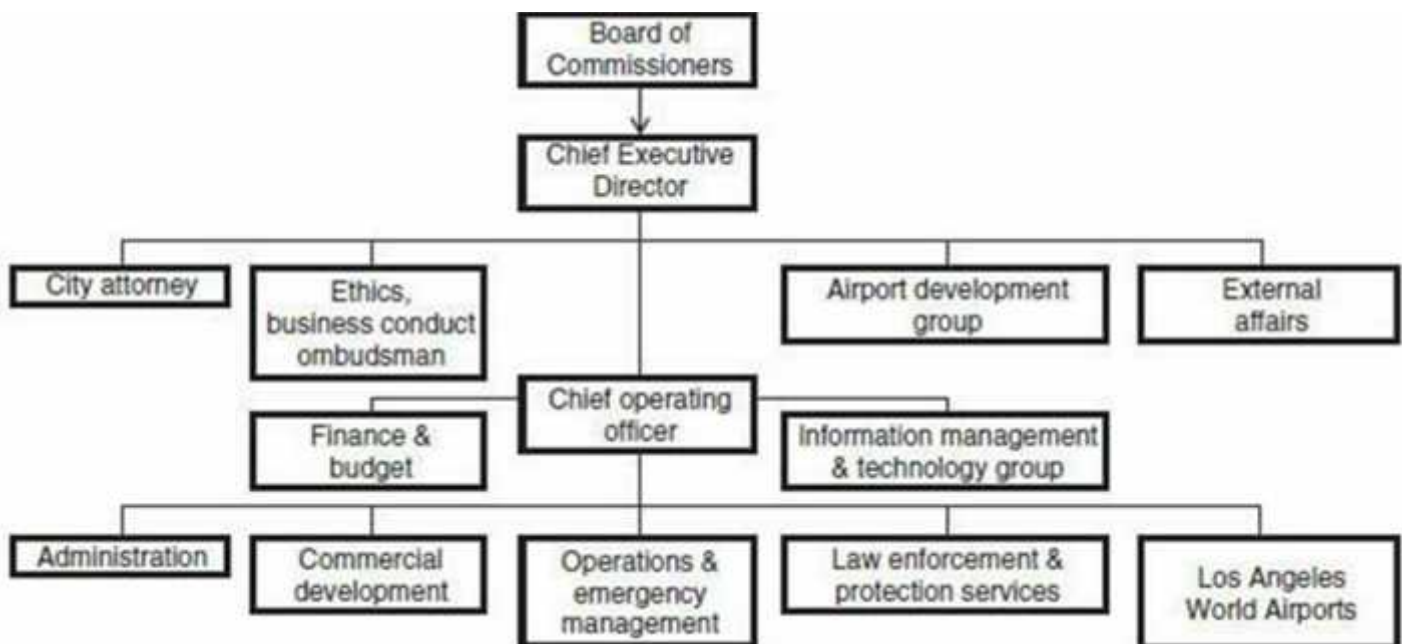


Figure II.8 : Organizational structure of Los Angeles World Airports (LAWA), 2011.

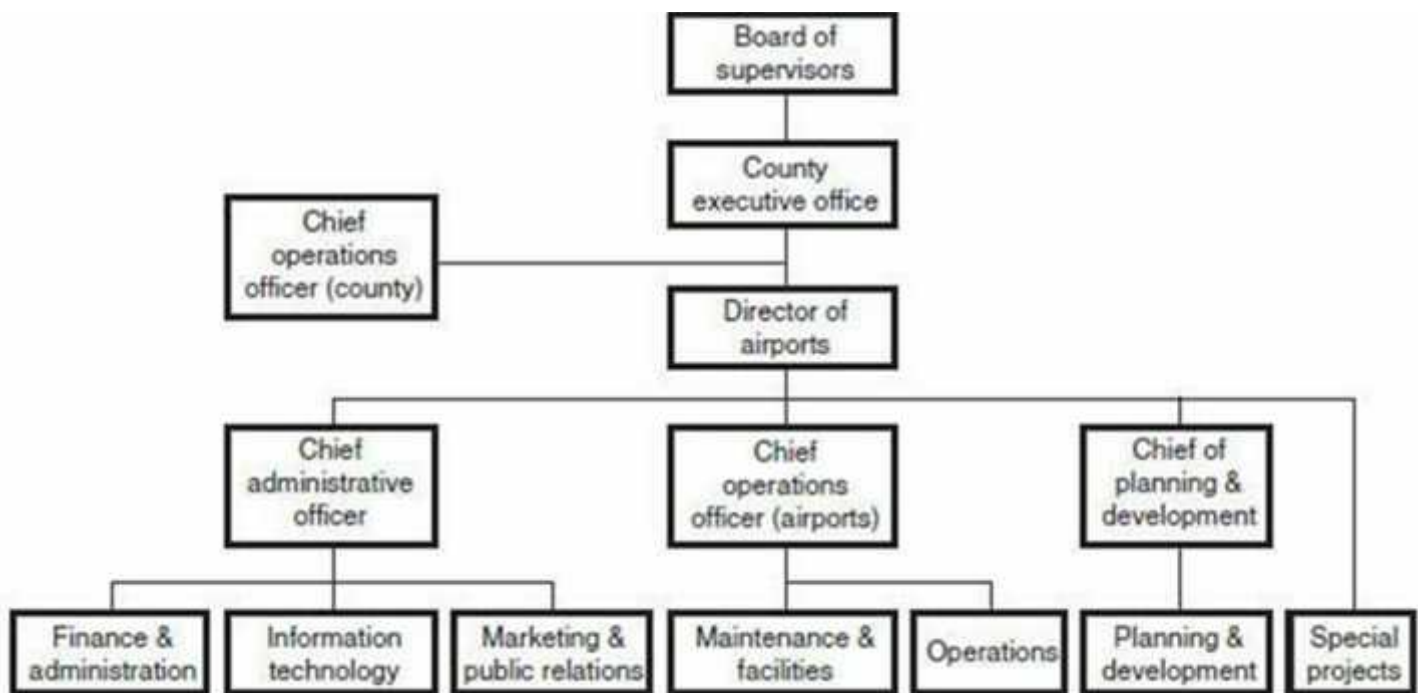


Figure II.9 : Organizational structure of Sacramento Airport, 2011.

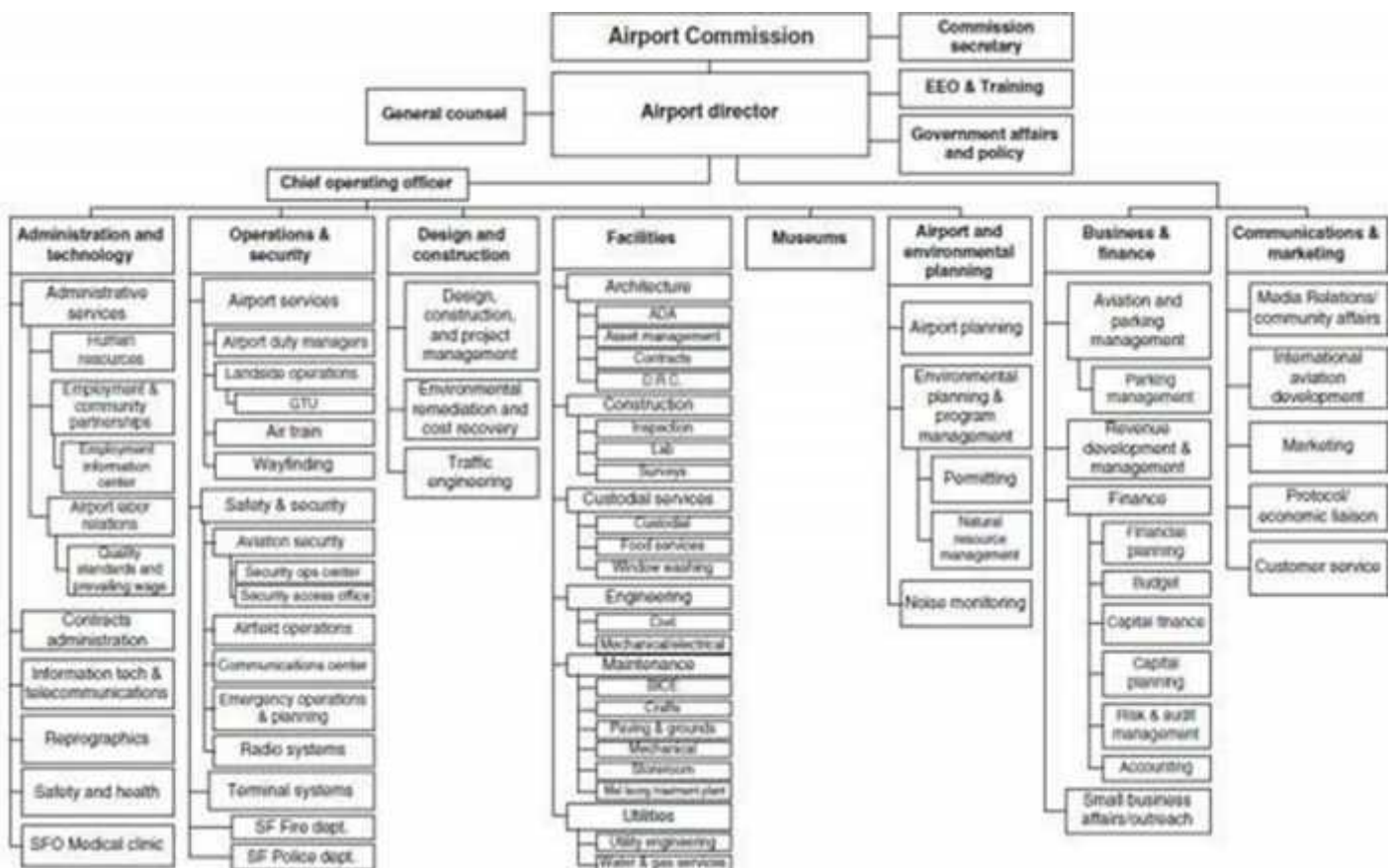


Figure II.10 Organizational structure of San Francisco Airport, 2011.

In many countries, governmental or quasi-governmental authorities are charged with the operation of a number of airports (e.g., the Port Authority of New York and New Jersey [PANYNJ], Aeroports de Paris [AdP] in France, and Aeroportos e Navagaceo Aerea [ANA] in Portugal). The organizational structure of such multiairport authorities is usually designed for achieving system-wide objectives. Therefore, policies are directed by an overall executive, to whom the usual staff functions give support. Individual airports become operational elements in the overall structure. Wiley developed a typical pro forma organization structure for a three-airport authority within a multimodal authority (Figure II.11). His model was based on his administrative experience in the PANYNJ (Wiley 1981).

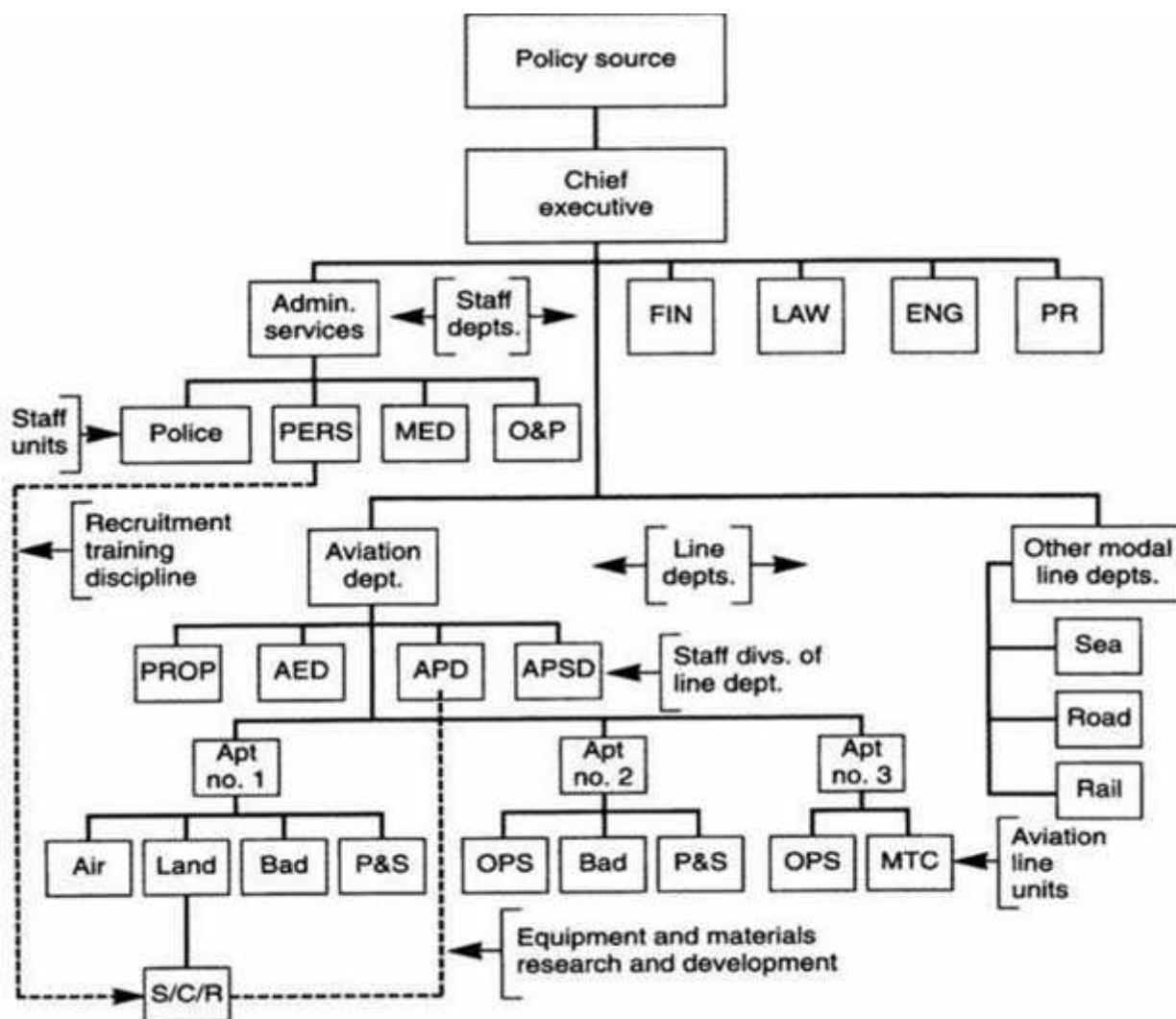


Figure II.11 Pro-forma organogram for a three-airport multimodal planning and operating authority.

Practical examples of structures of this nature are shown in Figures II.12 and II.13, which show the actual organizational structures of the PANYNJ and the equivalent of the Civil Aviation Authority (ANA) of Portugal. In each case, the structure of the organization permits the development of system-wide policies affecting a number of airports; this is a requirement that is clearly not necessary in the case of an autonomously operated single airport. The PANYNJ structure is especially interesting because of the multimodal interests of the authority. Aviation constitutes only one department within the complex structure, even though this department operates the three very large airports of the New York metropolitan area.

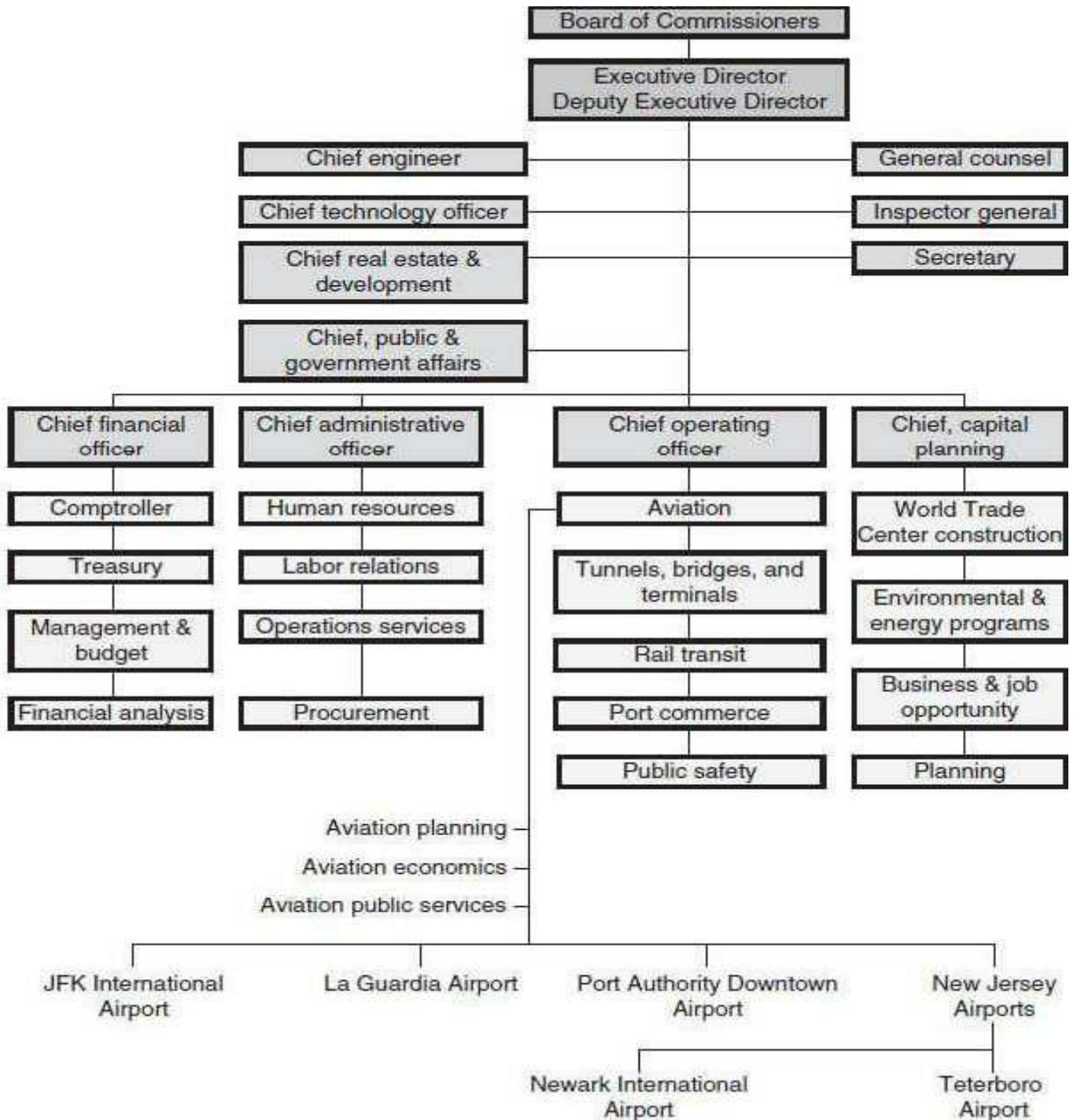


Figure II.12 : Organizational structure of the Port Authority of New York and New Jersey, 2011.



Figure.II.13 : Organizational structure of the Portuguese civil aviation system.

With the privatization of many of the larger airports since 1987, a number of private companies now own airports on a multinational basis. The organograms of these organizations become very complex, as can be seen from the example shown in Figure II.14. This indicates the structure of an organization involved in the ownership, management, or operation of some 30 airports in North and South America and Europe in 2011.

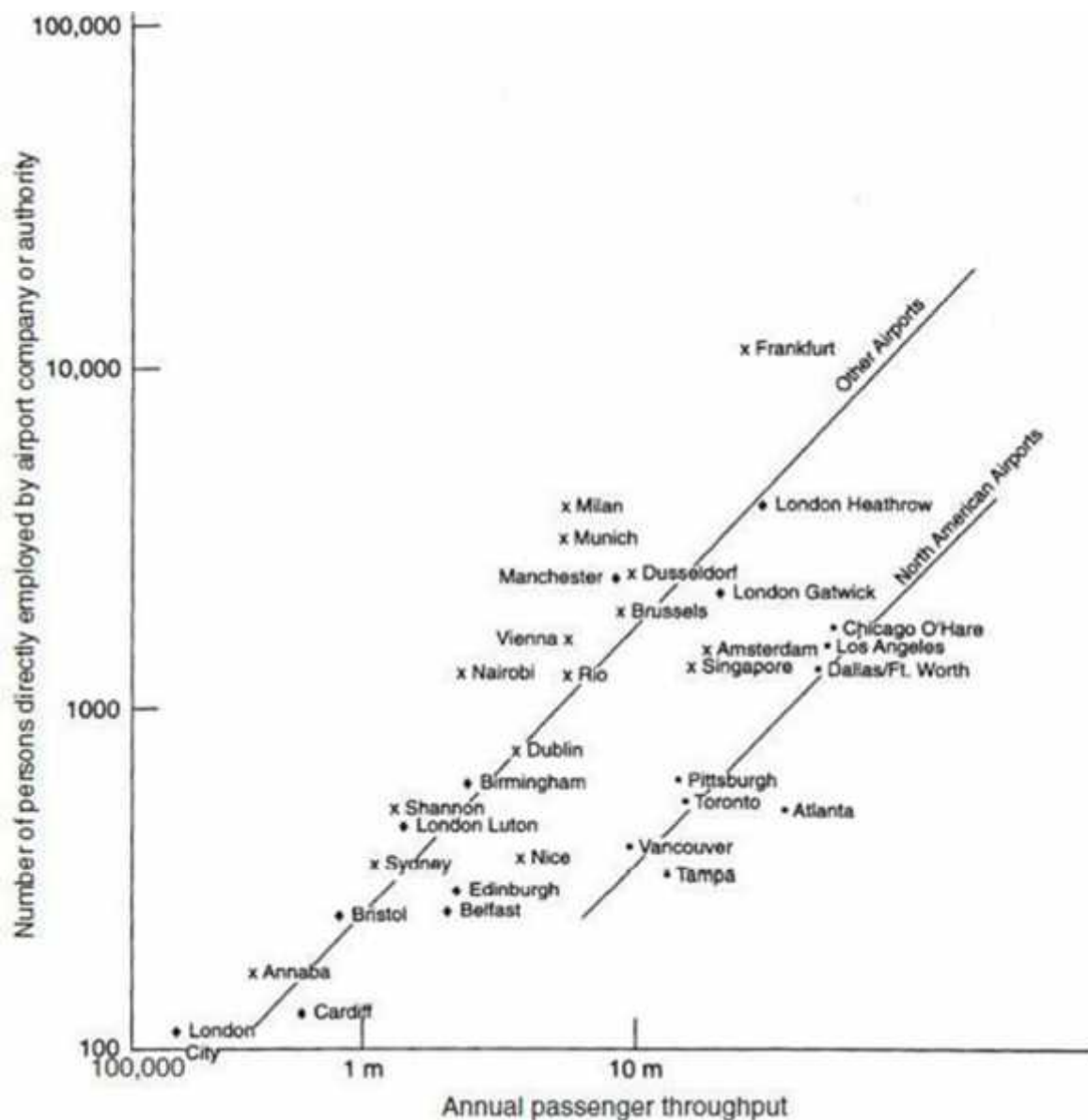


Figure II.15 : Annual passenger throughput in relation to airport company staff.

A study carried out for the Airports Council International examined a range of European airports in 2003 (York Aviation 2004). It examined the level of employment at a number of airports and grouped the range of airports examined into four categories:

- Low density.
- Medium density.
- High density.
- Very high density.

Figure II.16 shows the four classifications along with the types of activities likely to occur within each class and the range of employment observed within each category. The low, medium, and high-density airports show increases in employment related to growth in passenger and freight traffic. Very high-density employment is not related to high workload units (WLUs) of traffic but rather to specialized large employment centers such as airline maintenance bases and airline headquarters.

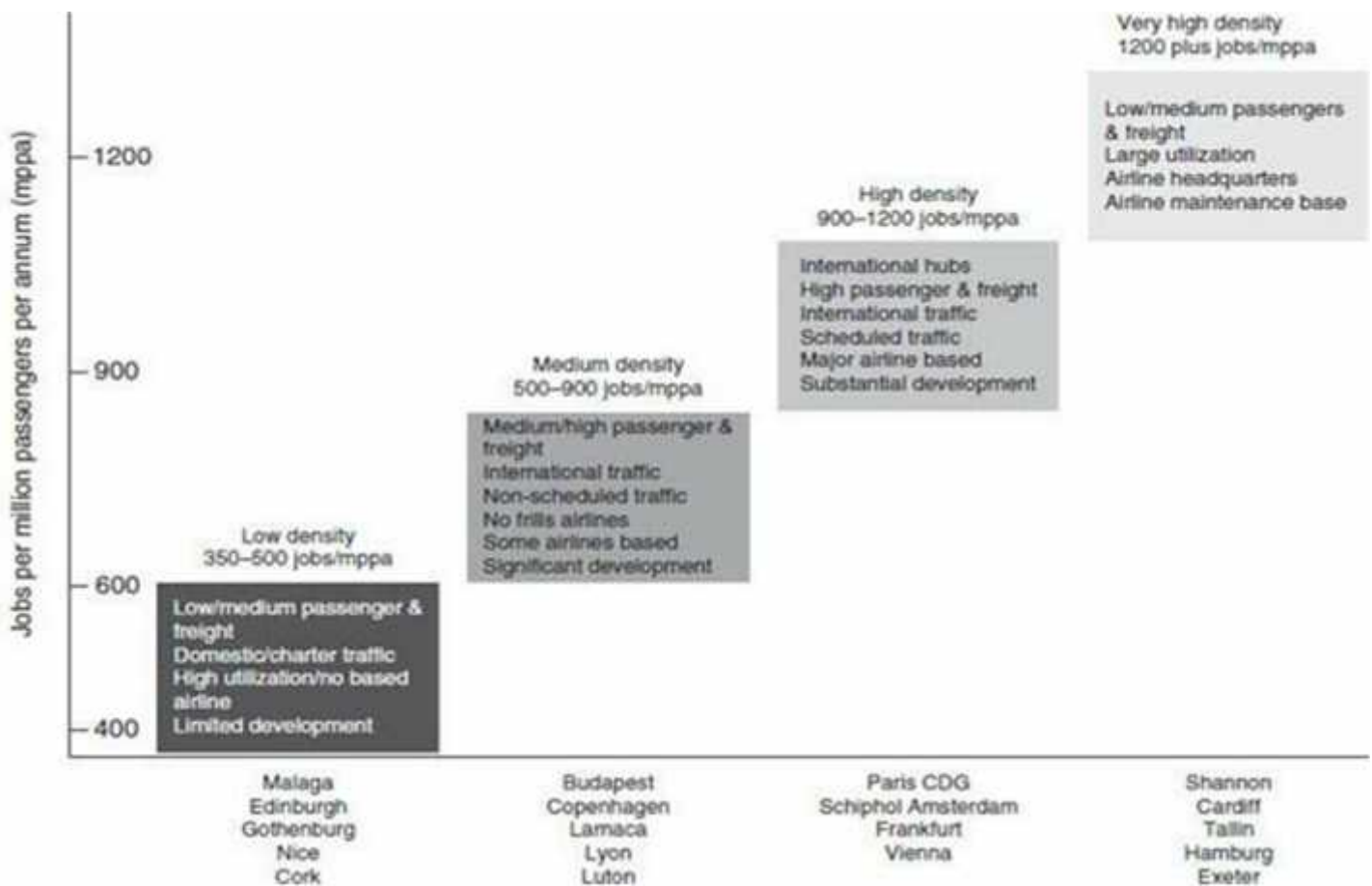


Figure II.16 : Onsite employment types at European airports, 2003. (York Aviation 2004.)

II.7 Typical airport management organization chart

An organization chart shows the formal authority relationships between superiors and subordinates at various levels, as well as the formal channels of communication within the organization. It provides a framework within which the management functions can be carried out. The chart aids employees to perceive more clearly their positions in the organization in relation to others and how and where managers and workers fit into the overall organizational structure.

Airport management organization charts range from the very simple to the very complex, depending primarily on the size, ownership, and management structure of the airport.

The organization chart is a static model of an airport's management structure; that is, it shows how the airport is organized at a given point in time. This is a major limitation of the chart, because airports operate in a dynamic environment and thus must continually adapt to changing conditions. Some old positions might no longer be required, or new positions might have to be created in order that new objectives can be reached; therefore, it is necessary that the chart be revised and updated periodically to reflect these changing

conditions.

The duties, policies, and theories that govern the job of airport management vary widely over time. In addition, many such policies vary from airport to airport on the basis of individual airport operating characteristics. As a result, it is difficult to say that any organization chart is typical or that the chart of one airport at any particular time is the one still in effect even a few months later; however, all airports do have certain common functional areas into which air-port activities are divided. Understandably, the larger the airport, the greater the specialization of tasks and the greater the departmentalization. Figure II-17 shows the major functional areas and typical managerial job titles for a commercial airport.

II.7.a Job descriptions

The following is a brief job description for each position shown in Fig. II-17

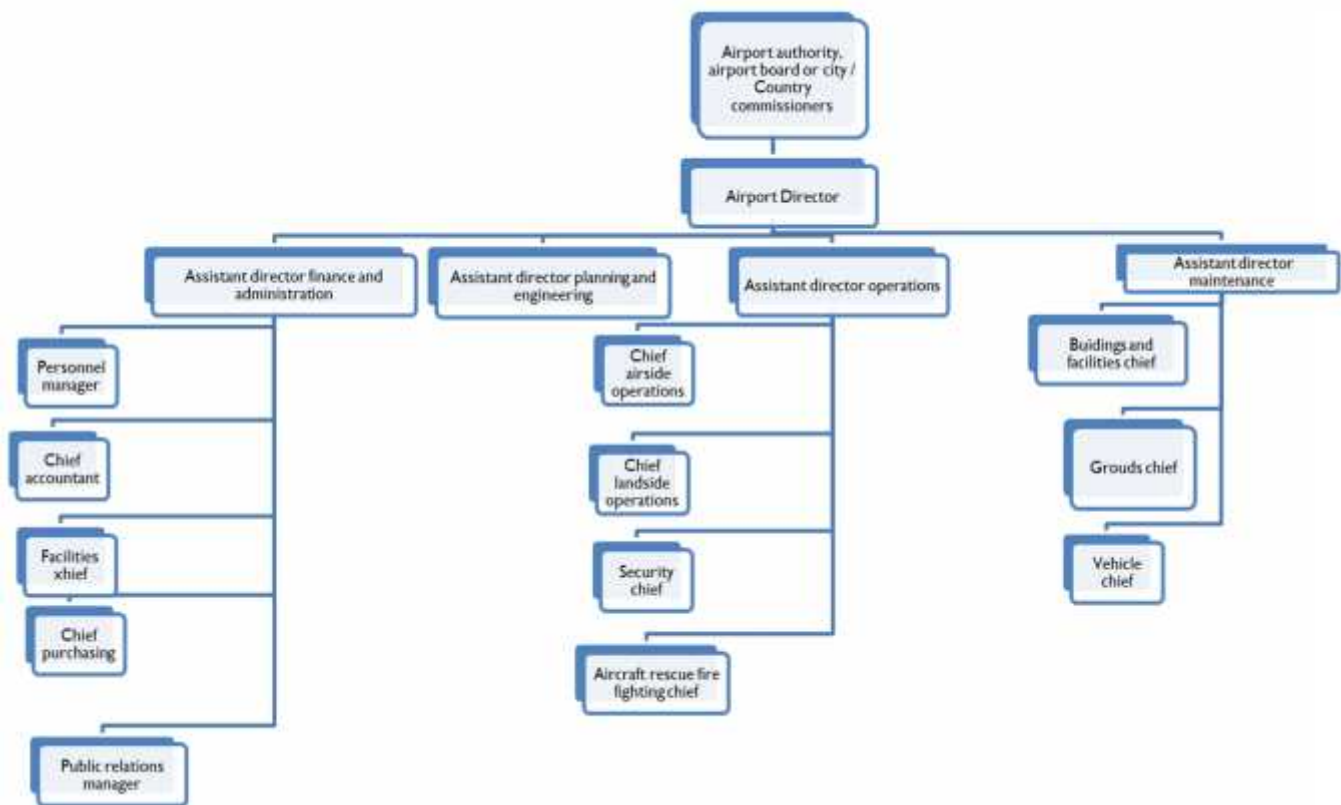


Figure II.17 : Typical airport management organization chart.

Airport director. The airport director is responsible for the overall day to day operation of the airport. He or she reports directly to the airport authority, the airport board, or governmental commission charged with the development and administration of the airport. This individual directs, coordinates, and reviews through subordinate supervisors, all aircraft operations, building and field maintenance, construction plans, community relations, and financial and personnel matters at the airport. The airport director also:

- Supervises and coordinates with airline, general aviation, and military tenants use of airport facilities.
- Reviews airport tenant activities for compliance with terms of leases and other agreements.
- Supervises enforcement of aircraft air and ground traffic and other applicable regulations.
- Confers with airlines, tenants and others regarding airport regulations, facilities, and related matters.
- Participates in planning for increased aircraft and passenger volume and facilities expansion.
- Determines and recommends airport staffing requirements.
- Compiles and submits for review an annual airport budget.

- Coordinates airport activities with construction, maintenance, and other work done by departmental staff, tenants, public utilities, and contractors.
- Promotes acceptance of airport oriented activities in surrounding communities.

Assistant director finance and administration. The assistant director finance and administration is charged with the responsibility for overall matters concerning finance, personnel, purchasing, facilities management, and office management. Specifically, this individual's duties include:

- Fiscal planning and budget administration.
- Accomplishment of basic finance functions such as accounts receivable and payable, auditing, and payroll.
- Administration of the purchasing function.
- Administration and use of real property including negotiation of tenant leases and inventory control.
- Personnel functions including compensation, employee relations, and training.
- Adequate telephone and mail service.
- Public relations.

Personnel manager. The personnel manager is responsible for administering the airport personnel program. In such capacity, this individual's duties include:

- Dealing with personnel problems involving position classification, compensation, recruitment, placement, transfers, layoffs, promotions, leaves of absence, supervisor-subordinate relationships, and working conditions.
- Serving as equal rights and equal opportunity officer for the airport.
- Handling worker's compensation cases.
- Evaluating the organization pattern, reviewing and recommending proposed departmental organizational changes, and preparing position descriptions.
- Conferring with employees and their supervisors on personnel problems.
- Preparing personnel documents and maintaining personnel records.
- Interviewing or supervising the interviewing of applicants for airport positions.

Chief accountant. The chief accountant is responsible for financial planning, budgeting, accounting, payroll, and auditing. The principal duties include:

- Coordinating, consolidating, and presentation of financial plans.
- Administering basic accounts such as general accounts, cost accounting, and accounts receivable and payable.
- Administering budget; reviewing and analyzing actual performance at budget review sessions.
- Supervising all receipts and disbursements.
- Administering payroll.
- Conducting periodic internal audit of all airport functions.

Facilities chief. The facilities chief establishes criteria and procedures for the administration of all airport property. In this capacity, he or she is responsible for inventory control of all equipment and facilities. Principal duties and responsibilities of this individual include:

- Identification and control of all property and equipment including periodic audits.
- Evaluating and making recommendations concerning the most efficient use of airport real property utilization.
- Soliciting tenants and concessionaires.
- Developing policy and rate structure applicable to use of property by tenants and concessionaires.

- Coordinating with purchasing and legal staff concerning tenant and concessionaire leases.

Chief purchasing agent. The chief purchasing agent directs the procurement of materials and services to support the airport; he or she prepares, negotiates, interprets, and administers contracts with vendors. This individual's principal duties include:

- Coordinating requirements for materials and services to be purchased.
- Purchasing all materials and services.
- Establishing bidding policies and procedures.
- Working closely with the facilities' chief and legal staff regarding contracts associated with purchasing equipment.

Manager of public relations. The manager of public relations is the chief liaison officer between the airport and the surrounding community. In this capacity, he or she is responsible for all public relations activities including the development of advertising and publicity concerning the airport. This individual is also responsible for handling all noise and other environmental matters. Principal duties include:

- Consulting with and advising airport management regarding public relations policies and practices.
- Coordinating all publicity releases to the various media.
- Supervising all airport guides and information booths.
- Coordinating VIP visits to the airport.
- Receiving and analyzing all public complaints regarding such things as noise and other environmental concerns.
- Preparing answers to complaints and advising management as appropriate.
- Sponsoring activities and special events to generate goodwill and public acceptance.

Assistant director planning and engineering. The assistant director planning and engineering provides technical assistance to all airport organizations, and ensures the engineering integrity of construction, alteration, and installation programs. This individual also establishes industrial safety standards. Principal duties and responsibilities include:

- Developing standards and specifications for construction, alteration, and installation programs, monitors such programs to ensure compliance therewith.
- Reviewing all construction plans to determine technical integrity and conformance to aesthetic design standards.
- Developing and publishing standards and procedures for industrial safety.
- Participating in the negotiation of construction contracts.

Assistant director operations. The assistant director operations is responsible for all airside and landside operations including security, and crash, fire, and rescue operations. Principal duties include:

- Directing the operations and security programs for the airport.
- Coordinating and supervising security activities with field maintenance personnel, police and fire departments, federal agencies, and airport tenants.
- Recommending and assisting in promulgating operational rules and procedures.
- Supervising investigations of violations of airport regulations.
- Preparing annual operations budget.
- Directing monitoring of noise levels and coordinating noise level studies.
- Participating in special programs relating to or affecting airport operations, such as studies of height limits around airport property and studies of noise control.

Chief airside operations. The chief airside operations is responsible for all airfield operations. In this capacity, principal duties include:

- Enforcing operating and security rules, regulations, and procedures concerning landing, taxiing, parking, servicing loading and unloading of aircraft, operation of vehicular traffic on the airfield, airline activities, and emergency situations.
- Inspecting conditions of airfield lighting, runways, taxiways, and ramp areas.
- Correcting hazardous conditions.
- Coordinating airfield activities with maintenance and security personnel.
- Assisting in all airfield emergency calls and disasters by notifying control tower to close runways, directing maintenance personnel, directing security officers in crowd control, and overseeing other safety considerations and activities necessary to resume normal airport operations.
- Investigating and reporting on complaints and disrupted airport operations, including unscheduled plane arrivals, aircraft accidents, rule and procedure violations, airline activities, and other operations of the airport.
- Assigning gate and parking spaces to all aircraft.
- Coordinating special arrangements for arrivals and departures of important persons.
- Completing all report forms pertaining to operations activities on assigned shifts.
- Assisting in directing noise level studies with other departmental personnel.

Chief landside operations. The chief landside operations is responsible for all landside operations. In this capacity, principal duties include:

- Enforcing operating and security rules, regulations, and procedures concerning buildings, access roads, and parking facilities.
- Exercising authority to halt hazardous or unauthorized activities by tenants, employees, or the public in violation of safety regulations and procedures.
- Answering inquiries and explaining terminal use procedures and safety regulations to tenants.
- Coordinating terminal building and other facility activities with maintenance and security personnel.
- Coordinating all parking facility activities with tenants and transit companies.
- Preparing personal injury and property damage reports and general incident reports.
- Completing all report forms pertaining to operations activities on assigned shifts.

Security chief. The security chief enforces interior security, traffic, and safety rules and regulations and participates in law enforcement activities at the airport. This individual also works closely with federal security officials assigned to the airport. Principal duties include:

- Enforcing ordinances and regulations pertaining to parking, traffic control, safety, and property protection.
- Patrolling facilities to prevent trespass and unauthorized or hazardous use.
- Preventing public entry into dangerous or restricted areas.
- Issuing citations and warnings for violations of specific provisions of airport rules and regulations.
- Securing gates and locks and watching buildings and facilities for indications of fire, dangerous conditions, unauthorized entry, and vandalism.
- Responding to emergencies and taking immediate action to control crowds, direct traffic, assist the injured, and turn in alarms.
- Responding to calls for police service; participating in arrests; apprehending, or assisting members of the police department in apprehending, law violators.
- Providing information to the public regarding locations and operations of the airport.
- Assigning uniformed and armed personnel to patrol and stand watch, on a 24-hour basis, to protect and safeguard all persons in the airport and property on the airport.

Aircraft rescue / fire fighting chief. The aircraft rescue / fire fighting chief develops procedures and implements accident, fire, and disaster plans. Principal duties include:

- Conducting a training (continuing) program for all aircraft rescue, fire fighting personnel.
- Developing and implementing all aircraft rescue and fire fighting programs.
- Staffing and operating all aircraft rescue and fire fighting equipment on the airport.
- Inspecting and testing all types of fixed fire prevention and extinguishing equipment on the airport.
- Inspecting all facilities for fire and/or safety hazards.

Assistant director maintenance. The assistant director maintenance is responsible for planning, coordinating, directing, and reviewing the maintenance of buildings, facilities, vehicles, and utilities. Principal duties include:

- Developing, directing, and coordinating policies, programs, procedures, standards, and schedules for buildings, utilities, vehicle maintenance, and field facilities.
- Coordinating work done by tenants and contractors.
- Inspecting maintenance work for compliance with plans, specifications, and applicable laws.
- Making recommendations as to adequacy, sufficiency, and condition of buildings, facilities, and vehicles.
- Overseeing maintenance contracts.

Buildings and facilities chief. The buildings and facilities chief is responsible for ensuring that buildings are adequately maintained with a minimum of cost. Types of maintenance required are primarily electrical, mechanical, plumbing, painting, carpentry, masonry, and cement work. Principal duties include:

- Developing an approved maintenance schedule for all building maintenance requirements.
- Assigning qualified personnel to perform maintenance.
- Inspecting work for adequacy and compliance with requirements.
- Developing special maintenance methods where necessary.

Grounds chief. The grounds chief is responsible for ensuring that the grounds are maintained in good repair and that the landscape is adequately maintained. Principal duties include:

- Developing approved schedules for maintaining all airport surface areas including paving, landscaping, and drainage systems.
- Assigning qualified personnel to accomplish ground maintenance.
- Inspecting work for adequacy and compliance with maintenance standards.

Vehicle chief. The vehicle chief is responsible for the maintenance of all vehicles utilized by the airport. Vehicle maintenance includes tune-up, minor maintenance, washing and polishing, tires and batteries, lubrication, and fueling. Principal duties include:

- Developing an approved vehicle maintenance schedule.
- Coordinating schedule with users of airport vehicles.
- Assigning qualified personnel to perform maintenance.
- Inspecting all work to determine compliance with established maintenance standards.
- Coordinating with purchasing to obtain vendor services as required.
- Maintaining vehicle usage and maintenance records.

- Coordinating with purchasing in developing a vehicle disposal and replacement program.

Although the aforementioned positions represent a typical managerial structure at a commercial airport, there are numerous employees with a wide variety of job skills reporting to them. Some of the typical job titles found at major air-ports include the following:

Accountant	Buyer
Administrative assistant	Carpenter
Air-conditioning mechanic	Cement finisher
Airport guide	Civil engineer
Airport noise abatement officer	Construction inspector
Architect	Contract analyst
Auditor	Custodian
Auto mechanic	Drafter
Bus driver	Electrician
Elevator mechanic	Plumber
Equipment mechanic	Public relations representative
Equipment operator	Secretary
Facility planner	Security officer
Financial analyst	Sheet metal mechanic
Firefighter	Software engineer
Groundskeeper	Student intern
Heavy-duty equipment operator	Supervisor of operations
Industrial engineer	Tilesetter
Maintenance and construction laborer	Toolroom keeper
Maintenance foreman	Traffic painter and sign poster
Operations assistant	Tree surgeon
Painter	Truck operator
Personnel representative	Welder
Plasterer	Window cleaner

CHAPTER III

Airport Master Planning

Introduction

Along with the multitude of responsibilities and tasks associated with operating an airport on a day-to-day basis, airport management is also ultimately responsible for the significant responsibility of providing a vision for the future of the airport. On a larger scale, municipalities that are served by more than one airport, as well as individual states and even the United States as a whole, are handed the responsibility of strategically planning for a coordinated system of airports to best meet the future needs of the traveling public. Airport planning may be defined as the employment of an organized strategy for the future management of airport operations, facilities designs, airfield configurations, financial allocations and revenues, environmental impacts, and organizational structures.

III.1 Airport Master Plan: Definition And Objectives

The planner's idealized concept of the form and structure of the ultimate development of the airport is contained in the airport master plan. This plan is not simply the physical form of the ultimate development but a description of the staging of development and both the financial implications and the fiscal strategies involved. Master planning applies to the construction of new airports as well as to the significant expansion of existing facilities.

The goal of a master plan is to provide the framework needed to guide future airport development that will cost-effectively satisfy aviation demand while considering potential environmental and socioeconomic impacts. Considering the possible environmental and socioeconomic costs associated with alternative development concepts and the possible means of avoiding, minimizing, or mitigating impacts to sensitive resources at the appropriate level of detail for facilities planning.

Specific objectives of the master plan include:

1. Document the issues that the proposed development will address.
2. Justify the proposed development through the technical, economic, and environmental investigation of concepts and alternatives.
3. Provide an effective graphic presentation of the development of the airport and anticipated land uses in the vicinity of the airport.
4. Establish a realistic schedule for the implementation of the development proposed in the plan, particularly the short-term capital improvement program.
5. Propose an achievable financial plan to support the implementation schedule.
6. Provide sufficient project definition and detail for subsequent environmental evaluations that may be required before the project is approved.
7. Present a plan that adequately addresses the issues and satisfies local, state, and federal regulations.
8. Document policies and future aeronautical demand to support municipal or local deliberations on spending, debt, land use controls, and other policies necessary to preserve the integrity of the airport and its surroundings.
9. Set the stage and establish the framework for a continuing planning process.

III.2 Hierarchy Of Planning / Case studies

In the United States, airport planning is carried out by a multilevel governmental process, where plans are formulated to meet overall transport demand in coordination with other transportation and comprehensive land use planning. These levels are as follows:

- ***The National Plan of Integrated Airport Systems (NPIAS)*** , a 10-year plan continually updated and published biennially by the FAA. It lists public-use airports and describes the development considered to be in the national interest, making them eligible under the Airport and Airway Improvement Act of 1982 for financial assistance for airport planning and development.
- ***Statewide integrated airport systems planning***, which is executed by state aviation planning agencies. This level of planning identifies the general location and characteristics of new airports and the expansion needs of existing airports in furthering state-wide aviation goals.
- ***Regional/metropolitan integrated airport systems planning***, which identifies and plans for large regional or metropolitan areas. Needs are stated in general terms within the context of state-wide system plans.
- ***Airport master plans*** are prepared for individual facilities. The operators usually require the assistance of consultants for such detailed studies of the long-range development plans of the individual airport within the context of state-wide plans.

III.3 Elements Of Airport Master Plan:

The structure and content of the FAA master plan are closely aligned to the FAA's objective to establish a planning process that is uniform across the United States and is suitable for implementing development of U.S. airports within a coordinated federal funding process. As such, it is at variance with the more heterogeneous approaches of countries which plan according to ICAO guidelines. Elements which are generally to be included in any master planning exercise :

1. Preplanning. The preplanning process includes:

- Initial needs determination based on observed or potential deficiencies in the existing plan or airport.
- The manner of calling for requests for proposals and subsequent consultant selection.
- Development of study design, showing a scope of work that includes goals and objectives, data availability, forecast horizons, environmental considerations, schedules, and deliverables; organization of a formal structure of review committees for coordination and public involvement program; adjustment of the scope of work to budgetary requirements.
- Negotiation of consultant contract.
- Application for study funding.

2. Public Involvement. Once the consultant team is under contract and has been issued a notice to proceed, a public involvement program is established and the key issues of various stakeholders are identified and established, ensuring:

- Timing of public involvement that ensures that all major decisions are set before the public at an early stage of the planning process before irreversible decisions are made.
- Appropriate public involvement techniques where appropriate: technical advisory and citizens' advisory committees, public information meetings, small group meetings and briefings, public awareness campaign, and Internet exposure with Web pages.

- Stakeholder identification, including potentially users and tenants, groups and individuals within the sponsor's (airport's) organization, resource agencies and governmental units with regulatory or review authority, and other interested groups.
- Identification of key issues, broadening those earlier identified in the preplanning stage to include the stakeholders.
- Documentation of the key issues and the operation of the public involvement program itself.

3. Environmental Considerations. It is necessary that the airport master plan demonstrate a clear understanding of the environmental requirements needed to move forward with each project in the recommended development program. One of the requirements of the Airport and Airway Development Act of 1970 is that environmental factors must be considered both in the site selection process and in the design of the airport.

A proposed project must be considered not with respect to individual work items but from a broader program context and will be classified into one of three categories :

- Categorical exclusions.
- Actions normally requiring an environmental impact assessment.
- Actions requiring an environmental impact statement (EIS).

Environmental quality must be accompanied by an EIS which will cover the following areas :

• **Purpose and Need for Action.** The problem being addressed, alternatives to resolve the problem, the benefits, the need for the proposed action, preferences of the applicant and agency, and the parameters for defining a reasonable range of alternatives to be considered.

• **Alternatives Including Proposed Action.** These must be reasonable, feasible, and meet the project's purpose. Reasonable alternatives not within the agency's jurisdiction should be included.

• **Affected Environment.** The existing environmental conditions of the potentially affected geographic area.

• **Environmental Consequences.** Environmental consequences of the alternatives, including the proposed action, adverse environmental impacts which cannot be avoided, relationship between short-term use of the environment and the maintenance and enhancement of long-term productivity, and the irreversible commitment of resources.

• **Mitigation.** The EIS describes mitigation measures considered or planned to minimize environmental impact.

It is therefore suggested that any airport master plan be evaluated factually in terms of the following potential effects where applicable:

Air quality	Fish, wildlife, and plants	Noise
Coastal resources	Floodplains	Secondary Impacts
Compatible land use	Hazardous materials, pollution prevention, and solid waste	Socioeconomic impacts
Construction impacts	Historical, architectural, archeological, and cultural resources	Water quality
DOT Act	Light emissions and visual impact	Wetlands
Farmlands	Natural resources and energy supply	Wild and scenic rivers

4. Existing Conditions. An inventory of pertinent data for use in subsequent plan elements. The inventory is a large data collection exercise that allows the airport planner to gain complete understanding of the nature and scale of existing facilities. For all potential sites, the planner needs data relating to the following: the physical and environmental characteristics of the site; the presence nearby of any existing airport; the structure of airspace and the status of air traffic management in the area and the availability and location of navigational aids; existing and projected land uses at and in the general affected area of the site; the location of utilities, schools, hospitals, and other public infrastructures; and the legislative constraints related to ordinances, bylaws, zoning, building codes, and so on, which could affect the nature and scope of any projected airport development.

5. Aviation Forecasts. There is a need to develop short, medium, and long-term forecasts of aeronautical demand to permit well-conceived planning leading to the ultimate development of the airport site. The planner needs forecasts of passenger volumes as well as movement of aircraft and cargo both at the annual and the peak levels. Knowledge of annual movement is necessary for estimating the magnitude of revenues that will accrue to the facility; peak movement levels determine the scale of facility required to assure a balance of capacity to demand.

The aviation demand elements which need to be forecast for airport master planning purposes may be summarized as follows:

Aircraft operations

Itinerant: Air carrier, air taxi, commuter, general aviation, military

Local: General aviation, military

Where appropriate, further forecasting of operations should predict domestic/international splits, annual instrument approaches, IFR versus VFR operations, and helicopters.

Passenger volumes

Total enplanements, air carrier, air taxi, and commuter passengers. Where appropriate, the passenger forecasting would also include domestic versus international split, general aviation, and helicopter passengers.

Based aircraft

Aircraft mix

Air cargo and mail

For master planning purposes, forecasts are usually prepared in terms of levels of annual activity for 5, 10, and 20 year horizons. In addition to this, peak load forecasts are made. It is not generally appropriate to design airport facilities to meet the full requirements of short lived peaks of demand. Some middle ground between supplying for average and peak demands is sought.

A commonly used concept in this regard is the “design hour,” which is an estimate of the peak hour of an average day in the peak month. Additional peaking forecasts may be required for special areas in the airport. For example, peak 20-min forecasts are frequently used for designing baggage facilities.

For forecasting purposes, it is recommended using estimates of economic growth and changes in industrial activity, demographic patterns, disposable personal income, geographic factors, alternative technology, sociological and political factors, regulatory changes, and historical air traffic data.

6. Facility Requirements. At this stage, having determined the levels of future demand, it is possible to assess the ability of the existing airport, both airside and landside, to support the forecast demand. Furthermore, the planner will identify the demand levels that will trigger the need for facility additions or improvements and will estimate the extent of new facilities that may be required to meet that demand.

The requirements for new facilities can be driven by a number of factors:

- Lack of capacity due to increased demand.
- Changes in security requirements required by the Transportation Security Administration.
- Changes in standards or noncompliance with existing standards.
- Changes in the nature of the airport's vision of service provision.
- Outdated and unsuitable existing facilities.

Future facility requirements can be estimated by simulation of future operations. These should be related to future levels of demand, so that the planner can identify what demand levels trigger the need for expansion or improvement of a particular facility.

7. Demand–Capacity Analysis. With knowledge of forecast demand for a proposed airport site and with different estimates of staged development beyond existing infrastructure levels, the analyst is able to test a variety of options of development through a demand–capacity analysis.

The analysis should be broad and should cover the following areas of operation in sufficient detail to permit preliminary facility sizing. The planner can then compare:

- (a) Forecast aircraft operations vis-à-vis airspace capacity.
- (b) Forecast aircraft operations vis-à-vis air traffic control facilities.
- (c) Forecast aircraft operations vis-à-vis airfield capacity.
- (d) Forecast passenger movements vis-à-vis passenger terminal capacity.
- (e) Forecast cargo volumes vis-à-vis air cargo terminal capacity.
- (f) Forecast access traffic vis-à-vis surface access route capacity.

The types of new facilities required, their scale, and the staging of their construction are determined as a result of the demand–capacity analysis. These elements are developed according to ICAO standards. The facilities required and the elements requiring consideration are as follows :

(a) **Runways.** Orientation, length, width, clearances, clear zones, approach slopes, orientation, crosswind runway provision, grades, capacity, staged construction, cost implications of delay to aircraft, pavement design strength and cost effectiveness.

(b) **Taxiways.** Width, location, clearances, design and location of exits, grades, effect on runway capacity, staged construction, pavement design strength and cost effectiveness.

(c) **Electronic, Visual, and Satellite Aids to Navigation.** This provision depends on fleet mix, percent of time bad weather is present, and cost to users.

(d) **Airspace Requirements.** This may require a detailed examination, often using simulation techniques. Major airfield reconfigurations can require significant airspace changes or redesign.

(e) **Passenger Terminal Complex.** Gates and apron frontage: Clearances, grades, aircraft mix, number of aircraft gate positions by aircraft class, aircraft parking clearances, ground servicing equipment space requirements.

(f) **General Aviation Requirements.** These include a wide variety of users: business aircraft, light cargo, recreation, law enforcement, flight training, agriculture, and fixed base operators. They require aircraft storage areas and buildings for the based aircraft, transient aircraft parking areas, and terminal facilities.

(g) **Air Cargo.** For commercial service airports and large general aviation airports, cargo operations can be very diverse. They include the following:

- Belly freight carriers: passenger aircraft, using some of the belly space for containerized freight
- Combination carriers: passenger aircraft with a reconfigured cabin, using some of the main deck for containerized freight.

- All cargo carriers: sell space to freight forwarders or companies and carry freight between airports.

- Integrated carriers: door-to-door services using their own aircraft and trucks, often requiring their own freight terminal.

- Freight forwarders: arrangers of transport which includes ground transport at either end of the flight and customs clearance where necessary. The air transport leg is arranged but not carried by the forwarder.

(h) **Support Facilities.** The future requirements of the following support facilities should be examined: aircraft rescue and firefighting, airport maintenance, fuel storage, aircraft maintenance and deicing.

(i) **Ground Access.** Regional transportation network: Only at the largest airports, the demand on the regional network must be examined and the impact of increased air transport demand evaluated.

(j) **Utilities.** The master plan will address the future requirements for water, sanitary sewage, stormwater drainage, de-icing run-off, industrial waste, communications, natural gas, and electric power supply.

(k) **Other Requirements.** At many airports there are extensive areas and some developments that are nonaeronautical in character. Some are considered temporary until the land is needed for aeronautical purposes; others have been developed along with the airport. Agricultural land is an example of the first type; the newly developing airport cities covered. At this stage the planner needs to review the future spatial and infrastructure needs of these areas.

8. Alternative Development and Evaluation. Options are identified to meet projected facility requirements and to provide alternative configurations for each major component. In an elaborate three-stage process, the expected performance of each alternative is assessed against a wide range of evaluation criteria, including its operational, environmental, and financial impacts, plus consideration of best planning practice. Qualitative and quantitative measures are used.

9. Airport Layout Plan Drawing Set. One of the key products of a master plan is a set of drawings that provides a graphic representation of the long-term development plan for an airport. The primary drawing in this set is the airport layout plan. Other drawings may also be included, depending on the size and complexity of the individual airport.

The full set of recommended drawings comprises:

- Cover sheet / Airport layout plan

- Data sheet

- Facilities layout plan

- Terminal area plan

- Airport airspace drawing

- Inner portion of approach space drawing
- On-airport land use drawing
- Off-airport land use drawing
- Airport property map
- Runway departure surface drawing
- Utility drawing
- Airport access plan
- Other necessary plans that are specific to the airport

10. Facilities Implementation Plan. This section of the master plan provides a summary description of the recommended improvements and associated costs. The actual timing of improvements depends, in large part, on the levels of demand that trigger the need for expansion of existing facilities. However, based on the output of the demand/capacity analysis, a capital improvement program can be produced that identifies expenditure and the most likely time that these will be incurred. Table III.1 shows an example of a simple capital improvement program. The scheduling of the various elements of facilities implementation is usually in the form of a time- and activity-based Gantt chart.

11. Financial Feasibility Analysis. The financial plan for the airport describes how the sponsor will finance the projects recommended in the master plan and demonstrates the financial feasibility of the program.

An approved Airport Layout Plan Update (ALU) may be considered satisfactory for airport development purposes, where a full master plan incorporating steps 1–11 above is considered more than is necessary. The ALU must be considered as a substitute for a master plan only for small changes in airport planning.

Figure III.1 shows a typical structure for the preparation of the master plan in diagrammatic form.

Planning Step	Description
Preplanning considerations	Coordination, planning procedure, planning organization, goals, and policy objectives
Forecasting for planning purposes	Requirements, forecasts required, accuracy, methods and principles of forecasting, factors, presentation of forecasts
Financial arrangements and controls	Capital costs: currency requirements, source of funds, domestic and foreign financing; operational costs: sources of income; financial control and accounting
Site evaluation and selection	Land required, location of potential sites, factors affecting airport location, preliminary study of possible sites, site inspection; operational, social, and cost considerations; environmental study; review of potential sites; outline plans and estimates of costs and revenues; final evaluation
Runways and taxiways	Dimensions, strength; aircraft characteristics, performance, and runway length; configuration; airfield capacity
Aprons	Layout of aprons, size of stands, parking, service, and hangar aprons, holding bays, security, apron accommodations
Air and ground navigational and traffic control aids	Visual aids, radio navigation aids and their buildings, demarcation of critical areas, air traffic services, search and rescue services, apron control, communications
Passenger building	Planning principles, airport traffic and service characteristics, factors affecting scale of services to be supplied, capacity and demand Connection of passenger building to access system, passenger and baggage processing, waiting areas, governmental frontier controls, airside linkages, apron passenger vehicles, transit and transfer passengers, passenger amenities and other passenger building services
Cargo facilities	Siting, building function and type, apron, facility requirements, access, parking, inspection, and control
Ground transport and internal airport vehicle circulation and parking	Private and public transport modes, traffic data, internal roadway circulation, curbside, vehicle parking
Airport operations and support facilities	Administration and maintenance, medical center, ground vehicle fuel stations, generating stations, water supply and sanitation, flight catering, kitchens, meteorological services, aircrew briefing and reporting, aircraft maintenance, rescue and firefighting, general aviation facilities, police, hotels
Aircraft fuel facilities	Safety, implications for gate occupancy times, movements of large and heavy vehicles, storage capacity, fuel storage location, aircraft fueling systems
Security	Airside security: roads, fencing, isolated parking position, security parking area, emergency explosive holding area Landside security: passenger buildings, public storage lockers

Table III.1 Outline of ICAO Master Planning Process.

III.4 ICAO Guidelines for Structure of Master Plan

The ICAO manual states that the airport master plan is a guide for:

- Development of physical facilities of the airport.
- Development of land uses for areas surrounding the airport.
- Determination of environmental effects of aerodrome construction and operation.
- Establishment of airport access requirements.

In addition, the plan can be used to provide guidance on policy and decisions in both the long and short term, to identify potential problems and opportunities, to assist in securing financial aid, to serve as a basis for negotiations between the airport authority and its tenants, and to generate local interest and support.

The manual identifies a number of areas that will be included in any master planning activity. These are policy and coordinative planning, economic planning, physical planning, environmental planning, and financial planning. The master planning process itself is made up a number of defined steps:

1. Prepare a master work plan.
2. Inventory and document existing conditions.
3. Forecast future air traffic demand.
4. Determine scale and time phasing of facilities.

5. Evaluate existing and potential constraints.
6. Determine the relative importance of constraints and other considerations.
7. Develop a number of master plan options.
8. Evaluate and screen all plan options.
9. Select the most acceptable and appropriate option, refining and modifying it in response to the evaluation process.
10. Prepare master plan documents in final form.

The ICAO manual states that the master plan is no more than a guideline that must later be developed into a more detailed implementation program. Table III.1 outlines the ICAO master planning process.

III.5 Airport Layout Design

There are no firm rules which can be stated for determining airport layout. The procedure is a design exercise in which compromises in one area must be weighed against advantages gained in others. The design for each airport layout is site specific, and whereas general concepts can be moved between sites, the individual aspects of each site will almost certainly result in slightly different layouts. The layout of an airport is dependent upon a number of factors, of which the most important are:

1. Number and orientation of runways.
2. Number of taxiways.
3. Size and shape of aprons.
4. Area and shape of available land.
5. Topography and site soil conditions.
6. Obstacles to air navigation.
7. Required proximity of land uses within the airport boundary.
8. Surrounding land uses.
9. Timing and scale of phased development of the airport.
10. Meteorology.
11. Size and scale of airport facilities being planned.

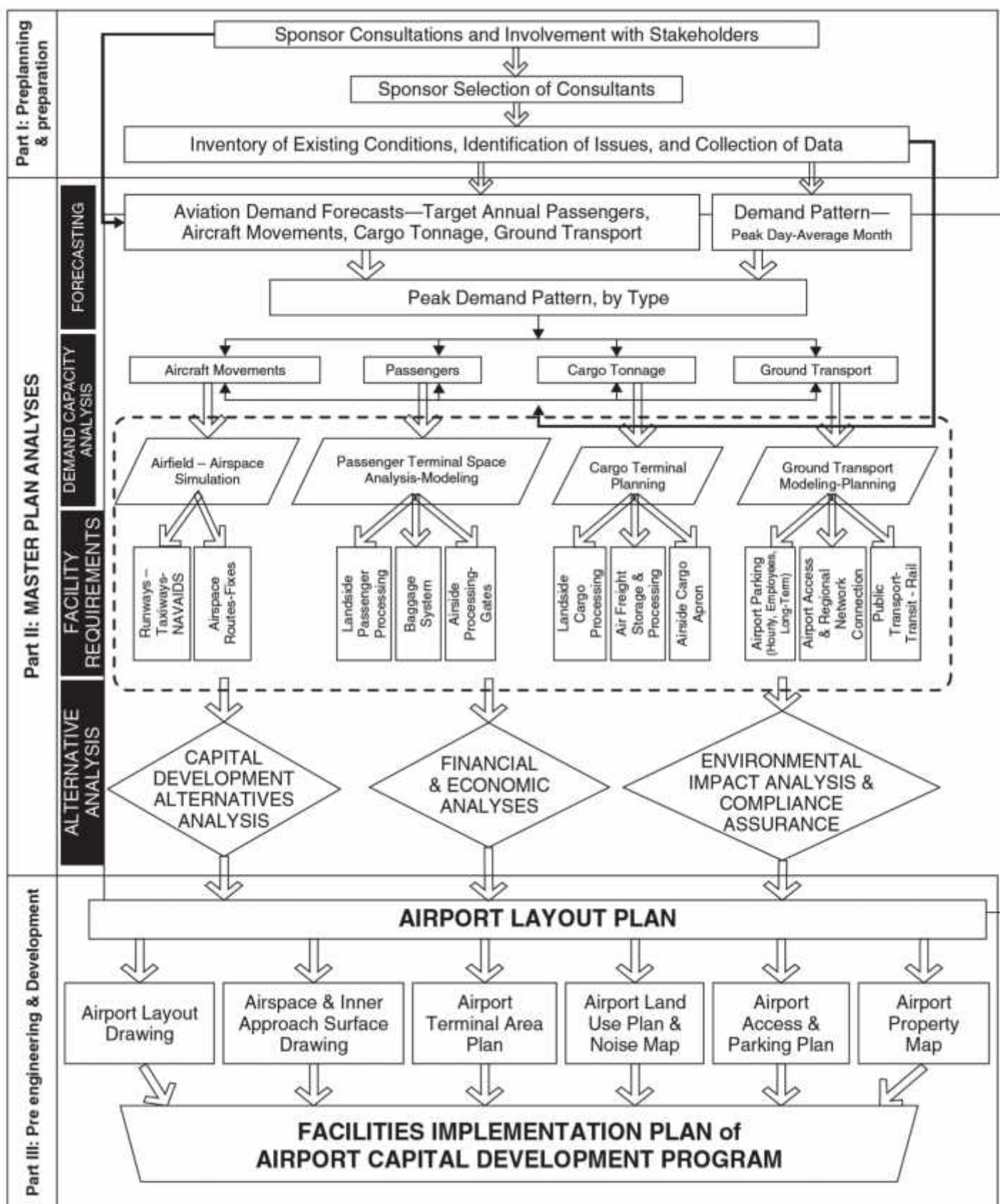


Figure III.1 Master plan preparation process.

In preparing a layout plan, it is normal to examine a number of potential layouts and to select the best option from competitive solutions. This best solution is further refined by developing and selecting from suboptions.

The principal facilities to be considered in an airport plan include:

- Runways.
- Taxiways.
- Passenger terminals and aprons.
- Cargo terminals and aprons.
- Rescue and firefighting services.
- Air traffic control tower.
- Aircraft maintenance.
- Long-term and short-term parking.
- Access roads.
- Rail and public transport access.
- Airport maintenance, snow clearance, engineering base.
- Nav aids.
- Lighting.
- Flight kitchens.
- Fuel farm.
- General aviation terminal and apron.
- Sewage treatment and pumping stations.
- Electrical substations.
- Security fences and control gates.
- Hotels.
- Industrial uses.

Figure III.2 shows three schematic layouts of an airport with two runways of orientation 18-36 and 13-31. The closed-V layout is reasonably compact in its overall space requirements, has reasonable taxiing distances, and provides reasonable space for expansion of the terminal area between the two runways. On the other hand, the crossed-runway layout, while providing short taxiing distances and a compact overall site, squeezes the terminal into a site which offers little opportunity for expansion. The extended-V layout provides ample flexibility in the design of the terminal area but at the expense of a large overall land requirement and poor operational efficiency on the airside.

At large airports which are used by large transport aircraft, there is a need for parallel runways to accommodate the high volumes of air transport movements, the spatial needs of the extensive passenger terminals and the associated aprons require much greater runway separation than the minima required for IFR parallel approaches.

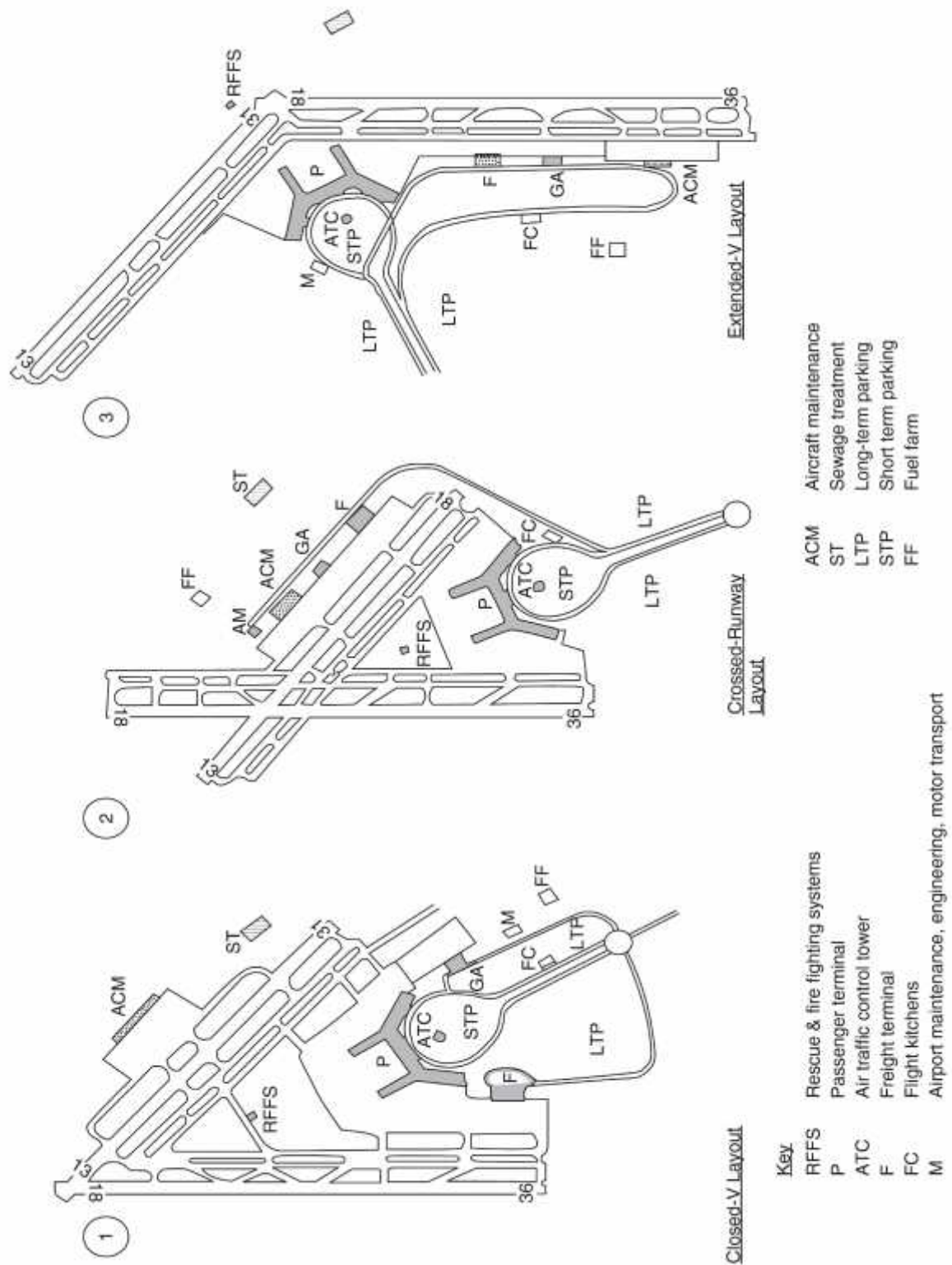


Figure III.2 : Layout options for given runway lengths and orientation.

III.6 Data Requirements For Master Planning

Notwithstanding the method used, all master plans must be founded on assumptions and forecasts built from an extensive and valid database. The collection and validation of data are therefore important and time-consuming elements of the master planning process. In a master planning exercise, the following data requirements could be expected:

III.6.a Demand and Traffic

Passengers

- Annual passenger movements over the last 10 years.
- Monthly passenger movements over the last 5 years.
- Hourly passenger movements for 10 peak days during the last 5 years.

Aircraft

- Annual movements over the last 10 years.
- Monthly movements over the last 5 years.
- Hourly movements for 10 peak days during the last 5 years.
- Airline and ICAO estimates of regional passenger growth, both domestic and international.
- Current and future aircraft fleet mix over the next 15 years.
- Historic patterns of military movements and estimates of growth of these movements if the airport is a shared facility.
- Scheduled patterns of operating airlines.

General socioeconomic data

- based on the size and projected growth rates in the locality and region of airport, including data on population, employment, income, tourism, building activity, retail sales, industrial output, and so on; current income distribution within city, region, and nation, with projected changes in distribution pattern

Cost and service

- levels of competing land (and, if applicable, sea) transport modes

III.6.b Environmental Data

- Local planning regulations.
- Local development plans, both detailed and structural, indicating plans for metropolitan and regional development.
- Existing land uses and status of development in the airport surroundings.
- Local transportation plans.
- Relationship between local transportation plans and national transportation plans and investment strategies at various governmental levels.
- Local and national noise regulations, both current and planned.

III.6.c Physical Data

- Description and modal share of existing access modes.
- Meteorological data—wind records, rainfall, snow, periods of low visibility.
- Topographical details to approximately 30 km (18 mi) around each airport with contours to 10m at a scale of 1:50,000.

- More detailed topography to a limit of 3–5 km (2–3 mi) outside airport boundary to a contour of approximately 1m at a scale of 1:2000.
- As-built plans of existing facilities with details of ownership.
- Detailed breakdown of square footage of existing building space allotted to various functions.
- Architectural detail plans of any existing terminal, designating usage to various facilities: for example, immigration, customs, departure lounge, check-in, baggage claim, administration, concessions.
- Structural details of construction of aprons, taxiways, runways, and major buildings; evaluation of the strength and surface condition of these structural elements.
- Appraisal of the structural soundness of existing buildings, plus an indication of structure type (permanent, light construction, or temporary).
- Condition and extent of existing drainage and sewerage.
- Condition and extent of existing lighting on runways, taxiways, aprons, and approaches.
- Condition and extent of existing markings.
- Condition, type, and capability of existing navigation and telecommunication aids.
- Data on hazards to aircraft penetrating protected surfaces.
- Details of existing services/ firefighting/apron services.
- Other necessary physical data, including environmental data.

III.7 Structure Of Master Plan Report

The presentation of the master plan is in the form of a report which describes the following:

-) Introduction and purpose of the master plan.
-) Inventory of the existing conditions and facilities.
-) Demand analysis: forecasts of passenger traffic, cargo traffic, air transport movements, general aviation and military movements, ground access traffic movements by public and private modes.
-) Demand/capacity analysis: comparison of the existing capacity vis-à-vis the forecast demand approaches, runways, taxiways, aprons, terminals, support facilities, access, and parking.
-) Sequenced facility provision: sequenced and staged provision of capacity in accordance with the development of demand. Where necessary, capacity enhancement will be computed for:
 - Airside*: Runways, taxiways, apron, holding areas, support facilities.
 - Terminals*: Passenger and cargo.
 - Landside*: Access modes and parking, support facilities.
-) Passenger terminal layout with preliminary sketches.
-) Cargo terminal.
-) Schedule of improvements: usually in the form of a Gantt chart showing major improvement items and timing.
-) Cost estimates: runways, taxiways, aprons, and holding areas; cargo and passenger terminals; navigaids, control tower.
-) Utilities and support facilities (meteorological, fire, fuel, catering, security, etc.); roads, parking, and other access facilities; military areas; general aviation facilities; aircraft maintenance areas, airport maintenance areas.
-) Capital improvement program: usually supplied in spreadsheet format, for example, as in Table III.2.

	Stage 1	Stage 2	Stage 3
Type of expenditure	2013–2017	2018–2022	2023–2032
Paving			
Airfield (includes lights)			
Runways	9,440,550	2,161,890	25,590,330
Taxiways	16,952,640	9,475,590	24,157,350
Aprons	4,116,660	3,700,155	20,776,500
Roads	—	—	—
Terminal and services	3,985,200	3,645,000	16,912,800
Parking lots	1,093,500	—	3,523,500
Buildings			
Expansion of existing terminal	27,216,000	9,225,000	—
New terminal	—	—	153,090,000
Fire fighting and rescue equipment	—	—	2,430,000
Airport maintenance	—	—	4,009,500
Relocation			
Fixed base operator	4,860,000	—	—
Military	972,000	2,430,000	—
Airport maintenance	850,500	—	—
Miscellaneous			
Electrical	3,280,500	534,600	2,041,200
Utilities	1,093,500	—	4,860,000
Drainage	730,500	364,500	4,252,500
Landscaping	—	—	3,645,000
Fencing	243,000	—	972,000
Site preparation	5,491,800	3,256,200	14,337,000
Total estimate for construction	80,326,350	34,792,935	280,597,680
Legal, administrative, and engineering costs	17,215,545	7,645,725	61,731,495
Total project	97,541,895	42,438,660	342,329,175
Land acquisition	39,183,750	0	0
Total estimated cost	136,725,645	42,438,660	342,329,175

Table III.2 Example of a Master Plan Cost Estimate for a Typical Project with Three-Stage Expansion of Existing Facility

The following drawings will form part of the master plan report:

A. Airport Layout Plan

1. Location map (1:500,000)
2. Vicinity map (1:25,000) approximately
3. Airport layout map, which includes:
 - (a) Prominent airport facilities, such as runways, taxiways, aprons, blast pads, stabilized shoulders, runway end safety areas, buildings, nav aids, parking areas, roads, lighting, runway marking, pipelines, fences, drainage, segmented circle, wind indicators, and beacon.
 - (b) Natural and man-made features: trees, streams, rock outcrops, ditches, railroads, power lines, towns.

- (c) Revenue-producing, nonaviation-related property.
- (d) Areas reserved for future aviation and services development.
- (e) Areas reserved for nonaviation uses: industrial areas, hotels, etc.
- (f) Existing ground contours.
- (g) Fueling facilities, tie-down areas.
- (h) Facilities to be phased out.
- (i) Airport boundaries.
- (j) Runway clear zones and associated approach surfaces, including location and height of controlling objects.
- (k) Airport reference point.
- (l) Coordinates and elevation of existing and ultimate runway ends and thresholds.
- (m) True azimuth or runway.
- (n) North point-true and magnetic, with magnetic declination (variation) and epoch year.
- (o) Pertinent dimensional data: runway and taxiway widths, runway length, taxiway widths, taxiway–runway–apron clearances, apron dimensions, building clearance lines, runway clear zones and parallel runway separation.
- (p) Map scale 1:2500–1:7500 should be used depending on size of airport.

4. Basic data table showing:

- (a) Airport elevation.
- (b) Airport reference point and coordinates.
- (c) Airport magnetic variation.
- (d) Mean maximum daily temperature in hottest month.
- (e) Airport and terminal nav aids.
- (f) Runway identifications in magnetic numerals, for example, 13/31, 4/22.
- (g) Percent effective runway gradients on each existing and proposed runway.
- (h) Percent wind coverage by runways.
- (i) Designated instrument runway.
- (j) Pavement type (grass, asphalt, p.c. concrete).
- (k) Pavement strength designation of each runway.
- (l) Approach surfaces for each runway.
- (m) Runway lighting.
- (n) Runway marking.
- (o) Electronic and visual approach aids and weather facilities.

5. Wind information ,wind rose with runway orientation superimposed

6. Designated instrument runway or runways for precision instrument approach procedures.

7. ICAO Type A (operating limitations) and Type B (protected surfaces) drawings.

8. Property map, with ownership type size and routing of utilities.

To illustrate the ALP diversity and extensive content for a range of airports, three types of airports are presented: (1) medium- International, (2) small- US, and, (3) large US/international. Figure III.3 depicts the airport layout plan for an international airport in a developing country (Kuching, Malaysia), where (a) depicts the existing airport layout plan and facilities, and (b) the ultimate development of the airport. Figure III.4 depicts the airport layout plan for the ultimate development of a small US airport (Palm Beach, Florida). Figures III.5 (a) to (d) provide representative airport layout plan for a large international airport in the United States with a high-design capacity (Dallas Fort Worth International Airport, Texas). A large set of drawings and tables is typically required to represent the extensive ALP information for such large airport, and Figures III.5 provide only a partial list of the entire ALP drawings set: Figure III.5 (a) presents the airport location map and airport data table; Figure III.5 (b) provides all-weather wind coverage table and the wind rose; Figure III.5 (c): presents details contained in the airport runway tables; and Figure III.5 (d): depicts the airport ultimate layout plan.

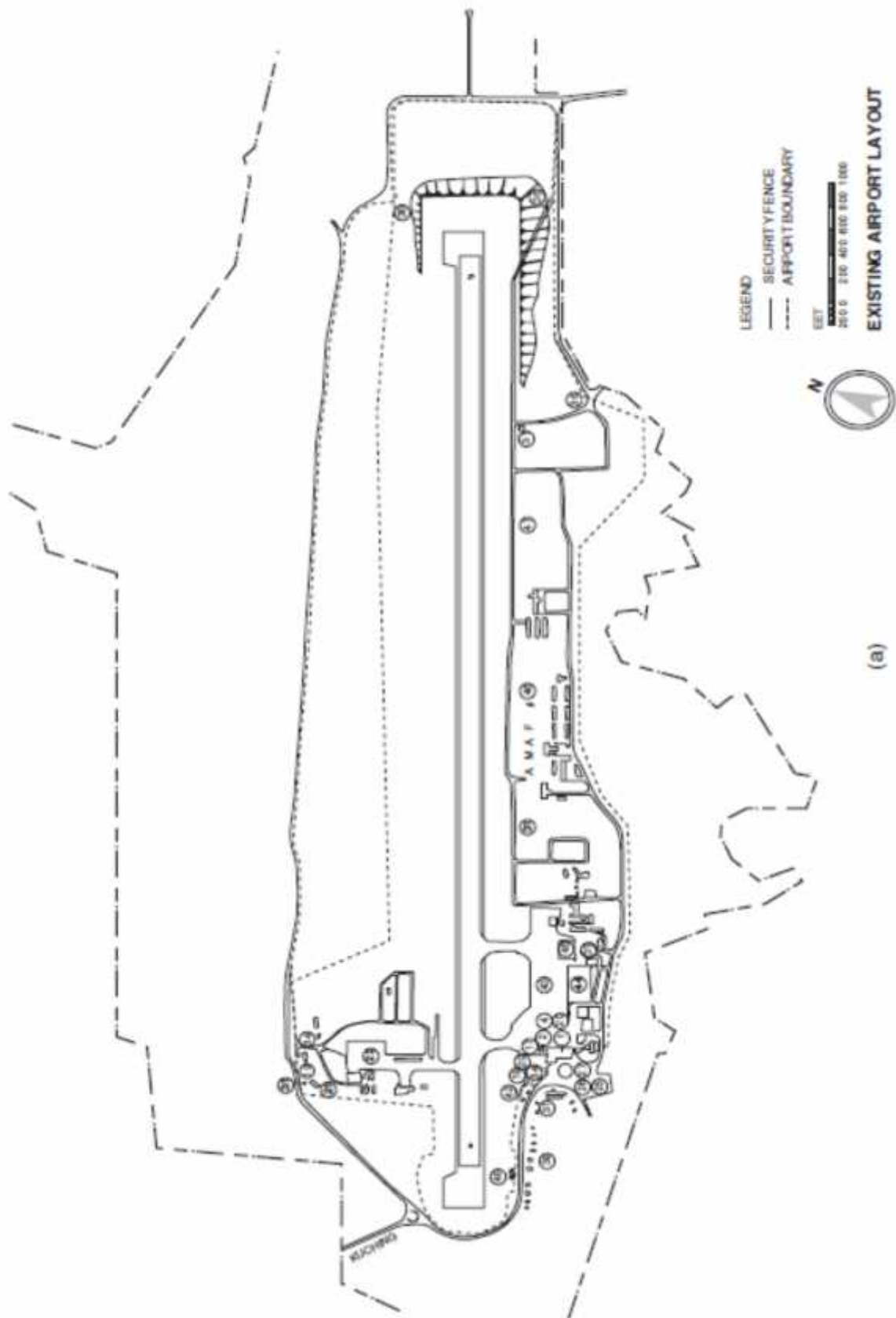


Figure III.3(a) : Kuching, Malaysia airport layout plan current facilities.

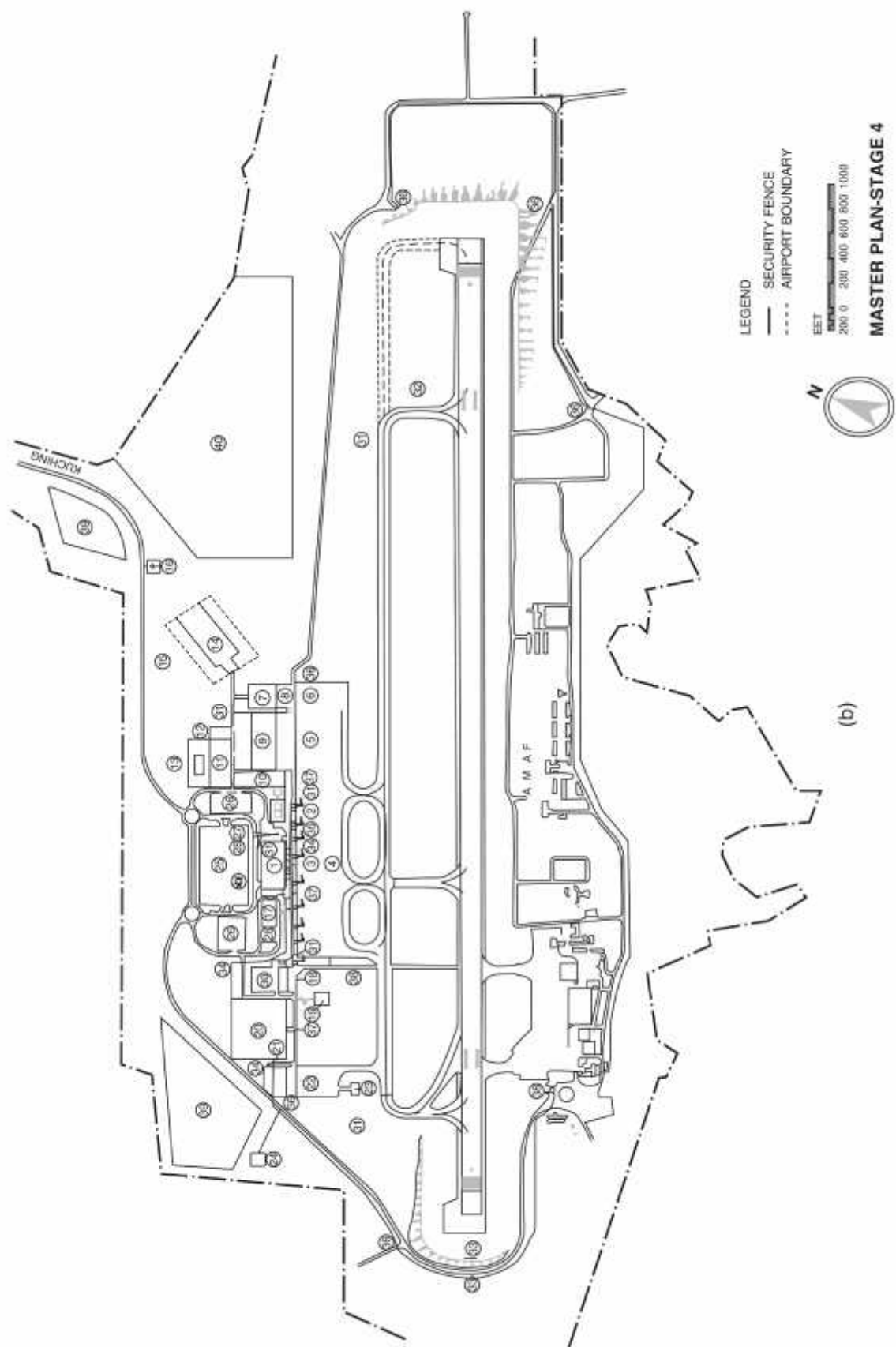
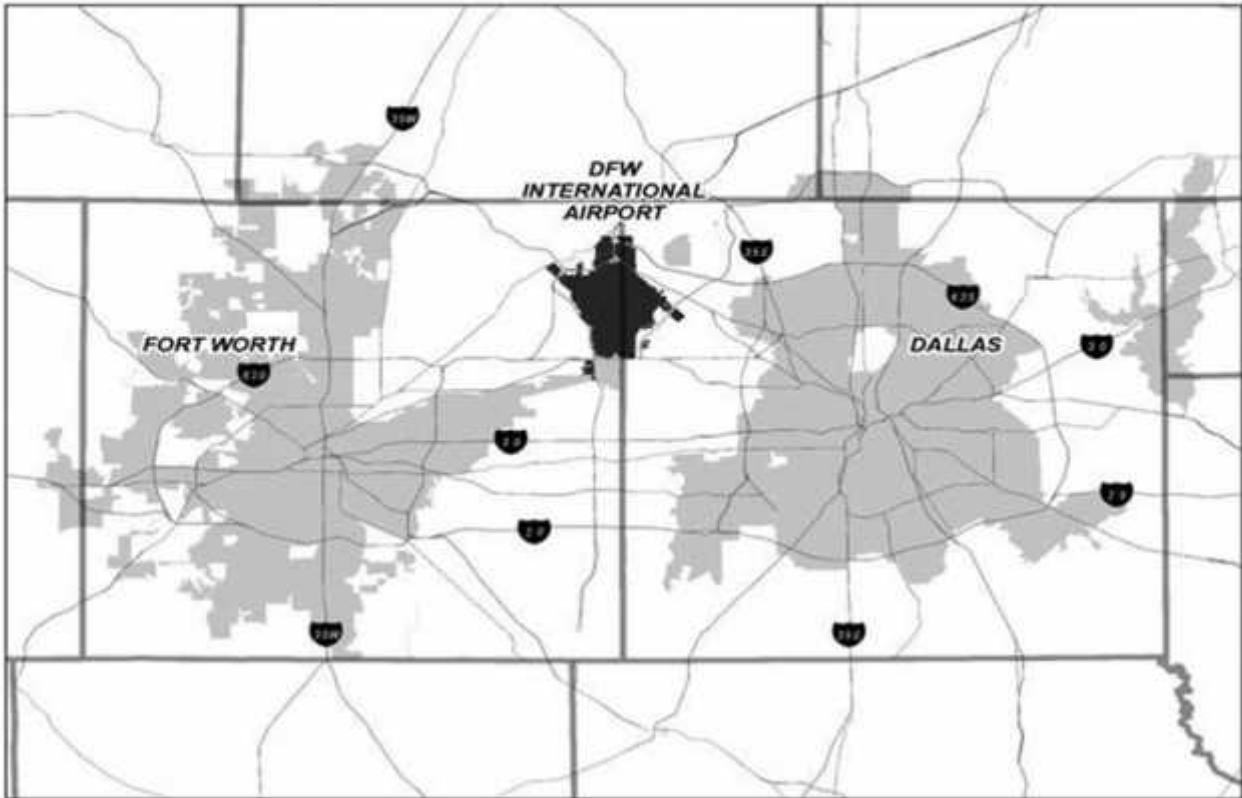


Figure III.3(b) Kuching, Malaysia airport layout plan ultimate development.

Airport Location and Data Table



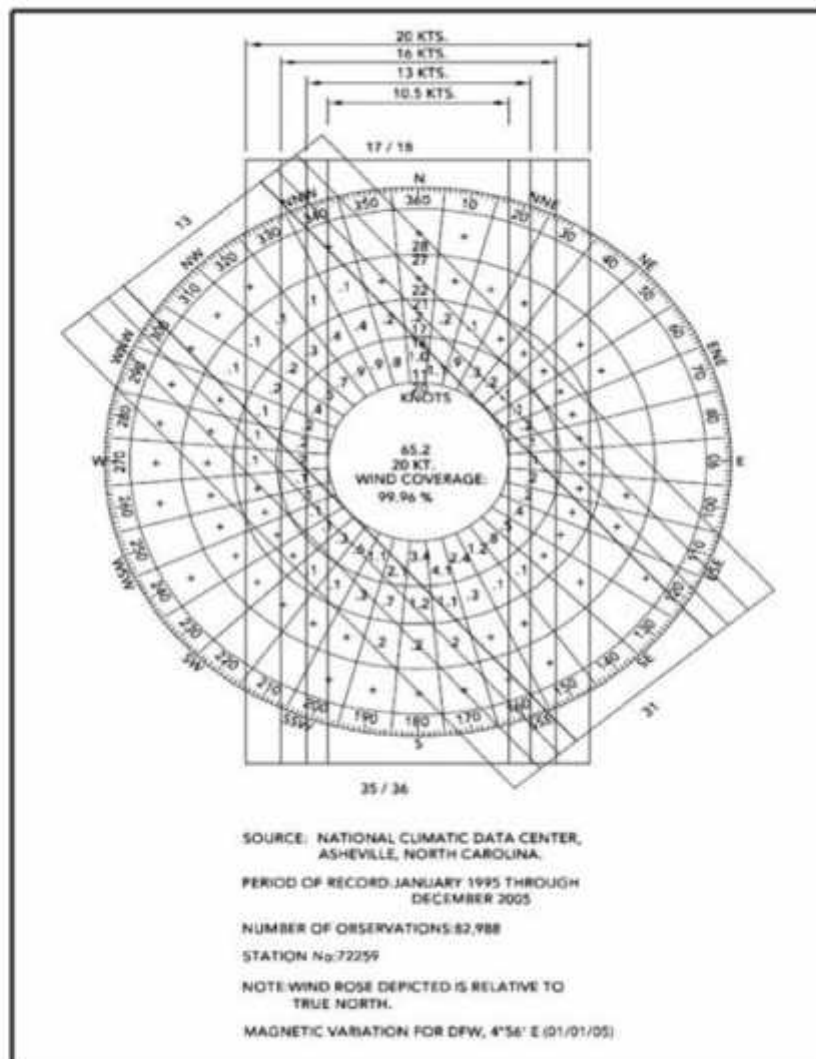
DESCRIPTION	EXISTING	ULTIMATE
AIRPORT ELEVATION (MSL_NAVD 88)	606.7'	637.5'
AIRPORT SERVICE LEVEL	COMMERCIAL SERVICE-PRIMARY	SAME
AIRPORT ROLE	LARGE HUB	SAME
- MEAN TEMPERATURE (F°)- HOTTEST MONTH	95°	95°
- TOTAL AIRPORT ACREAGE (2005)	18,092 AC.	18,201 AC.
AIRPORT REFERENCE CODE	D / E-VI	D / E-VI
AIRPLANE APPROACH CATEGORY	D / E	D / E
AIRPLANE DESIGN GROUP	VI	VI
AIRPORT NAVIGATION AIDS	DVOR / DME	DVOR / DME
AIRPORT VISUAL AIDS	ROTATING BEACON	ROTATING BEACON
AIRPORT REFERENCE POINT (ARP):		
- LATITUDE	N 32° 53' 50.4511"	N 32° 53' 47.69807"
- LONGITUDE	W 097° 02' 15.68587"	W 097° 02' 21.64290"
- NORTHING (STATE PLANE NAD-83-HARN)	7,012,483.40248	7,012,239.16782
- NORTHING (STATE PLANE NAD-83-HARN)	2,417,298.15362	2,416,793.62764

(a)

Figure III.5(a) : Dallas Fort Worth International Airport / airport location map and airport data table.

ALL WEATHER WIND COVERAGE					
DALLAS / FORT WORTH INTERNATIONAL AIRPORT					
		RUNWAY CROSSWIND COMPONENT			
		10.5 KTS	13 KTS	16 KTS	20 KTS
COMBINED	13 - 35, 18 - 36, 13 - 31	98.53%	99.40%	99.84%	99.96%
BI-DIRECTIONAL	17 - 35, 18 - 36	95.12%	97.59%	99.23%	99.78%
	13 - 31	89.21%	95.04%	98.61%	99.74%
UNI-DIRECTIONAL	17 / 18	63.54%	64.66%	65.31%	65.47%
	35 / 36	36.31%	37.67%	38.66%	39.06%
	13	60.80%	64.70%	67.10%	67.90%
	31	33.14%	35.07%	36.26%	36.58%

NOTE: RUNWAYS 17-35 ARE PARALLEL TO 18-36.



(b)

Figure III.5(b) Dallas Fort Worth International Airport / all-weather wind coverage table and wind rose.

DFW Runway Data Table *

RUNWAY DATA ITEM	ITC	36C	36R (Future 36C)	13R	31L
* Airport Reference Code		D / E-V	D / E-V		D / E-V
* Critical Gear Configuration		Double Dual Tandem	Double Dual Tandem		Double Dual Tandem
* Runway Ends Coordinates:					
- Latitude (NAD 83)	N 32° 54' 56.548"	N 32° 52' 43.962"	N 32° 52' 44.298"	N 32° 54' 34.472"	N 32° 53' 24.970"
- Longitude (NAD 83)	W 97° 01' 33.494"	W 97° 01' 34.218"	W 97° 03' 03.344"	W 97° 04' 59.278"	W 97° 03' 47.794"
* Runway Orientation:					
- True Azimuth	180° 13' 29.113"		180° 14' 58.435"		139° 03' 10.519"
- Grid Azimuth	179° 27' 15.177"		179° 27' 33.112"		138° 16' 29.116"
* Runway Length & Width (Feet)					
* Runway Declared Distances:					
- Takeoff Run Available (TORA)	13,400'	13,400'	15,200'	15,200'	9,301' x 150'
- Takeoff Distance Available (TODA)	13,400'	13,400'	15,200'	15,200'	9,301'
- Accelerate - Stop Distance Available (ASDA)	13,400'	13,400'	15,200'	15,200'	9,301'
- Landing Distance Available	13,400'	13,400'	15,200'	15,200'	9,301'
* Runway Pavement Type	CONCRETE	CONCRETE	CONCRETE	CONCRETE	CONCRETE
* Runway Pavement Strength	1,000,000 lbs. (PCNS2-RBXT)	1,000,000 lbs. (PCNS2-RBXT)	1,000,000 lbs. (PCNS2-RBXT)	1,000,000 lbs. (PCNS2-RBXT)	1,000,000 lbs. (PCNS2-RBXT)
* Runway Lighting	HIRL, RCL	HIRL, RCL	HIRL, RCL	HIRL, RCL	HIRL, RCL
* Runway Marking	PRECISION	PRECISION	PRECISION	PRECISION	PRECISION
* Runway Approach Data					
- Visibility Minimum	Category III	Category III	Category I	Category I	Category I-LPV
- Approach Lighting	ALSF2, TDZ, PAPI 4	ALSF2, TDZ, PAPI 4	MALS, TDZ, PAPI 4	MALS, TDZ, PAPI 4	MALS, TDZ, PAPI 4
- Approach NAVAIDS	LOC, GS, RVR	LOC, GS, RVR	LOC, GS, RVR	LOC, GS, RVR	LOC, GS, RVR
* Runway Effective Gradient (%)	0.0%	0.0%	-0.2%	-0.15%	0.15%
* Runway Elevation Data (AMSL/NAVD 85)					
- Runway End	561.91	562.20	572.34'	590.90'	577.10'
- Touchdown Zone	562.02	562.20	588.63'	590.90'	581.62'
* Runway Blast Pad (Length x Width)	400' x 220'	300' x 150'	400' x 280'	400' x 220'	400' x 220'
* Runway Shoulder	36' (Asphalt)	25' (Asphalt)	35' (Asphalt)		
* Runway Object Free Area (OFA)					
- Length Beyond Stop End	1,000'	1,000'	1,000'	1,000'	1,000'
- Width	800'	800'	800'	800'	800'
* Runway Safety Area (RSA)					
- Length Beyond Stop End	1,000'	1,000'	1,000'	1,000'	1,000'
- Width	500'	500'	500'	500'	500'
* Runway Obstacle Free Zone (OFZ)					
- Length Beyond Stop End	200'	200'	200'	200'	200'
- Width	400'	400'	400'	400'	400'
* Precision Obstacle Free Zone (POFZ)	200' L x 800' W CLEAR	200' L x 800' W CLEAR	200' L x 800' W CLEAR	200' L x 800' W CLEAR	200' L x 800' W CLEAR
* Hold Position Sign/Markings from CL	287'	287'	280'	280'	280'
* Displaced Runway Threshold Details	N / A	N / A	N / A	N / A	N / A
* Runway Protection Zone (RPZ)					
- Inner Width	1,000'	1,000'	1,000'	1,000'	1,000'
- Outer Width	1,750'	1,750'	1,750'	1,750'	1,750'
- Length	2,500'	2,500'	2,500'	2,500'	2,500'

* Represents existing runway orientations, excluding future runway orientations

(c)

Figure III.5(c) Dallas Fort Worth International Airport / airport runway tables.

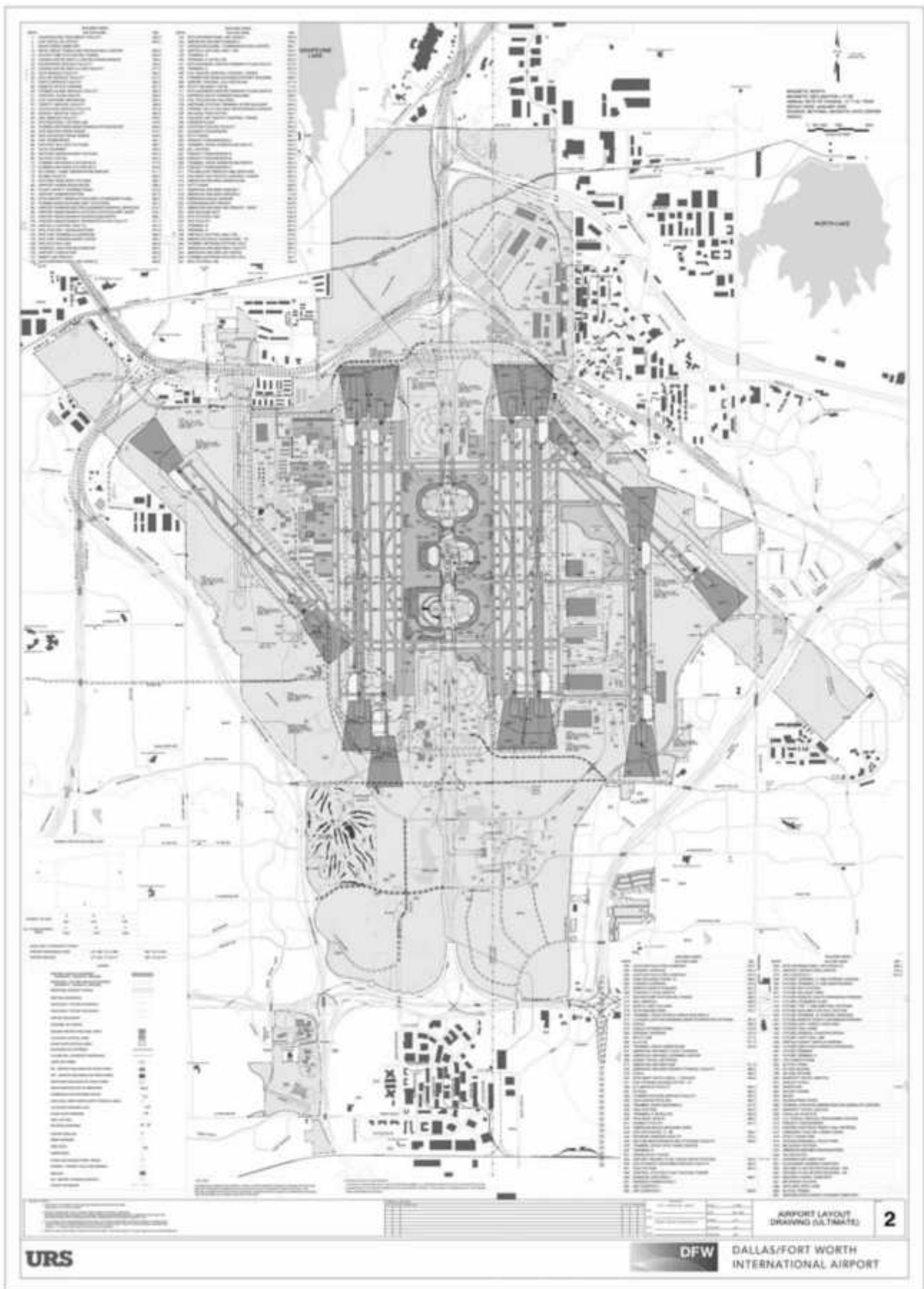


Figure III.5(d) Dallas Fort Worth International Airport ultimate airport layout plan.

CHAPTER IV

Airport Capacity and Delay / Case Studies

Introduction

The efficient movement of aircraft and passengers between airports is highly dependent on two key characteristics of an airport's operations: the demand for service by aircraft operators and passengers and the capacity at the airport, both in airspace and local environment. A major concern of airport planning and management is the adequacy of an airport's airfield, specifically in relation to the layout of the airport's runways, to handle the anticipated demand of aircraft operations. If air traffic demand exceeds airport or airspace capacity, delays will occur, causing expense to air carriers, inconvenience to passengers, and increased workload for the air traffic control system as well as airport employees and administrators.

At most airports in the United States, particularly those commercial service and general aviation airports serving smaller communities, the demand for service does not consistently exceed capacity. The Federal Aviation Administration estimates that airports with single runways have the capacity to serve approximately 200,000 operations annually, a demand level typically generated by metropolitan areas with approximately 350,000 inhabitants. Other airports, particularly those primary commercial service airports serving large metropolitan areas with populations exceeding 5,000,000 inhabitants, experience consistent periods of time where demand exceeds capacity, despite the fact that two or more such airports serve the area. Examples of these metropolitan areas include Chicago, Los Angeles, South Florida, the San Francisco Bay Area, Washington, D.C., and New York City.

Throughout the late 1990s and the first 20 months of the twenty-first century, the overall increase in demand for air transportation in the United States resulted in a growing number of airports that suffered from delays resulting from demand exceeding capacity. Within the entire system, over 550,000 air carrier operations suffered from at least 15 minutes of delay each during the year 2000, the year of greatest delays in the history of commercial aviation. The events of September 11, 2001, resulted in significant reductions in the overall demand for air travel for the year, which in turn resulted in fewer flight delays. It is projected, however, that the demand for air travel will rebound, reaching year 2000 levels by 2004, and continue to grow in the years beyond. With such growth, associated flight delays will increase as well, unless the capacity of the nation's airports and airspace system increases to accommodate the demand (Fig. IV-1).

There are a number of potential specific reasons for any given aircraft to experience delay. The most common factors that might cause an aircraft to experience delay are weather, aircraft mechanical issues, or simply operating at a time when overall demand for operations exceeds capacity. The FAA estimates that the majority of flight delays occur because of adverse weather. Other delays are attributed to equipment, runway closures, and excessive volume or demand (Fig. IV-2).

The task of managing airports in particular, and the aviation system in general, with the goal of minimizing delays, either by providing sufficient capacity to handle demand, or managing the demand itself, is a challenging one. To effectively achieve this task, a fundamental understanding of capacity, demand, and associated delays is needed.

IV.1 Defining capacity

Capacity, in general, is defined as the practical maximum number of operations that a system can serve within a given period of time. Capacity is, in fact, a rate, similar to velocity. An automobile for example, might travel at a rate of 50 miles per hour, meaning that over an hour, traveling at this rate, the automobile will travel 50 miles. Traveling this rate for 30 minutes, the automobile will travel 25 miles, and so forth. Airport capacity is measured in aircraft operations per hour. A single runway at an airport, might have an operating capacity of 60 operations per hour, meaning, over the course of an hour, the airport will be able to serve approximately 60 aircraft takeoffs and landings; in 30 minutes, the airport can serve 30 such operations, and so forth.

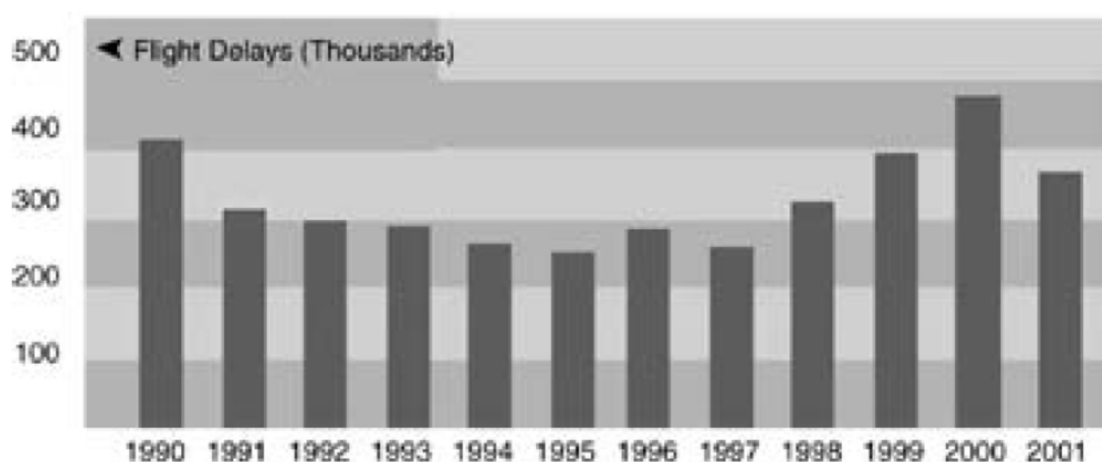


Figure IV-1. Number of flights experiencing greater than 15 minutes of delay, annually

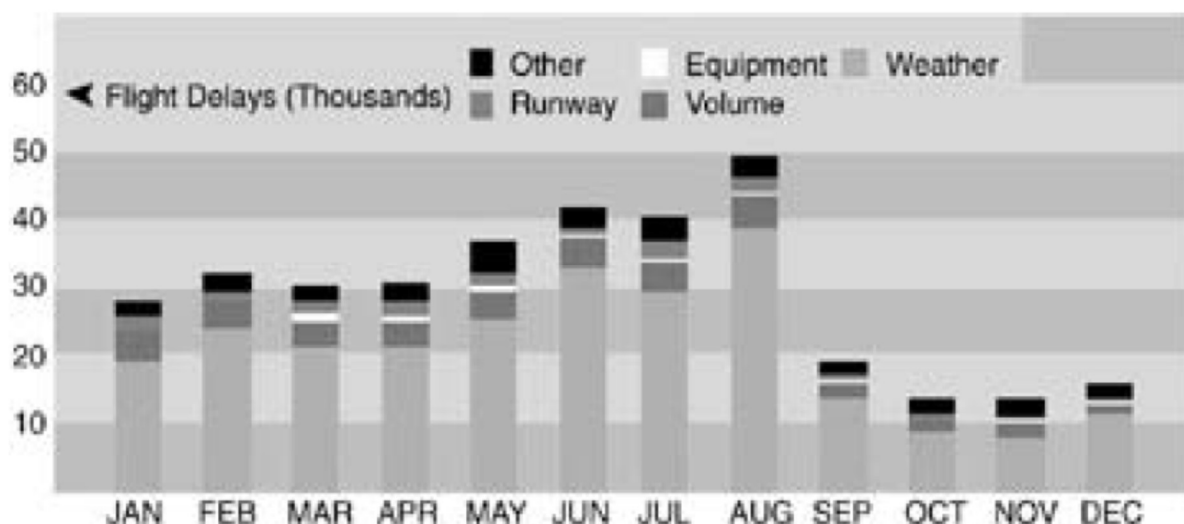


Figure IV-2. Causes of flight delays by month, year 2001.

It should be noted that although airport capacity typically refers to the capacity to handle aircraft operations, there are other areas of operation at an airport where other measures of capacity are equally important. For example, the efficient movement of passengers through points within an airport terminal is determined, in part, by the passenger processing capacity of locations within the terminal, and the number of automobiles that can unload passengers at an airport's curb may be measured in terms of vehicle capacity. The theories that govern capacity and delay are similar regardless of location. With this in mind, however, the focus of airport capacity will heretofore feature airport capacity in its traditional definition, that of aircraft operating capacity.

There are actually two commonly used definitions to describe airport capacity: throughput capacity and practical capacity. **Throughput capacity** is defined as the ultimate rate at which aircraft operations may be handled without regard to any small delays that might occur as a result of imperfections in operations or small random events that might occur. Throughput capacity, for example, does not take into account the small probability that an aircraft will take longer than necessary to take off, or a runway must close for a very short period of time because of the presence of small debris. Throughput capacity is truly the theoretical definition of capacity and is the basis for airport capacity planning.

Practical capacity is understood as the number of operations that may be accommodated over time with no more than a nominal amount of delay, usually expressed in terms of maximum acceptable average delay. Such minimal delays may be a result of two aircraft scheduled to operate at the same time, despite the fact that only one runway is available for use, or because an aircraft must wait a short time to allow ground vehicles to cross. The FAA defines two measures of practical capacity to evaluate the efficiency of airport operations. **Practical hourly capacity (PHOCAP)** and **Practical annual capacity (PANCAP)** are defined by the FAA as the number of operations that may be handled at an airport that results in not more than 4 minutes average delay during the busiest, known as the peak, 2-hour operating period, hourly and annually, respectively.

IV.2 Factors affecting Capacity and capacity estimation

IV.2.a Factors affecting capacity and delay

The capacity of an airfield is not constant. Capacity varies considerably based on a number of considerations, including the utilization of runways, the type of aircraft operating, known as the fleet mix, the percentage of takeoff and landing operations being performed, ambient climatic conditions, and FAA regulations which prescribe the use of runways based on these considerations. When a specific number is given for airfield capacity at an airport, it is usually an average number based either on some assumed range of conditions or on one specific set of conditions.

An understanding of the variability of capacity, rather than its average value, however, is crucial to the effective management of an airfield. Much of the strategy for successful management of an airfield involves devising ways to compensate for a number of factors that, individually or in combination, act to reduce capacity or induce delays.

The physical characteristics and layout of runways, taxiways, and aprons, for example, are basic determinants of the ability to accommodate various types of aircraft and the rate at which they can be handled. Also important is the type of equipment, particularly the presence of instrument landing systems, installed on the airfield as a whole or on a particular segment.

One of the characteristics that affects an airport's capacity is the configuration of its runway system. Although every airport is different, the configurations of airport runways may be placed in the following categories: single runway, parallel runways, open-V runways, and intersecting runways. Although every runway configuration has a uniquely different capacity that is determined by a variety of factors, the FAA has established some basic estimates of capacity by runway configuration.

The single runway, for example, the simplest of runway configurations, can accommodate up to 99 operations per hour for smaller aircraft and approximately 60 operations per hour for larger commercial service aircraft during fair weather conditions, known as visual meteorological conditions (VMC), or operating under visual flight rules (VFR). Under poor weather conditions, known as instrument meteorological conditions (IMC), when aircraft fly according to instrument flight rules (IFR), the capacity of a single runway configuration is reduced to between 42 and 53 operations per hour, depending primarily on the size of the aircraft using the runway and any navigational aids that may be available.

In general, airport capacity is usually greatest in VMC, whereas IMC, in the form of fog, low cloud ceilings, or heavy precipitation, tends to result in reduced capacity. In addition, strong winds or significant accumulations of snow or ice on a runway can significantly reduce capacity or close an airport to aircraft operations altogether. Even a common occurrence such as a wind shift can reduce operating capacity while air traffic is appropriately rerouted.

The parallel runway configuration, characterized by two or more runways aligned parallel to each other, increases runway capacity at an airport over single runway configurations depending primarily on the distances between the parallel runways, specifically their lateral separation, defined as distance between the centerlines of each runway. Parallel runway configurations are typically found at airports that require increased levels of runway capacity but do not require any crosswind runways.

For two parallel runways separated by at least 4,300 feet, total runway capacity is double that of the capacity of a single runway. However, if the lateral separation is less than 4,300 feet, then under IFR operations, operations on each runway must be highly coordinated, effectively reducing capacity. If the parallel runways are separated by less than 2,500 feet, the airfield must operate as a single runway configuration under IFR (Fig. IV-3).

The open-V runway configuration describes two runways that are not aligned in parallel with each other, yet do not intersect each other at any point on the airfield. The runway oriented into the prevailing winds is known as the primary runway. The other runway is identified as the crosswind runway. During low wind conditions, both runways may be used simultaneously. When aircraft operate outwardly from the V, the runway configuration is said to be used for diverging operations. Typically, takeoffs are allowed simultaneously during divergent operations. When the runway configuration is used in a converging manner, landings tend to be handled simultaneously.

Runway capacity is typically greater when operations are performed under divergent operations. Under divergent operations total runway capacity can reach nearly 200 operations per hour for smaller aircraft and 100 operations per hour for commercial service aircraft. Under convergent operations, capacity rarely exceeds 100 operations per hour for smaller aircraft and frequently less than 85 operations per hour for commercial service aircraft. When winds are sufficiently strong or when IFR operations are in effect, only one runway in the open-V configuration is typically used, reducing capacity to that of a single runway configuration (Fig. IV-4).

The intersecting runway configuration describes two runways that are not aligned in parallel with each other and intersect each other at some point on the airfield. As with open-V runways, the runway oriented into the prevailing winds is known as the primary runway. The intersecting runway is identified as the

crosswind runway. During low wind conditions and operating under VFR, both runways may be used simultaneously, yet in a highly coordinated manner, so as to avoid any incursions between two aircraft (Fig. IV-5).

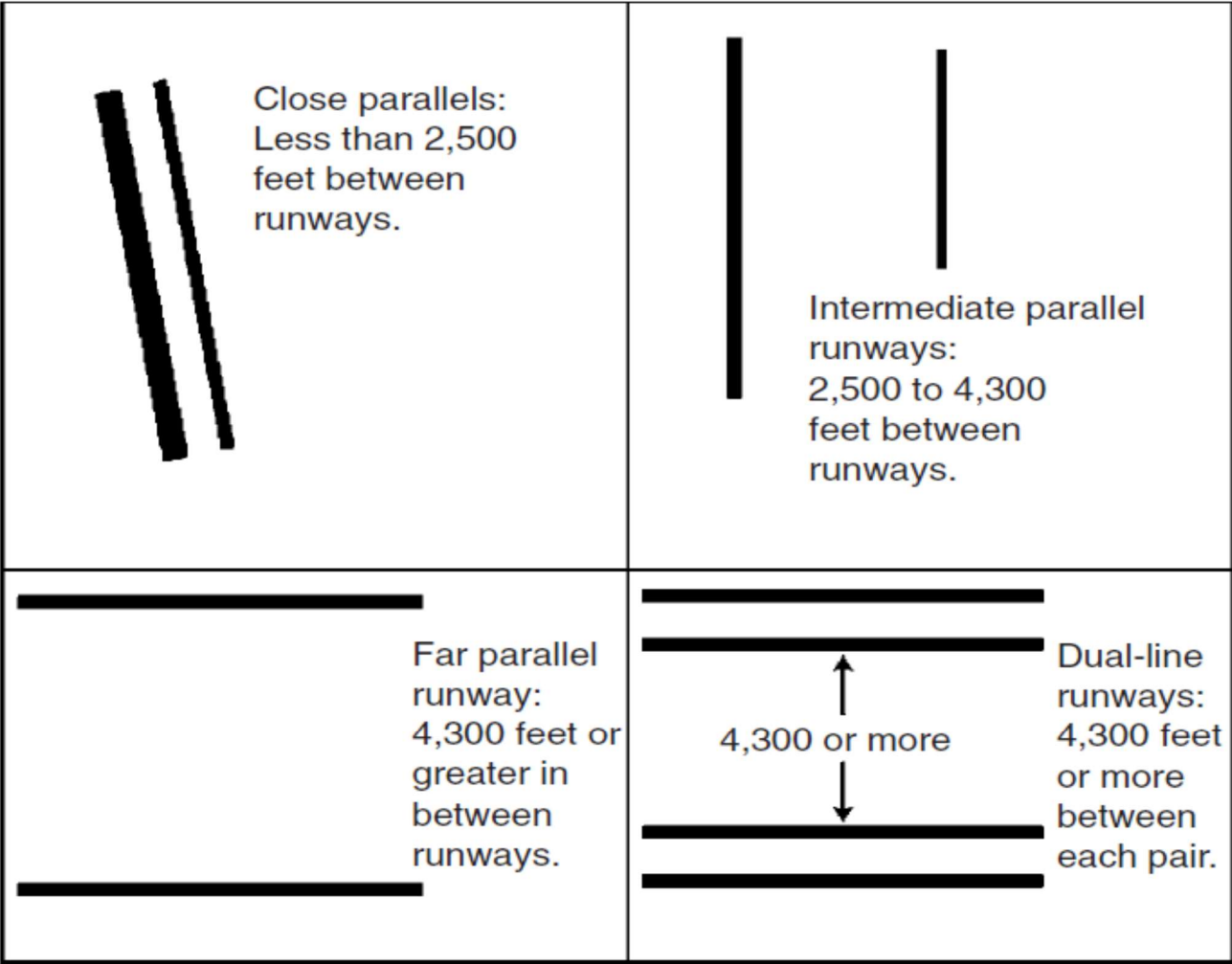


Figure IV-3. Parallel runway configurations.

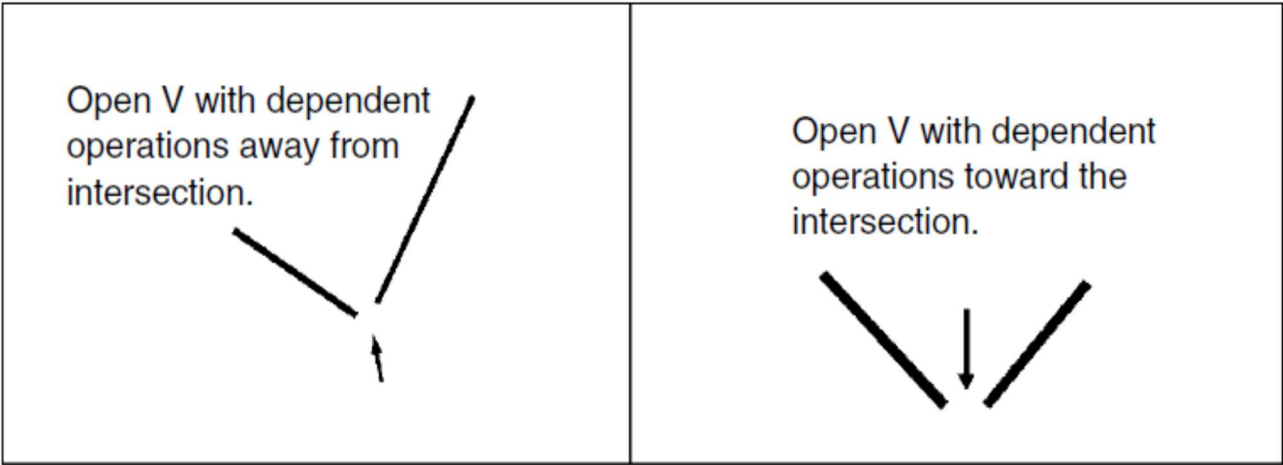


Figure 12-4. Open-V runway configurations.

Under certain specific conditions, aircraft may land simultaneously and independently on intersecting runways. These operations, known as **LAHSO (land and hold short operations)**, may be conducted with approval from the FAA and only when there is sufficient runway length on each runway before the intersection of the two runways for each aircraft to land and stop before reaching the intersection (Fig. IV-6).

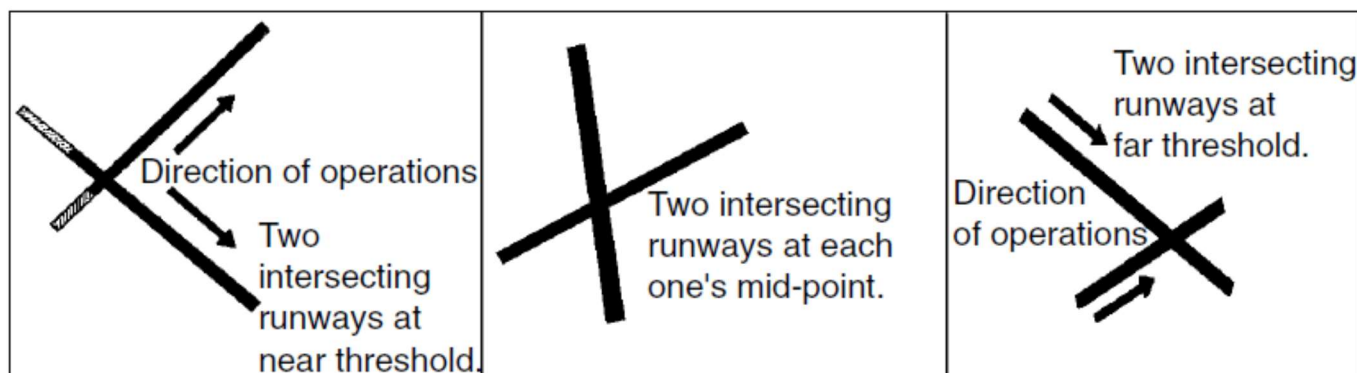


Figure IV-5. *Intersecting runway configurations.*

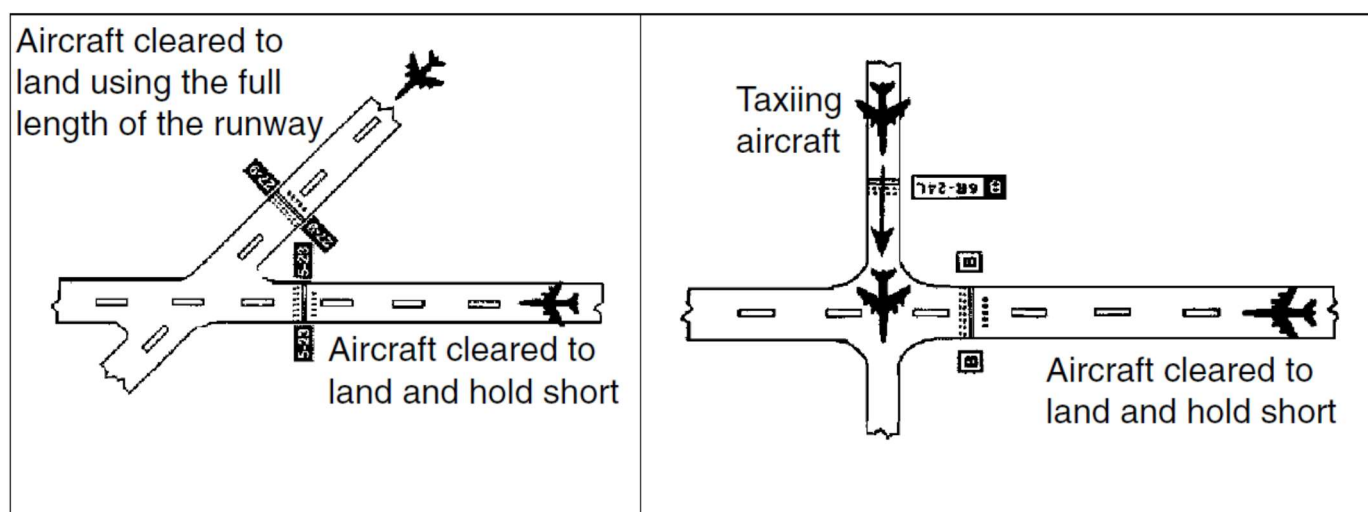


Figure IV-6. LAHSO (land and hold short operations) on intersecting runways.

LAHSO is one example of a spectrum of rules and procedures employed by air traffic control, intended primarily to ensure safety of flight that fundamentally determines airport capacity. Other such rules governing, for example, the speeds of aircraft, separations between aircraft, runway occupancy, and prescribed routes to be followed by aircraft on departure from, approach to, and enroute between airports all have an effect on the capacity of an individual airport.

Another significant factor in determining airport capacity is the consideration of the volume of demand and characteristics of the aircraft that wish to use the airport during any given period of time. For any given level of demand, the varying types of aircraft with respect to speed, size, flight characteristics, and even pilot proficiency will in part determine the rate at which they can perform operations. In addition, the distribution of arrivals and departures to the extent to which they are bunched rather than uniformly

spaced, as well as the sequence of such operations, also play a part in determining an airport's operating capacity. In part, the tendency of traffic to peak in volume at certain times is a function of the flight schedules of commercial air carriers using an airport. For example, at airports that serve as hubs for major air carriers, high volumes of aircraft all arrive in banks and all depart a short time later, after passengers have transferred from one flight to another to complete their travel. Arrival banks of aircraft result in one level of airport capacity, whereas departure banks result in another level of capacity, merely by the different operating characteristics of aircraft arrivals and departures.

IV.2.b Estimating capacity

The art of estimating the capacity of an airfield is a challenging one. Significant investments are made on the part of airport management to estimate as accurately as possible the capacity of an airfield under varying conditions and operating characteristics. However, if the basic fundamentals of aircraft operations are understood, initial estimates of runway capacity may be established with little effort.

The FAA categorizes the wide variety of aircraft types by their maximum certified takeoff weights (MTOW). Aircraft with MTOW less than 41,000 pounds are considered category A/B or small aircraft, aircraft with MTOW between 41,000 and 255,000 pounds are considered category C or large aircraft, and aircraft with MTOW greater than 255,000 pounds are considered category D or heavy aircraft (see Table IV-1). For the purposes of estimating runway capacity, an airport's fleet mix is defined by the percentage of small, large, and heavy aircraft that perform takeoff and/or landing operations over a given period of time on the runway.

Aircraft Fleet Mix Category	Maximum Takeoff Weight
A, B (small)	<41,000 lb
C (large)	41,000–255,000 lb
D (heavy)	>255,000 lb

Table IV-1 Aircraft Fleet Mix Categories

The capacity of a runway handling only takeoffs, known as **departure capacity**, is a function of two basic operating characteristics. One of these characteristics is a function of the type of aircraft taking off on the runway. The amount of time the aircraft requires to start from an initial position at the beginning of the runway to the time it in fact leaves the runway environment allowing another aircraft to depart is called an aircraft's **runway occupancy time (ROT)**. The shorter an aircraft's ROT, the greater the number of aircraft that can use the runway over time, and hence the greater the capacity of the runway. ROT of a given aircraft is a function of the performance specifications of the aircraft. In general, smaller and lighter aircraft (fleet mix categories A and B) tend to require smaller ROT for takeoff than larger or heavier aircraft (fleet mix categories C and D). As a result, the operating capacity of a given runway is higher when accommodating smaller aircraft departures than it is when accommodating departures of larger aircraft. ROTs for departing aircraft range from approximately 30 seconds for small aircraft to

approximately 60 seconds for larger and heavier aircraft. Witnessing a runway operating at departure capacity is clear. When a runway is constantly occupied by departing aircraft, that is, the runway is never empty or idle, the runway is operating at capacity.

The capacity of a runway handling only landings, known as arrival capacity, is similarly a function of the ROT of arriving aircraft. In addition, the velocity at which the aircraft travels while on approach to the runway (known as an aircraft's approach speed), as well as FAA regulations requiring that aircraft remain at least a given distance behind one another while on approach to landing (known as longitudinal separation), are determining factors in arrival capacity. In general, smaller and lighter aircraft tend to travel at lower approach speeds than larger and heavier aircraft. However, larger aircraft create the need for greater longitudinal separations. As a result of these characteristics, estimating arrival capacity becomes a nontrivial analysis of the various types of aircraft, known as the fleet mix, that wish to land over a given period of time. An airport's fleet mix is defined as the percentage of aircraft operations by aircraft type that occurs at the airport over a given period of time.

When two aircraft are on approach to a runway, the longitudinal separation required between the two aircraft is determined by the weight categories of the aircraft in front, known as the lead aircraft, and the aircraft following, known as the lag aircraft. Table IV-2 illustrates the FAA's required longitudinal separations, in nautical miles. As long as both aircraft are airborne on approach, these longitudinal separations must be maintained. The only exception to this rule is when operating under visual flight rules (VFR), small aircraft are required to maintain sufficient separation so that the lag aircraft does not touch down on the runway before the lead aircraft has landed and cleared the runway. In most airport environments, especially those airports with an operating air traffic control tower and those airports serving commercial air carriers, the longitudinal separation standards given in Table IV-2 are maintained. The primary reason for these standards is to prevent lag aircraft from experiencing severe wake turbulence as a result of very rough airflow emanating from the lead aircraft's wings.

Lead/Lag	Small	Large	Heavy
Small	3	3	3
Large	4	3	3
Heavy	6	5	4

Table IV-2 Required Longitudinal Separations for Arriving Aircraft to a Single Runway When Performing under IFR (Distances in Nautical Miles)

As implied in Table IV-2, the arrival capacity of a runway can be significantly affected by the airport's fleet mix. In general, the more distributed the mix, that is, the more variability in aircraft sizes, the lower the arrival capacity. As a result, airports with multiple runways often attempt to separate the arrivals of aircraft by size onto separate runways.

Contrary to that of departure capacity, witnessing the arrival capacity of a runway is not as visually intuitive. Even though a runway is operating at its arrival capacity, there are often periods of time when the runway itself is empty of aircraft. This is due to the fact that the required longitudinal separation of aircraft, which results in the lead aircraft often landing and exiting the runway prior to the lag aircraft touching down, prevents arriving aircraft from reaching the runway any sooner.

The capacity of a runway handling both landings and takeoffs is called the runway's mixed-use operating capacity. In general, a runway's mixed-use operating capacity is determined first by estimating arrival capacity, and then, taking advantage of the times that the runway is idle because of longitudinal separation requirements, allowing departures to occur.

IV.3 Illustrating capacity with a time-space diagram

Accurately estimating the capacity of a runway is a challenge, particularly when considering all the variations in aircraft and pilot performance, external conditions, and regulatory policies. However, to find basic estimates of runway capacity, a fundamental graphical analysis using what is known as a **timespace diagram** may be used.

A time-space diagram is a two-dimensional graph which may be used to represent the location of any particular object, such as an arriving or departing aircraft, at a given point in time. With a time-space diagram, visual representations of aircraft movements, based on performance characteristics and FAA regulations may be made.

For example, to illustrate the movement of departing aircraft on a runway, the time-space diagram illustrated in Fig. IV-7 may be used. Figure IV-7 represents the departure of aircraft along a runway. Each aircraft has a 60-second ROT. The diagram illustrates the fact that only one aircraft may be present on the runway at any given period of time. The trajectory of each aircraft is represented by a curve, which represents the aircraft's increase in velocity until it reaches takeoff speed. From the diagram, it can easily be seen that the departure capacity of the runway is one departure per minute, or 60 departures per hour.

Figure IV-8 illustrates the arrival capacity of a runway being used by small arriving aircraft under IFR conditions. Each aircraft has a velocity, known as the approach speed, of 60 nautical miles per hour and requires a 30-second runway occupancy time upon landing. In addition there is a required longitudinal separation of 3 nautical miles between lead and lag aircraft. From this diagram, it is realized that aircraft arrive to the runway at the rate of one landing every 3 minutes, resulting in an arrival capacity of 20 landings per hour.

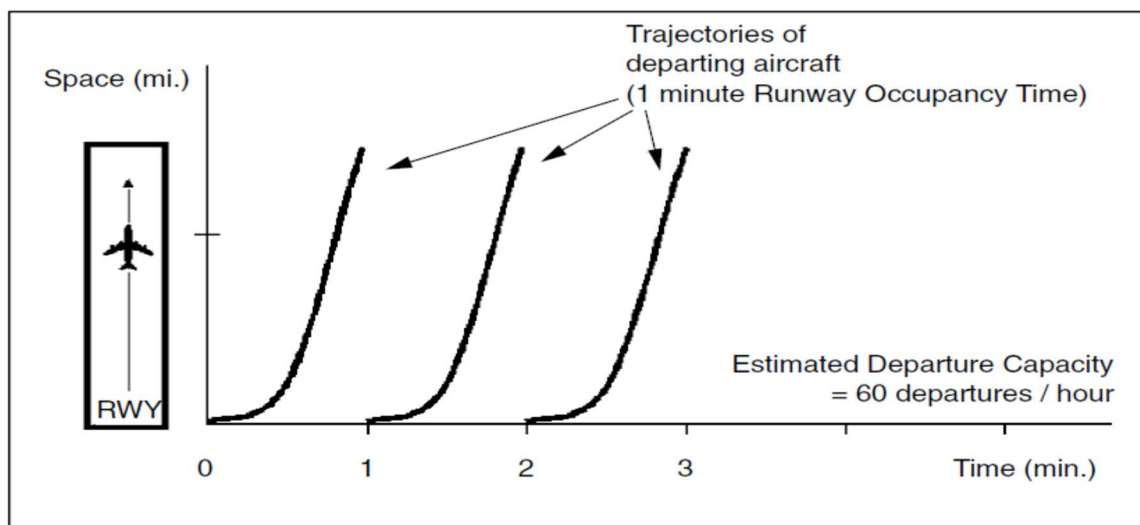


Figure IV-7. Time-space diagram illustrating departure capacity of a runway serving departing aircraft with a runway occupancy time of 1 minute.

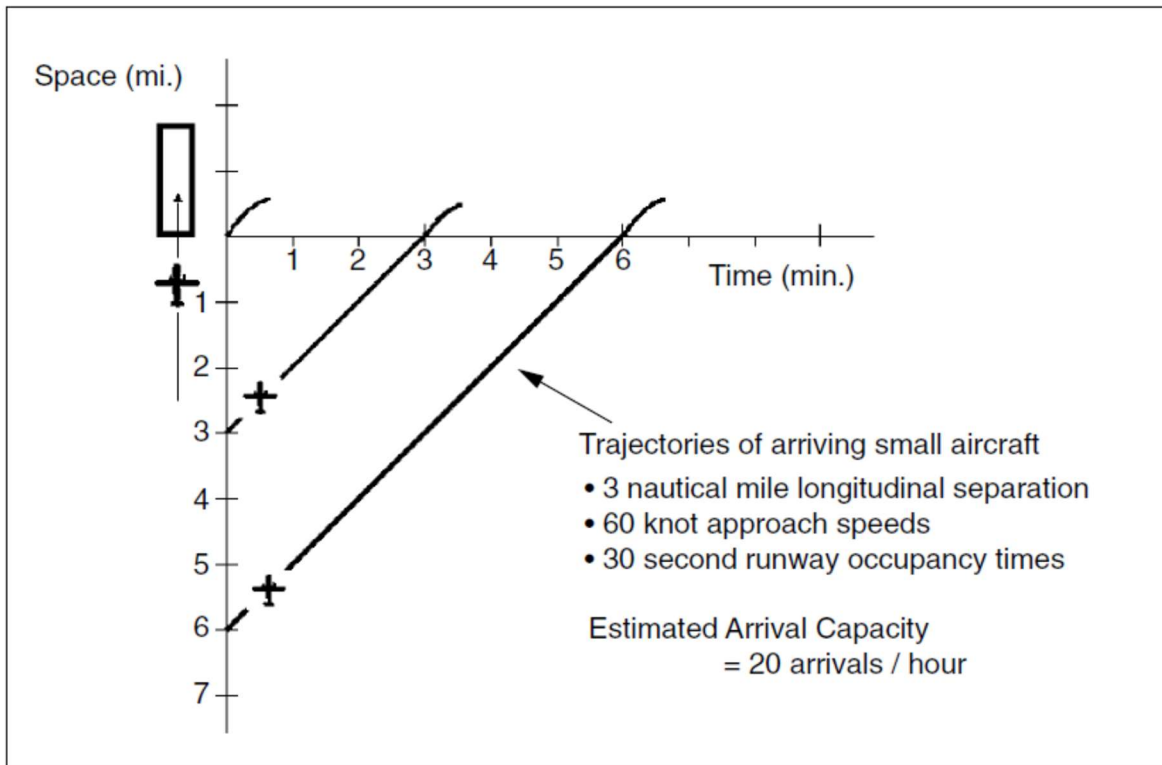


Figure IV-8. Time-space diagram illustrating departure capacity of a runway serving arriving small aircraft.

Figure IV-9 illustrates the mixed-use capacity of the runway. Departures are allowed to occur during idle runway times between landings. Because departures require 1-minute runway occupancy times, it is possible to allow two departures between landings, resulting in a mixed-use departure capacity of 40 departures per hour. When combined with the 20 arrivals per hour arrival capacity, this runway is estimated to have a mixed-use operating capacity of 60 operations per hour.

Applying the above simple analyses to aircraft with different performance characteristics reveals the interesting behavior of runway capacity. For example, the arrival capacity of large aircraft, which typically have approach speeds of approximately 90 nautical miles per hour and require longitudinal separations of 3 nautical miles between lead and lag aircraft, may be illustrated on a timespace diagram to yield a capacity of 30 arrivals per hour and a departure capacity of 30 departures per hour (Fig. IV-10).

In addition, a time-space diagram may be used to illustrate the degrading effects on capacity as a result of allowing aircraft of mixed sizes to use the same runway. As Fig. IV-11 illustrates, large longitudinal separation requirements for larger aircraft in front of smaller aircraft, along with the slower speeds of smaller arriving aircraft, result in significantly reduced arrival capacity.

One technique often used by air traffic controllers to increase capacity is to carefully sequence arriving aircraft to minimize the amount of time smaller aircraft are following larger aircraft. One example of sequenced arrivals may be illustrated in Fig. IV-12.

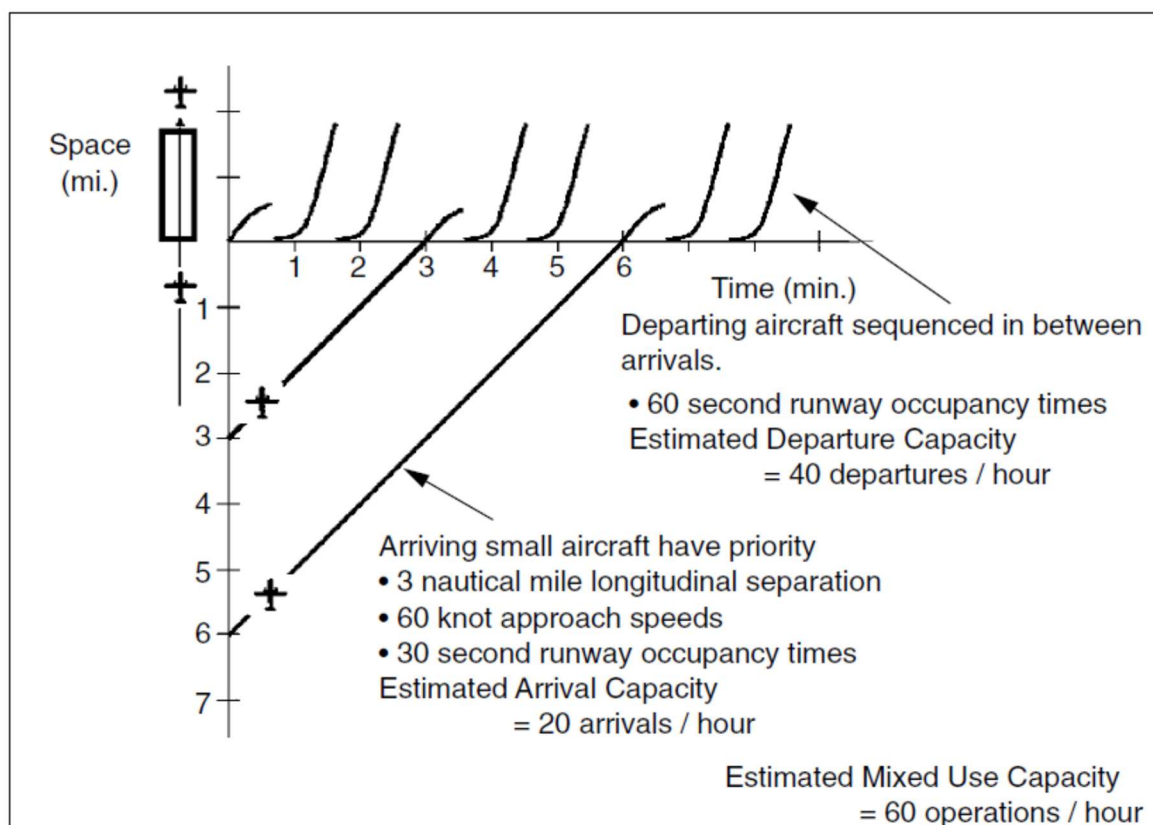


Figure IV-9. Time-space diagram illustrating mixed-use operating capacity of a runway serving arriving and departing small aircraft.

Even though the time-space diagram is an excellent tool for estimating runway capacity on the basis of fundamental principles, it quickly becomes cumbersome for multiple aircraft types, and particularly airfields with multiple runways. As such, other methods of estimating airfield capacity have been developed, ranging from very coarse approximations using charts and tables, to highly detailed complex estimations using computer simulation models.

IV.4 Approximation charts

Recognizing the need for fundamental approximations of runway capacity for the wide variety of runway configurations which in turn accommodate a wide variety of aircraft types under varying atmospheric conditions, the Federal Aviation Administration published Airport Advisory Circular AC 150/5060-6A Airport Capacity and Delay. Within this advisory circular are a series of charts that provide general approximations of hourly operating capacity under VFR and IFR flight rules, as well as an estimation of a typical annual operating capacity, known as ASV, or annual service volume. The charts are used by first selecting a runway configuration most similar to that of the airport whose capacity is being estimated. Second, a mix index is calculated, estimated by adding the percentage of large aircraft to the percentage of heavy aircraft multiplied by 3. The mathematical formula used to calculate mix index is $MI = C + 3D$. By applying the calculated mix index to the selected runway configuration, estimated VFR and IFR hourly capacities and ASV may be read from the chart.

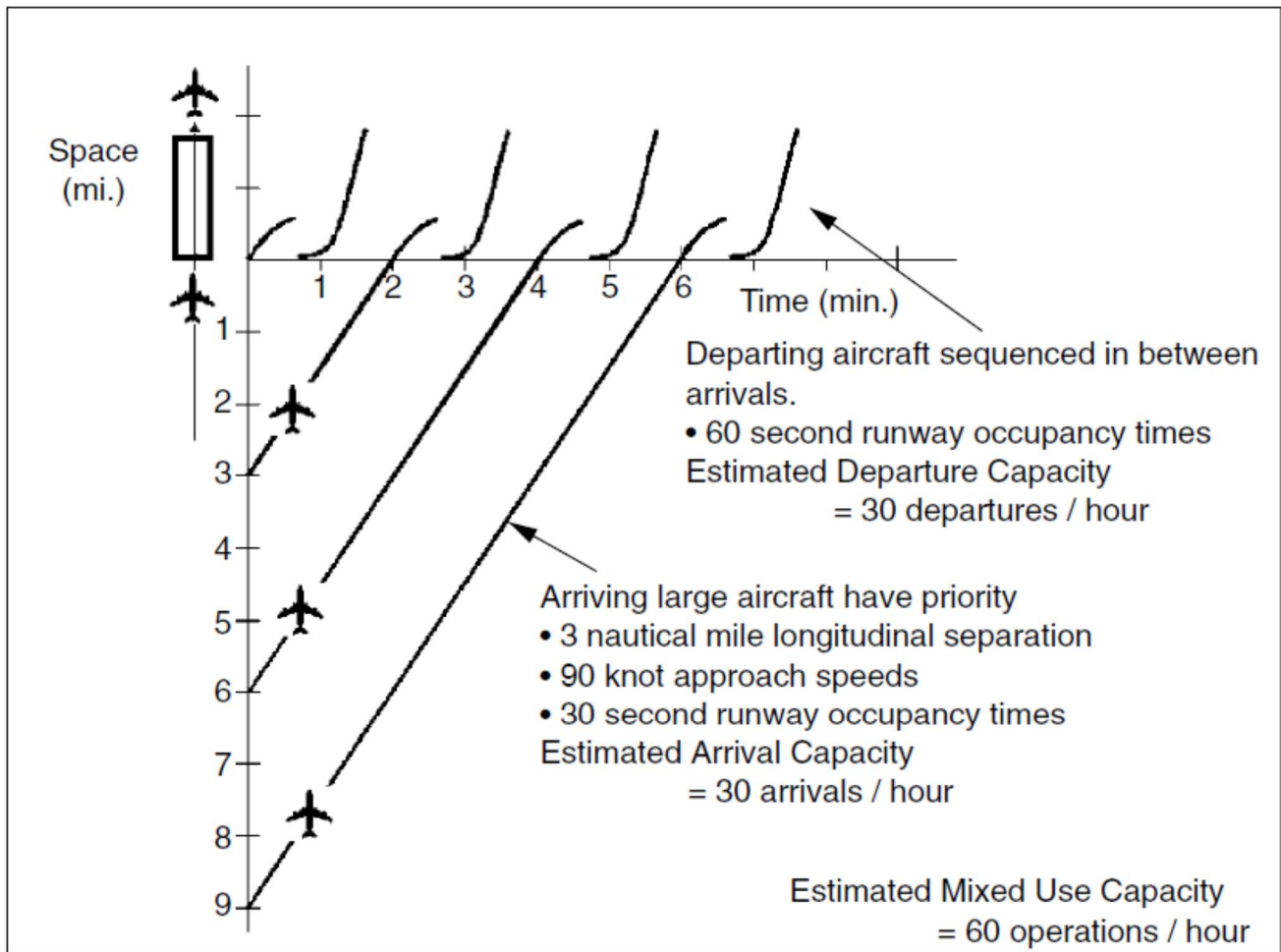


Figure IV-10. Time-space diagram illustrating mixed-use operating capacity of a runway serving arriving and departing large aircraft.

For example, consider an airport with a single runway and a fleet mix of 80 percent small aircraft, 18 percent large aircraft, and 2 percent heavy aircraft.

Such an airport is typical of a small general utility general aviation airport. The airfield configuration depicted in Fig. IV-1A which best represents this airport is configuration 1. The mix index of the airport is $18 + 3(2) = 24$. From reading the chart, it can be seen that the estimated hourly capacity of the airport is approximately 98 operations per hour under VFR, and 59 operations per hour under IFR (not coincidentally very close to the capacity estimated using a timespace diagram), and an annual service volume of approximately 230,000 operations per year.

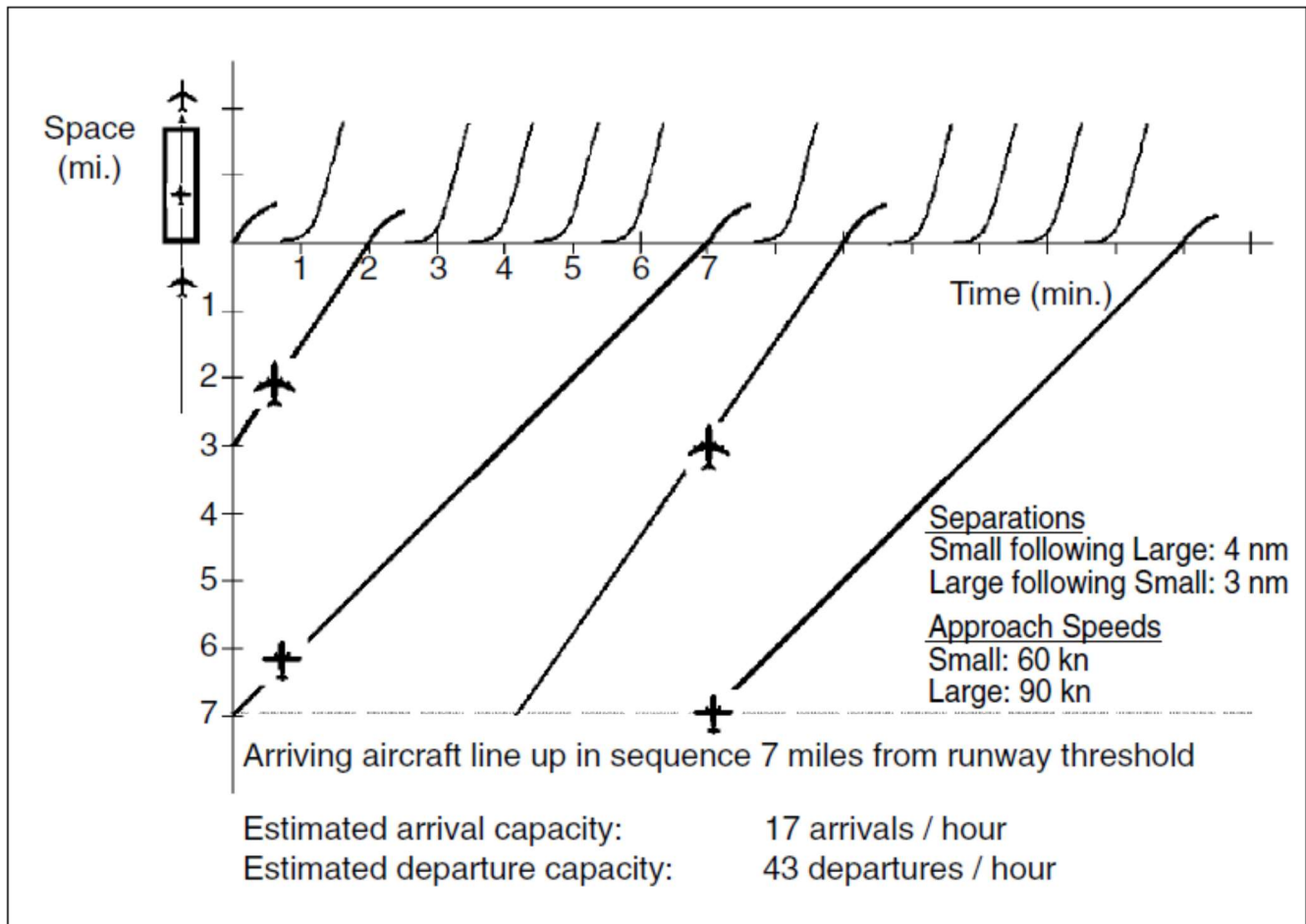


Figure IV-11. Time-space diagram illustrating mixed-use operating capacity of a runway serving arriving and departing large and small aircraft.

A large commercial airport with two sets of closely separated parallel runways, each set separated by at least 3,500 feet with a fleet mix of 5 percent small aircraft, 80 percent large aircraft, and 15 percent heavy aircraft, might be represented in Fig. IV-1B by configuration and a mix index of $80 + 3(15) = 125$, resulting in an hourly VFR capacity of 189 operations per hour, an hourly IFR capacity of 120 operations per hour, and an annual service volume of 675,000 operations per year.

IV.5 Simulation models

Although the charts described in Fig.A1 are appropriate for coarse approximations of airport capacity, they do not, in fact, provide the actual operating capacity that may be occurring at an airport at any given period of time. One of the few methods of estimating capacity, particularly as a function of a constantly changing airport environment, is computer simulation (Fig. IV-13).

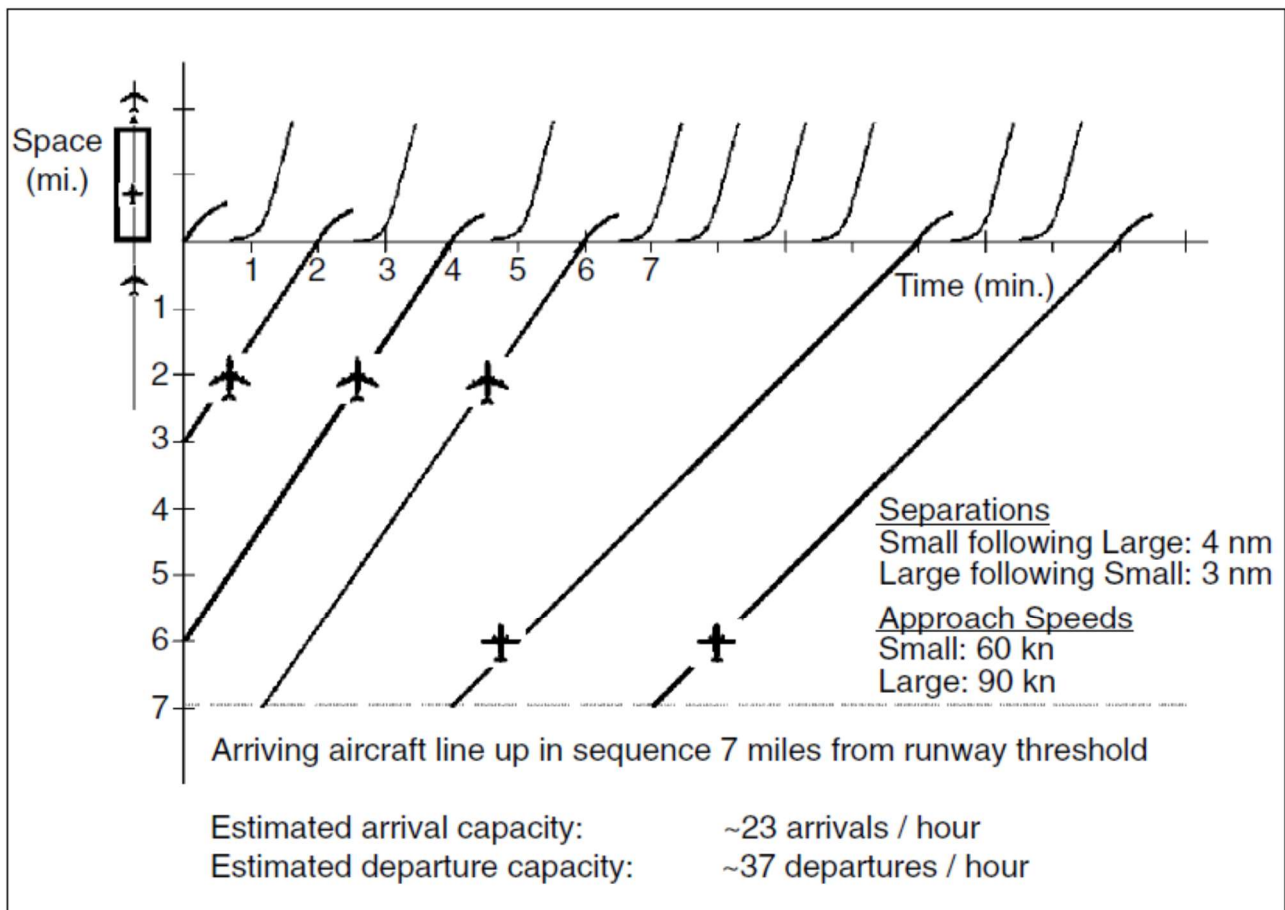


Figure IV-12. Time-space diagram illustrating mixed-use operating capacity of a runway serving arriving and departing large and small aircraft sequenced to maximize arrival capacity.

The Airport and Airspace Simulation Model (SIMMOD), is an industry standard analysis tool used by airport planners and operators, airlines, airspace designers, and air traffic control authorities for conducting high-fidelity simulations of current and proposed airport and airspace operations. SIMMOD is designed to “play out” airport and airspace operations on the computer and calculate the real-world consequences of potential operating conditions. It has the capability and flexibility to address a wide range of “what-if” questions related to airport and airspace capacity, delay, and efficiency, including questions associated with:

- Existing or proposed airport facilities (e.g., gates, taxiways, runways, pads).
- Airport operating alternatives (e.g., taxi patterns, runway use, departure queuing).
- Existing or proposed airspace structures (e.g., routes, procedures, sectors).
- Air traffic management/control technologies, procedures, and policies.
- Aircraft separation standards parameters (e.g., weather, aircraft type, flight state).
- Airline operations (e.g., flight schedule, banking, gate use, and service times).
- Current and future traffic demand (e.g., volume, aircraft mix, new aircraft types).

Based upon a user-input scenario, SIMMOD tracks the movement of individual aircraft through an airport/airspace system, detects potential violations of separations and operating procedures, and simulates air traffic control actions required to resolve potential conflicts. The model properly captures the interactions within and between airspace and airport operations, including interactions among multiple neighboring airports.

As SIMMOD simulates airport and airspace operations, it computes and records detailed information on the activities and events associated with the operation of each aircraft at the airport and within the airspace. These results are provided as outputs that are available to the user for evaluating alternatives, including aircraft travel time, delay and operating costs, and system capacity, throughput and traffic loading.

In recent years, TAAM (Total Airport and Airspace Modeler) simulation modeling software, owned by the Preston Group, a subsidiary of the Boeing Company, has become another standard accepted computer application for estimating the capacity of an airport and associated airspace. The makers of TAAM also offer specialized products to estimate the capacity of airport terminals and baggage processing centers, as well as software for use of the administrative staff planning airports.

IV.6 Defining delay

Delay is defined as the duration between the desired time that an operation occurs and the actual time the operation occurs. When aircraft depart and arrive “on time,” according to their respective schedules, for example, the aircraft is said to have experienced no delay. If, however, an aircraft actually departs an hour after its scheduled departure time, that aircraft is said to have suffered 1 hour of delay. This delay may have been the result of any number of factors. A mechanical repair may have been required, luggage may have been slow in being loaded, weather may have required the aircraft wait until conditions improve, or perhaps the aircraft was one in a large number of aircraft that were scheduled to depart during a high-demand period time of day when the capacity of the airfield was insufficient to accommodate such high demand.

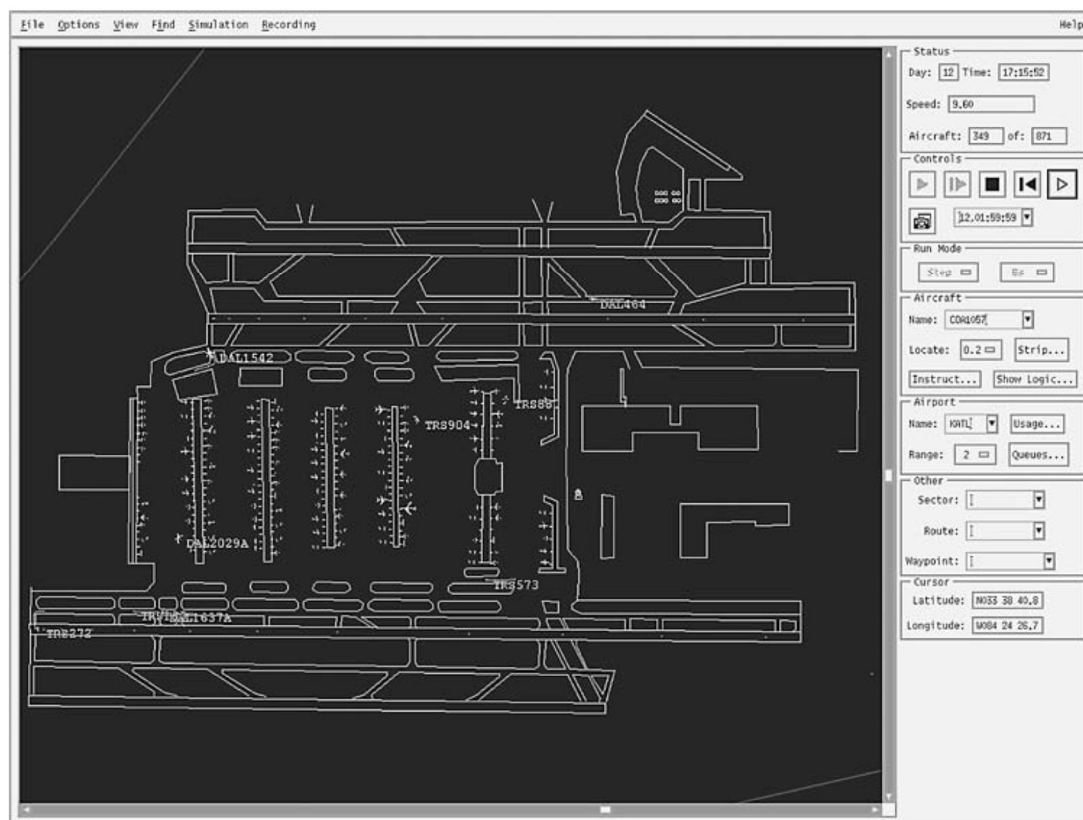


Figure IV-13. Example of airfield simulation using computer software.

Figure IV-14 illustrates the relationship between demand, capacity, and delay. As Fig. IV-14 illustrates, some amount of delay is often experienced by aircraft, even when levels of demand are significantly less than capacity. These delays are usually nominal, created as the result of sparse instances of two aircraft wishing to operate within very close intervals of time, or minor operational anomalies. As demand nears capacity, delays tend to increase exponentially as the potential for such anomalies and scheduling conflicts increase.

The FAA defines the maximum acceptable level of delay as the level of demand, in relation to throughput capacity, that will result in aircraft delays of no more than 4 minutes per operation. Congestive delay occurs when demand is sufficiently close to throughput capacity to result in an average of nine or more minutes of delay per aircraft operation. As demand asymptotically reaches throughput capacity, delays can reach several hours per operation. During extreme periods, when both demand is at its highest and capacity is significantly reduced because of weather or any other adverse condition, scheduled aircraft operations may be delayed for several days, if not canceled.

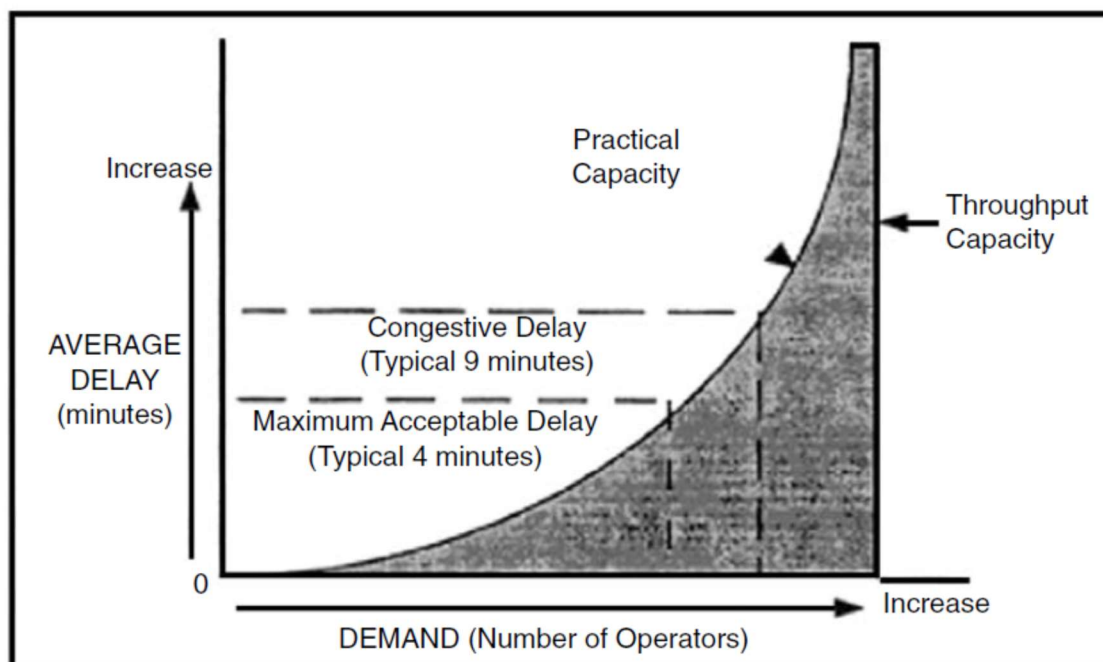


Figure IV-14. Delay as a function of capacity and demand.

How much delay is acceptable is, in fact, based on judgment involving three concepts. First is the concept that some delays are unavoidable because of factors beyond human control, such as changing meteorological conditions. Second, some delays, though avoidable, might be too expensive to eliminate. For example, the cost of building a new runway only to reduce delays by perhaps a few seconds per operation may be excessive. Third, even with the most vigorous effort, because aircraft operations are demanded on a somewhat random time frame (for example, even though an air carrier may be scheduled to land at 12:00 noon, it might actually wish to depart at some random period between 11:58 and 12:03, depending on winds or other factors that determine an aircraft's travel time to its destination), there always exists the probability that some aircraft will encounter delay greater than some "acceptable" amount. Thus, acceptable delay is essentially a policy decision about the tolerability of delay being longer than some specified amount, taking into account the technical feasibility and economic practicality of available remedies.

IV.7 Estimating delay

As with estimating capacity, various methods exist to estimate delay from fundamental analytical models, FAA tables and graphs, and computer simulation models. Similar to capacity estimation, analytical models allow an airport planner to estimate delays using fundamental estimations for aircraft demand and airport capacity. FAA tables provide cursory estimations of delay for more complex operating conditions, whereas computer simulation models provide detailed estimations of delay under a full variety of operating conditions, from the very simple to the highly complex.

A common analytical tool used to estimate delay over a period of time for a given airport capacity is the cumulative arrival diagram, also known as a queuing diagram. The diagram is based on the highly developed science of queuing theory, formed originally to estimate queues and delays for automobile traffic. Queuing theory may be applied to any environment where queues, and hence delays, occur, from toll booths, to grocery stores, to airports.

One example of a situation where a cumulative arrival diagram is particularly useful is a period of time where the demand changes while airport capacity remains essentially the same. This situation occurs often within airports. Periods of high demand, known as peak periods, tend to occur during morning and evening commute hours, at airports acting as hubs for major air carriers, and in periods of arrival or departure. Although the time and duration of peak periods of each individual airport is unique, peak periods, in general, are common to virtually all airports. Periods of time that experience less demand are known as off-peak periods.

Similar to capacity, demand is a rate, measured in operations per hour. Whereas capacity is the maximum number of operations that can be handled within an hour, demand is the number of operations that wish to occur over an hour. By definition, then, if a demand is less than capacity, the airport is said to be operating under capacity, and suffers minimal delays; as demand reaches capacity minor delays increase. When demand reaches, or exceeds capacity, the airport is said to be saturated, operating at capacity, but suffering large delays.

IV.7.a Analytical estimates of delay: The queuing diagram

Consider an airport with a single runway, having a capacity of 60 operations per hour. This airport may accommodate a demand for operations during most of the day, the off-peak period, of 30 operations per hour. During a 2-hour peak period, for example between 6:00 and 8:00 A.M., demand is 75 operations per hour. On the basis of this information, a **queuing diagram** may be constructed to illustrate aircraft demand, airport capacity, and overall delay that occurs as a result of the relationship between the two over time. Figure IV-15 represents such a queuing diagram.

The solid line in Fig. IV-15, known as the demand curve, represents the cumulative number of operations that have been scheduled to occur by any given time of day. In this example, the first operation of the day is scheduled for 5:00 A.M. The steady rise in the demand curve between 5:00 AM and 6:00 AM represents a schedule of operations that occur steadily at the off-peak rate of 30 operations per hour. The period between 6:00 A.M. and 8:00 A.M. is the peak period, where an additional 75 aircraft per hour, for a total of 150 aircraft, are scheduled to operate. At the end of the peak period, a cumulative total of 180 operations were scheduled to occur since the beginning of the operating day. After the end of the peak

period, the demand curve illustrates the return to offpeak demand levels, resulting in 210 cumulative operations scheduled by 9:00 A.M., 240 cumulative operations scheduled by 10:00 A.M., and so forth.

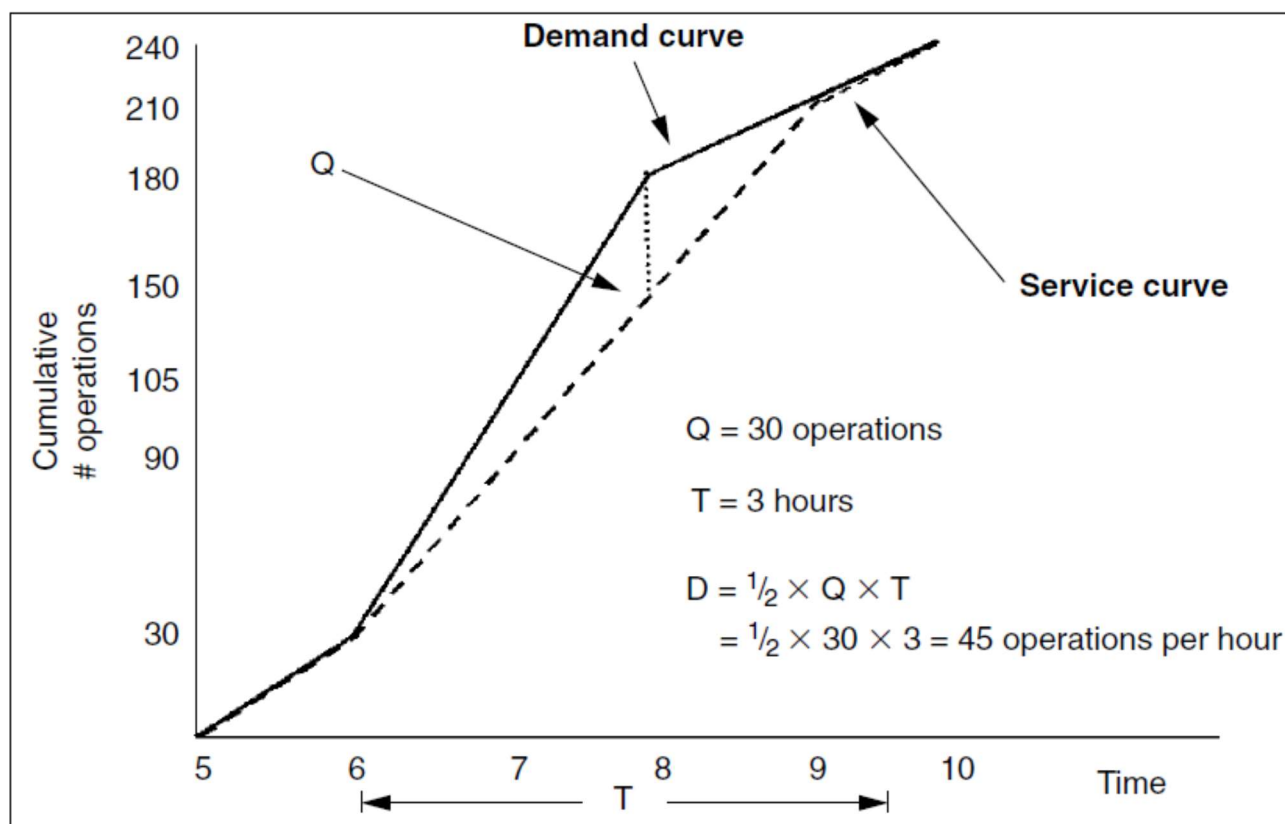


Figure IV-15. Example of queuing diagram.

The dashed line in Fig. IV-15, known as the service curve, represents the cumulative number of operations that will be served by any given time of the day. During the first hour of operation, between 5:00 A.M. and 6:00 A.M., the service curve is the same as the demand curve, illustrating the fact that during this relatively low demand period, when demand is less than capacity, aircraft, are served at the time they are scheduled. This portion of the cumulative arrival curve illustrates the fact that no significant delays occurred during this period.

During the peak period, however, the demand for service is greater than the service capacity. As such, the service curve illustrated during the peak period represents the maximum number of operations that could be served during this period, that is, the capacity of the system. Because the capacity of the system is only 60 operations per hour, by 8:00 A.M., the end of the peak period, only 150 cumulative operations could be served, less than the 180 that were scheduled.

The vertical distance between the demand and service curves represents the number of aircraft that are demanding service, but have not yet been served. That is, the number of aircraft in queue for service. The increasing vertical distance between the two curves during the peak period represents the evergrowing queue during this time. The end of the peak period bears witness to the longest queue, Q, during this analysis. In this case, Q equals 30 aircraft.

All aircraft that arrive during the peak period wait in a queue of some length, and thus experience an amount of delay. The amount of delay experienced by any given aircraft is illustrated by the horizontal

distance between the demand curve and the service curve. For example, the ninetieth aircraft observed in this system was scheduled to operate at 6:45 A.M., but was not served until 7:00 A.M., resulting in 15 minutes of delay time for this aircraft.

As illustrated on the queuing diagram, queues and delays do not end at the end of the peak period. At 8:00 A.M., the system continues to operate at capacity. Because the scheduled demand is less than the capacity after the peak period ends, the queue is able to decrease until it ultimately disappears. In this case, the queue is dissipated at 9:00 A.M., a full hour after the end of the peak period. Thus, between 6:00 A.M. and 9:00 A.M., which includes the period of peak demand, and part of the off-peak period which occurs after the peak period ends, aircraft scheduled to operate experience some amount of delay. This time period, T , is known as the period of time the system is in a delayed state.

On a queuing diagram, the amount of delay experienced by all aircraft in the system is defined by the area that exists between the demand and service curves. In this example, this area may be represented by calculating the area of the triangle defined by length T and height Q . Thus the total delay experienced by this system is defined by the area of the triangle, calculated as $1/2 QT$. In this case, $1/2(30)(3) = 45$ operating hours of delay. Averaged over the 180 aircraft that experienced some delay, each aircraft experienced an average of 0.25 hours, or 15 minutes, of delay.

The queuing diagram illustrated in Fig. IV-15 is a very simple application of queuing theory as used to estimate airport capacity. For a more comprehensive description of this very rich methodology, the reader is referred to Gordon Newell's text, **Applications of Queuing Theory**.

IV.7.b Other measures of delay

Traditionally, the FAA has gathered aircraft delay data from two different sources. The first is through the **Air Traffic Operations Network System (OPSNET)**, in which FAA personnel record aircraft that are delayed 15 or more minutes by specific cause (weather, terminal volume, center volume, closed runways or taxiways, and NAS equipment interruptions). Aircraft that are delayed by less than 15 minutes are not recorded in OPSNET.

The delay data reported through OPSNET is not without its problems. It reports only delays of 15 minutes or more; it aggregates flight delays, thus making it impossible to determine if a particular flight was delayed; and it reports only flight delays that are due to an air traffic problem (i.e., weather, terminal, volume, center volume, closed runways or taxiways, and NAS equipment interruptions). OPSNET is based on controller reports, and the quality and completeness of reporting vary considerably with controller workload. In addition, it measures delay against the standard of flight times published in the Official Airline Guide (OAG).

This, in all probability, results in an overestimation of delay because there is wide variation in the "no delay" time from airport to airport and, at a given airport, among various runway configurations. Many operations, when measured against a single nominal standard, are counted as delays but are within the normal expectancy for a given airport under given circumstances. There might also be a distortion in the opposite direction. Most airline schedules, especially for flights into and out of busy airports, have a built-in allowance for delay.

In part, this is simply realistic planning, but there is also a tendency to inflate published flight times so as to maintain a public image of online operation. Finally, OPSNET incorporates whatever delay might be

experienced en route. Delays en route might not be attributable to conditions at the airport, and including them in the totals for airports probably leads to overestimation.

The second source of delay data is through the **Consolidated Operations and Delay Analysis System (CODAS)**. CODAS is a newer FAA database and reporting system containing delay information by phase of flight for U.S. domestic flights. CODAS was developed by merging the former **airline service quality performance (ASQP)** database with the FAA's **Enhanced Traffic Management System (ETMS)**. In addition, CODAS contains flight schedule information from the OAG and weather data from the National Oceanic and Atmospheric Administration (NOAA). CODAS contains actual times for gate out, wheels off, wheels on, and gate in. From this information, gate delays, taxi-out delays, airborne delays, and taxi-in delays as small as 1 minute are computed. CODAS measures a delay where it occurs, not where it is caused. The principal purpose of CODAS is to support analytical studies and not the day-to-day management of the ATC (air traffic control) system.

IV.8 Approaches to reducing delay

Many commercial service airports, particularly those in large metropolitan areas, have experienced significant operating delays on their airfields, and also in their terminals, and on ground access systems around the airports, as well as between the airport and the associated area. The strategies that may be employed to reduce delays fall into two categories: increasing system capacity and managing system demand. Increasing capacity includes the addition of new infrastructure, such as additional runways, terminal facilities, and ground access roads. Increasing capacity also includes provision of technologies and policies to make existing infrastructures operate more efficiently. For example, it reduces the amount of processing time required at any given facility to allow more operations over a given period of time. Managing demand focuses more on changing the behavior of system users that in turn will lead to better use of existing system capacity.

IV.8.a Creating new airport infrastructure

Historically, the development of new airports and the construction of new runways and runway extensions at existing airports have offered the greatest potential for increasing aviation system capacity. The new Denver International Airport (DIA), completed in 1995, increased capacity and reduced delays not only in the Denver area, but also throughout the aviation system. However, at a cost of over \$5 billion for a new airport like Denver, it will remain a challenge to finance and build others.

These options for achieving major capacity increases have become more difficult because of surrounding community development, environmental concerns, shortage of available adjacent property and funding required, lack of public support, rival commercial and residential interests, and other competing requirements.

Between January 1997 and October 2002, a total of seven new runways at major commercial airports in the United States were opened. Another 19 capacity enhancing construction projects were completed during this period, including 15 runway extensions. There are 39 additional projects planned between November 2002 and 2007 including the building of 13 new runways.

In addition, the increase in properly located taxiways, particularly those that provide egress from runways, has an important effect on reducing runway occupancy time. The placement of exit taxiways,

where landing aircraft turn off the runways, and the angle at which these taxiways intersect the runways can be crucial. Poorly placed exit taxiways prolong runway occupancy by forcing arriving aircraft to taxi at low speed for an excessive distance before clearing the runway. Taxiways that leave the runway at right angles force the aircraft to reduce to very slow speeds in order to safely turn off the runway. The addition of taxiways in strategic locations along runways can contribute to the minimization of runway occupancy times, leading to increased runway capacity.

IV.8.b Converting military airfields

In a somewhat similar manner to the transfer of military air bases to municipal civil aviation airports after World War II, the downsizing of United States military facilities in the 1990s contributed to an increase in commercial aviation system capacity by allowing the conversion of closed military airfields to civilian use. Most of the military airfields that have been considered for conversion are already designed to accommodate heavy aircraft, with runways up to 13,000 feet in length. Many of these airfields are located in the vicinity of congested metropolitan airports where the search for major new airports has been under way. A prime example of military airfield conversion is the new Austin- Bergstrom International Airport, in Austin, Texas, located on the site of the Bergstrom Air Force Base. The new airport improves the capacity of aircraft operations for the area as it replaces the smaller Robert Mueller Municipal Airport.

In addition to military airfield conversions to civil airports, there are a number of military airfields now in operation accommodating joint civil and military use. For the most part, these joint-use airfields provide primary service to the communities and have a modest impact on system capacity. Figure IV.16 provides a representative list of joint civil- and military-use airfields.

To assist in the transition of military airfields to civilian airports, the Military Airport Program (MAP), established as a funding set-aside under the Airport Improvement Program (AIP), provides grant funding of airport master planning and capital development. The MAP allows the secretary of transportation to designate current or former military airfields for participation in the program.

To participate, eligible airport sponsors apply to the FAA. In determining whether or not to designate a facility, the FAA considers proximity to major metropolitan air carrier airports with current or projected high levels of delay, capacity of existing airspace and traffic flow patterns in the metropolitan area, the availability of local sponsors for civil development, existing levels of operation, existing facilities, and any other appropriate factors.

IV.9 Administrative and demand management

Two basic approaches to managing demand have the same objective: to ease congestion by diverting some traffic to times and places where it can be handled more promptly or efficiently. This might be done through administrative management; the airport authority or another governmental body might allocate airport access by setting quotas on passenger enplanements or on the number and type of aircraft operations that will be accommodated during a specific period. The alternative approach is economic to structure the pricing system so that market forces allocate scarce airport facilities among competing users; thus, demand management does not add capacity, it promotes more effective or economically efficient use of existing facilities.

Any scheme of demand management denies some users free or complete access to the airport of their choice. This denial is often decried as a violation of the traditional federal policy of freedom of the airways and the traditional “first come, first-served” approach to allocating the use of airport facilities. Economists reject this argument on the grounds that it is a distortion of the concept of freedom to accord unrestricted access to any and all users without regard to the societal costs of providing airport facilities. Attempts to manage demand are also criticized for adversely affecting the growth of the aviation industry

and the level of service to the traveling public. Nevertheless, as growth in traffic has outstripped the ability to expand and build airports, some forms of demand management have already come into use, and many industry observers have taken the position that some form of airport use restrictions will become increasingly important in dealing with delay and in utilizing existing airport capacity efficiently.

AIR FORCE	ARMY	NAVY
1. AF Plant 42, Palmdale, CA	1. Blackstone AAF, (Ft. Pickett), VA	1. MCAS Yuma, Yuma, AZ
2. Barter Island LRRS, Barter Island, AK	2. Camp Guernsey AAF, Guernsey, WY	
3. Charleston AFB, Charleston, SC	3. Dillingham AAF, Waiialua, HI	
4. Dover AFB, Dover, DE	4. Forney AAF (Fort Leonard Wood), MO	
5. Eglin AFB, Valparaiso, FL	5. Gray AAF, Ft. Hood/Killeen, TX 4/	
6. Grissom ARB, , Peru, IL	6. Grayling AAF, (Camp Grayling), MI	
7. Kelly/Lackland AFB, TX	7. Libby AAF (Ft. Huachuca), Sierra Vista, AZ	
8. March ARB, Riverside, CA	8. Sherman AAF, (Ft. Leavenworth), KS	
9. Pt. Lay LRRS, Point Lay, AK	9. Sparta/Fort McCoy (Sparta), WI	
10. Scott AFB (Mid America), Belleville, IL		
11. Sheppard AFB, Wichita Falls, TX		
12. Westover ARB, Chicopee, MA		

Figure IV-16. Joint civil- and military-use airports as of 2002. (Source: Federal Aviation Administration)

IV.9.a Administrative management

Several administrative management approaches are being adopted to manage demand at individual airports or for a metropolitan region. Among these are required diversion of some traffic to reliever airports, more balanced use of metropolitan air carrier airports, restriction of airport access by aircraft type or use, establishment of quotas (either on the number of operations or on passenger enplanements), and “rehubbing” or redistributing transfer traffic from busy airports to underused airports.

In some metropolitan areas, the shortage of airport capacity might not be general, but confined to one overcrowded airport. Perhaps other airports in the region could absorb some of the demand. The FAA lists 27 airports in the Chicago area, 51 in the Los Angeles area, and 53 in the Dallas–Fort Worth region. The vast majority of these airports are small and suited only for general aviation (GA) aircraft, but in some cases there is also an underutilized commercial service airport.

The best regionwide solution to the problem of delay at a major airport might be to divert some traffic away from the busy airport to either a general aviation reliever airport or a lightly used commercial airport. To some extent, this can occur as a result of natural market forces. When delays become intolerable at the busy airport, users begin to divert of their own accord. Even though those who choose to move to a less crowded facility do so for their own benefit, they also reduce somewhat delays incurred by users that continue to operate at the crowded airport. Public policy might encourage this diversion through administrative action or economic incentives before traffic growth makes conditions intolerable or necessitates capital investment to accommodate peaks of demand at the busy airport.

Diversion of general aviation from busy air carrier airports is often an attractive solution. GA traffic, because it consists mostly of small, slow-moving aircraft, does not mix well with faster, heavier air carrier traffic. GA operators especially those flying for recreational or training purposes want to avoid the delays and inconveniences (and sometimes the hazards) of operating at a major airport. These fliers are often willing to make use of GA airports located elsewhere in the region if suitable facilities are available.

Diversion of GA traffic from commercial air carrier airports has been taking place for many years. As air carrier traffic grows at a particular location, it almost always tends to displace GA traffic. FAA has encouraged this trend by designating approximately 334 airports as “relievers” or “satellites” to air carrier airports, and earmarking funds especially for developing and upgrading these airports. Many other airports, although not specifically designated as relievers, serve the same function; they provide an alternative operating site for GA aircraft well removed from the main commercial airport of the region.

To be attractive to a broad spectrum of GA users, a reliever airport should be equipped with instrument approaches and provide runways capable of handling the larger, more sophisticated GA aircraft. In addition, users need facilities for aircraft servicing, repair, and maintenance, as well as suitable ground access to the metropolitan area.

Not all GA aircraft can make use of reliever airports. Some might be delivering passengers or freight to connect with commercial flights at the air carrier airport.

Others might be large business jets that require the longer runways of a major airport. In general, airport authorities do not have the power to exclude GA as a class, although this has been attempted on occasion. For example, in the late 1970s, the airport management and city government of St. Louis attempted to exclude all private aircraft from Lambert Airport. This ordinance was overturned by the courts as discriminatory.

Where they have had any policy on the matter, local airport authorities have attempted to make GA airports attractive to users by offering good facilities or by differential pricing schemes. This approach is most effective where the commercial airport and the principal reliever are operated by the same entity.

The state of Maryland, owner of Baltimore-Washington International Airport, operates a separate GA airport, Glenn L. Martin Field, and has a specific policy of encouraging GA traffic to use it rather than the main airport. The master plan for Cleveland Hopkins International Airport depends on the availability of the city-owned Lakefront Airport as a reliever. If that airport should for some reason cease operation as a GA reliever, Hopkins would experience a great increase in traffic, which might necessitate additional construction that is not now planned.

Most local airport authorities, however, do not operate their own GA relievers. Some large airport authorities plan and coordinate activities with nearby reliever airports operated by other municipalities or private individuals, but this has not been the general case. The system of relievers in each region has tended to grow up without any specific planning or coordination on the regional level.

Development of GA relievers is not without problems. These airports are also subject to complaints about noise, and they experience the same difficulties as commercial airports in expanding their facilities or in developing a new airport site. Further, because many GA airports are small and function just on the ragged edge of profitability, problems of noise or competing land use can actually threaten the airport's existence. The number of airports available for public use in the United States has been declining. Between 1980 and 1998, for example, the number of public-use airports declined from 6,519 to 5,357. Although most of the airports that closed were small, privately owned facilities, some industry observers worry that the nation is irrevocably losing many potential reliever airports just as it has become clear that they are vital.

At the largest commercial service airports, GA activity consists primarily of flights by large business and executive aircraft. This type of GA traffic accounts for approximately 10 to 20 percent of the use of major airports, a figure that many consider the "irreducible minimum." The delays that persist at these airports are primarily the result of air carrier demand that can be satisfied only by another commercial service airport. In several metropolitan areas, it is clear that the commercial airports are not used in a balanced manner, in order to encourage the diversion of some traffic to Newark. In practice, however, measures adopted to promote traffic redistribution have not been fully effective. The recent growth of traffic at Newark has been primarily due to new carriers entering the New York market and not diversion of established carriers.

In contrast, San Francisco and Oakland airports are operated by separate sponsors. San Francisco, despite severe problems of delay, would rightly be reluctant to encourage passengers and air carriers to move to Oakland. Even though more balanced regional airport use might be achieved and the long-range need for expansion at San Francisco reduced, the short-range effect would be that San Francisco would lose revenues to a competitor. There is no regional authority with the power to promote this reallocation of traffic.

One means of diverting certain traffic from a busy airport to one with unused capacity is to restrict access to the busy airport on the basis of aircraft type or use. Restriction of aircraft access to airports by size or performance characteristics might affect airport capacity and delay in several ways. First, the mix of aircraft using a runway system helps determine capacity. When aircraft are of similar size, speed, and operating characteristics, runway acceptance rate is greater than when performance characteristics vary widely. Similar aircraft can be more uniformly and accurately spaced on approach and departure, thereby smoothing out irregularities in the traffic stream, which is a major factor causing delay; thus, at airports where the bottleneck is in the runway system, restrictions that narrow the range of aircraft using that system might have a beneficial effect. Diversion of small GA or commuter aircraft to other airports or construction of a separate short runway dedicated to their use could improve the ability of the airport to handle larger transports or the overall traffic mix.

A second implication of limiting access to specific aircraft types is that it might reduce the need for capital improvements required to accommodate a larger variety of aircraft. For example, Ronald Reagan

Washington International Airport does not generally accept “heavy” jet aircraft. Allowing larger aircraft into National would probably necessitate changes in runways, taxiways, aprons, and gates. In addition, the larger number of passengers per aircraft would put additional strain on National’s already congested terminal and landside facilities, making a number of collateral improvements necessary.

One technique of administrative management now in use at a few airports is a quota, or slot, system, an administratively established limit on the number of operations per hour. Because delay increases exponentially as demand approaches capacity, a small reduction in the number of hourly operations can have a significant effect on delay. This makes the quota an attractive measure for dealing promptly (and inexpensively) with airport congestion.

Examples of airports with quotas are O’Hare, LaGuardia, JFK, and Ronald Reagan Washington International, airports covered by the FAA high-density rule.

The quotas at these airports were established by FAA in 1973 on the basis of estimated limits of the ATC system and airport runways at that time. An example of a locally imposed quota is John Wayne Airport in Orange County, California, which limits scheduled air carrier operations to an annual average of 41 operations per day. This quota is based on noise considerations as well as limitations on the size of the terminal and gate areas.

During busy hours, demand for operational slots typically exceeds the quota. At the airports covered by the high-density rule, the slots are allocated among different user classes. For example, at Ronald Reagan Washington International Airport, where there are 60 slots available per hour, 37 are allotted to air carriers, 11 to commuter carriers, and 12 to general aviation. During visual meteorological conditions, more than 60 operations can be handled, and aircraft without assigned slots may be accommodated at the discretion of air traffic controllers and the airport manager.

At airports where the quota system is in force, slots may be allocated in various ways: a reservation system, negotiation, or administrative determination. The GA slots are generally distributed through a reservation system the first user to call for a reservation gets the slot.

However, for commuters and air carriers, the slots at the high-density rule airports are still subject to a great deal of controversy. In 1986, FAA declared the slots the property of the airlines holding them by allowing carriers to sell or lease slots to other airlines. A few available slots were also distributed by lottery.

Under airline regulation, when the number of carriers and routes was fairly stable, airline scheduling committees would meet under antitrust immunity to negotiate the flights to be allotted to each user, which meant the incumbent carriers. From 1979 to 1986, the committees had to accommodate new entrants and the changing market strategies of incumbent carriers. On several occasions during this period, negotiations between carriers concerning available slots nearly broke down, which would have necessitated that the FAA use administrative means to distribute the slots.

A systemwide response to alleviate delays at busy airports is redistribution of operations to other, less busy airports in other regions. Some air carriers, especially those with a high proportion of interconnecting flights, might voluntarily move their operations to underutilized airports located some distance from the congested hub. Transfer passengers account for a large percentage of traffic at some large airports. About three-fourths of passengers at Atlanta and nearly half the passengers at Chicago, Denver, and Dallas Fort Worth arrive at those airports merely to change planes for some other destination. There is an advantage to carriers in choosing a busy airport as a transfer hub they can offer passengers a wide variety of possible connections; however, when the airport becomes too crowded, the costs of delay might begin to outweigh the advantages of the large airport, and carriers might find it attractive to establish new hubs at smaller, less busy airports.

IV.9.b Demand management

Administrative management of airport use, whether by restricted access for certain types of aircraft, by demand balancing among metropolitan area airports, or by imposition of quotas offers the promise of immediate and relatively low cost relief of airport congestion. As long-term measures, these solutions might not be as attractive. Administrative limits tend to bias the outcome toward maintenance of the status quo when applied over a long period of time. Because the economic value of airport access is not fully considered in setting administrative limits, incumbents cannot be displaced by others who would place a higher value on use of the airport. Further, incumbents and potential new entrants alike have no way to indicate the true economic value they would place on increased capacity. Economists contend that a vital market signal is missing and that airport operators and the federal government cannot obtain a true picture of future capacity needs. Administratively limiting demand, they say, creates an artificial market equilibrium that over the long term distorts appreciation of the nature, quality, and costs of air transportation service that the public requires. Economists, therefore, favor a scheme of allocating airport access by **demand management** which relies on the price mechanism.

At present, price plays a rather weak role in determining airport access or in modulating demand. Access to public-use airports, except for the few large airports where quotas are imposed, is generally unrestricted so long as one is willing to pay landing fees and endure the costs of congestion and delay. Landing fees, most often based solely on aircraft weight and invariant by time of day, make up a very small fraction of operational cost, typically 2 to 3 percent for air carriers and even less for GA. Further, landing fees are not uniform from airport to airport. In many cases, landing fees are set so that, in the aggregate, they make up the difference between the cost of operating the airport and the revenues received from other sources such as concessions, leases, and automobile parking fees.

This leads economists to the conclusion that landing fees are somewhat arbitrary and do not reflect the costs imposed on the airport by an aircraft operation. Economists suggest that by including airport costs and demand as determinants of user fees, delay could be significantly reduced. The two most commonly advocated methods of achieving this are differential pricing and auctioning of landing rights.

Many economists argue that weight-based landing fees are counterproductive because they do not vary with demand, and consequently provide no incentive to utilize airport facilities during off-peak hours. Further, they do not reflect the high capital costs of facilities used only during peak hours. Thus, economists contend, a more effective pricing method would be to charge higher user fees during peak hours and lower fees during off-peak hours. Theoretically, the net effect of such a pricing policy would be a more uniform level of demand.

Much of the traffic moved away from peak hours by higher landing fees would probably be GA. Correspondingly, the benefits of peak-hour fees would be greater at airports with a high proportion of GA activity. But peak-hour fees could also be structured so as to affect the pattern of air carrier activity. These charges would have to be fairly high because landing fees represent only a small fraction of air carrier operating costs and because increases can be passed on to passengers.

Despite increases in landing fees, carriers would want to continue to use the airport at peak times, either to allow access to a large number of passengers or because long-haul scheduling problems require them to serve a particular airport during certain hours; thus, they would absorb some increase in landing Fees just as they absorb the cost of delays as part of the cost of doing business.

However, some flights might be moved to off-peak hours if the charges were high enough. It is possible that properly structured peak-hour prices, if they were reflected in fares, could have an effect not only on the airline's scheduling patterns, but also on passengers' travel habits as well. If significant savings were possible, some passengers would choose to travel during offpeak hours.

It is difficult to project accurately the changes in patterns of airport use that might be brought about by peak-hour surcharges. Some analysts estimate that peak hour surcharges, along with improvement of the ATC system, would reduce anticipated air carrier delays significantly in the future. Others argue that although expansion might be inevitable at many airports, peak-hour surcharges could significantly delay the need for expansion and reduce financial pressure at a number of airports. Another important aspect of peak-hour surcharges noted by the Congressional Budget Office (CBO) is that even if they do not reduce traffic levels at peak hours to the desired levels, they could provide airports with increased revenues to expand facilities and, consequently, to reduce delays.

A major problem with the concept of peak-hour surcharges is how to determine the level of surcharge. One widely advocated method is to charge the airport user the full marginal costs of airport facilities. In other words, each airport user pays a share of the additional capital and operating costs to the airport authority providing service at the time demanded. For example, if a user lands at an airport during a period of peak demand where two or more runways are necessary to handle the traffic, the charge should include a contribution to the cost of building, operating, and maintaining those additional runways. On the other hand, if the user lands during an off-peak hour, when the one runway in use is not sought by others, there would be no additional charge. Although both on-peak and off-peak users would pay fees to cover maintenance, wear and tear, or other costs, only peak-hour users would pay the additional costs associated with the time of use. The resulting user fees would be directly related to the levels of airport activity, producing the desired effect of higher fees during peak hours and a strong price signal to use the airport at off-peak hours.

Some contend that a system of marginal cost pricing should be based on the delay costs that each peak-hour user imposes on other users. For example, during peak hours, airport users would be charged a fee based on the delay costs associated with their operations. This creates a system of user fees where the fees become progressively larger as delays increase. Proponents contend that using marginal delay costs as the basis for pricing airport access provides a stronger incentive for off-peak airport use than a scheme based on marginal facility costs alone. Implementing a policy of differential pricing, whether based on marginal facility cost, marginal delay cost, or some purely arbitrary scheme, is difficult.

It is likely that a significant increase in airport user fees will raise questions of equity. Higher fees might be more burdensome for small airlines and new entrants than for established carriers. There are a number of examples where airport operators have attempted to increase user fees and have been challenged by air carriers and general aviation. In some cases, air carrier landing fees are established in long-term contracts that cannot be easily changed. GA users often contend that differential pricing is discriminatory because it favors those with the ability to pay, and illegal because it denies the right to use a publicly funded facility. Economists rebut this argument by pointing out that time-of-use price is neither discriminatory nor illegal so long as price differences reflect cost differences. They contend that it is fair and just to set prices on the basis of the costs that each user imposes on others and on society generally.

In general, peak-hour surcharges represent an attempt to manage demand by charging cost-based landing fees. Access to airports is not limited except by the user's willingness to bear the additional cost imposed during peak hours. Another method of reducing peak-hour airport activity involves limiting airport access through a process by which landing rights (slots) are auctioned to the highest bidder. The auction is a hybrid process partly administrative, partly economic in which access is regulated, but the right of access is distributed through a market-oriented mechanism.

Slot auctions have been advocated as the best method of allocating scarce airport landing rights on the grounds that if airport access must be limited, it should be treated as a scarce resource and priced accordingly. The method to accomplish this is a system whereby the price of airport access is determined by demand.

Slot auctions allow peak-hour access only to those users willing to pay a market determined price. However, as operations increase, there might not be enough extra capacity in the traditional off-peak time periods to accommodate additional operations without significant delays. At this point, slot allocations will only be able to reduce delay by effectively “capping” the total number of operations at the airport.

This program can be cumbersome to execute both equitably and efficiently. Its use within this country has been restricted to the four high-density traffic airports, Ronald Reagan Washington International, Chicago O’Hare, New York LaGuardia, and New York Kennedy, where delays have historically affected the performance of the National Airspace System (NAS).

Critics also contend that the current slot sale process gives an advantage to the airlines already operating at the airport and denies access to competitors, providing the existing users with virtual monopolies and a financial windfall. Slot holders know that without a slot, no competitor can enter a market and, consequently, slots represent one of the most significant barriers to entry in the airline business today. Their impact on the industry extends far beyond the few airports where they are imposed because markets critical to many communities either begin or end at one of these facilities.

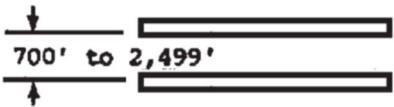
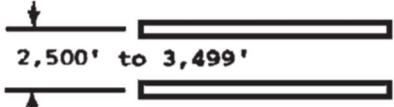
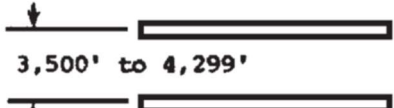
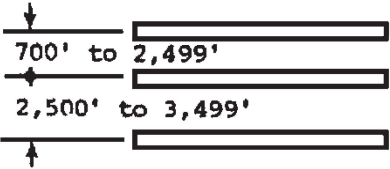
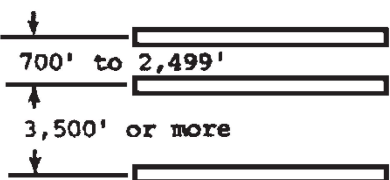
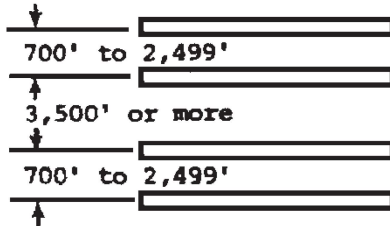
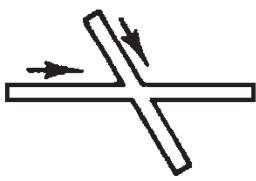
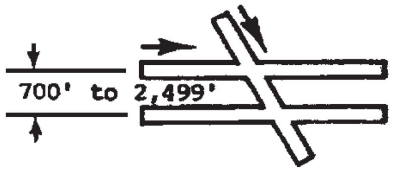
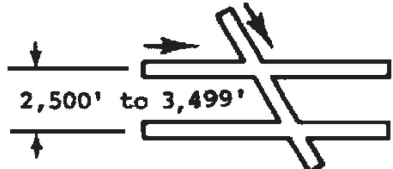
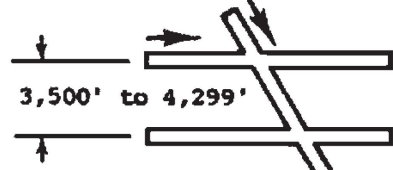
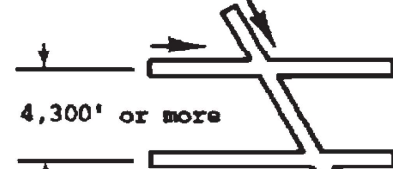
No.	Runway Configuration Diagram	Mix Index-- Percent(C+3D)	Hourly Capacity (operations per hour)		Annual Service Volume (operations per year)
			VFR	IFR	
1.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	98 74 63 55 51	59 57 56 53 50	230,000 195,000 205,000 210,000 240,000
2.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	197 145 121 105 94	59 57 56 59 60	355,000 275,000 260,000 285,000 340,000
3.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	197 149 126 111 103	62 63 65 70 75	355,000 285,000 275,000 300,000 365,000
4.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	197 149 126 111 103	62 63 65 70 75	355,000 285,000 275,000 300,000 365,000
5.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	197 149 126 111 103	119 114 111 105 99	370,000 320,000 305,000 315,000 370,000
6.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	295 213 171 149 129	62 63 65 70 75	385,000 305,000 285,000 310,000 375,000

Figure A1-1A. Preliminary analysis of capacity.

No.	Runway Configuration Diagram	Mix Index-- Percent (C+3D)	Hourly Capacity (operations per hour)		Annual Service Volume (operations per year)
			VFR	IFR	
7.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	295 219 184 161 146	62 63 65 70 75	385,000 310,000 290,000 315,000 385,000
8.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	295 219 184 161 146	119 114 111 117 120	625,000 475,000 455,000 510,000 645,000
9.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	394 290 242 210 189	119 114 111 117 120	715,000 550,000 515,000 565,000 675,000
10.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	98 77 77 76 72	59 57 56 59 60	230,000 200,000 215,000 225,000 265,000

NOTE: ➔ Denotes predominant direction of runway operation.

Figure A1-1B. Preliminary analysis of capacity (continued).

No.	Runway Configuration Diagram	Mix Index-- Percent (C+3D)	Hourly Capacity (operations per hour)		Annual Service Volume (operations per year)
			VFR	IFR	
11.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	197 145 121 105 94	59 57 56 59 60	355,000 275,000 260,000 285,000 340,000
12.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	197 149 126 111 103	62 63 65 70 75	355,000 285,000 275,000 300,000 365,000
13.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	197 149 126 111 103	62 63 65 70 75	355,000 285,000 275,000 300,000 365,000
14.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	197 149 126 111 103	119 114 111 105 99	370,000 320,000 305,000 315,000 370,000

NOTE: ➔ Denotes predominant direction of runway operation.

Figure A1-1C. Preliminary analysis of capacity (continued).

No.	Runway Configuration Diagram	Mix Index-- Percent(C+3D)	Hourly Capacity (operations per hour)		Annual Service Volume (operations per year)
			VFR	IFR	
15.		0 to 20	197	59	355,000
		21 to 50	147	57	275,000
		51 to 80	145	56	270,000
		81 to 120	138	59	295,000
		121 to 180	125	60	350,000
16.		0 to 20	150	59	270,000
		21 to 50	108	57	225,000
		51 to 80	85	56	220,000
		81 to 120	77	59	225,000
		121 to 180	73	60	265,000
17.		0 to 20	132	59	260,000
		21 to 50	99	57	220,000
		51 to 80	82	56	215,000
		81 to 120	77	59	225,000
		121 to 180	73	60	265,000
18.		0 to 20	295	59	385,000
		21 to 50	210	57	305,000
		51 to 80	164	56	275,000
		81 to 120	146	59	300,000
		121 to 180	129	60	355,000

NOTE: ➔ Denotes predominant direction of runway operation.

Figure A1-1D. Preliminary analysis of capacity (continued).

No.	Runway Configuration Diagram	Mix Index-- Percent (C+3D)	Hourly Capacity (operations per hour)		Annual Service Volume (operations per year)
			VFR	IFR	
19.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	197 145 121 105 94	59 57 56 59 60	355,000 275,000 260,000 285,000 340,000
20.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	301 210 164 146 129	59 57 56 59 60	385,000 305,000 275,000 300,000 355,000
21.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	264 193 158 146 129	59 57 56 59 60	375,000 295,000 275,000 300,000 355,000
NOTE: ➡ Denotes predominant direction of runway operation.					

Figure A1-1E. Preliminary analysis of capacity (continued).

No.	Runway Configuration Diagram	Mix Index-- Percent (C+3D)	Hourly Capacity (operations per hour)		Annual Service Volume (operations per year)
			VFR	IFR	
22.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	150 108 85 77 73	59 57 56 59 60	270,000 225,000 220,000 225,000 265,000
23.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	132 99 82 77 73	59 57 56 59 60	260,000 220,000 215,000 225,000 265,000
24.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	295 210 164 146 129	59 57 56 59 60	385,000 305,000 275,000 300,000 355,000
25.		0 to 20 21 to 50 51 to 80 81 to 120 121 to 180	197 145 121 105 96	59 57 56 59 60	355,000 275,000 260,000 285,000 340,000

NOTE: → Denotes predominant direction of runway operation.

Figure A1-1F. Preliminary analysis of capacity (continued).

No.	Runway Configuration Diagram	Mix Index-- Percent (C+3D)	Hourly Capacity (operations per hour)		Annual Service Volume (operations per year)
			VFR	IFR	
26.		0 to 20	301	59	385,000
		21 to 50	210	57	305,000
		51 to 80	164	56	275,000
		81 to 120	146	59	300,000
		121 to 180	129	60	355,000
27.		0 to 20	264	59	375,000
		21 to 50	193	57	295,000
		51 to 80	158	56	275,000
		81 to 120	146	59	300,000
		121 to 180	129	60	355,000

NOTE: ➡ Denotes predominant direction of runway operation.

SPECIAL NOTE:

- (1) The configurations shown above do not include layouts with more than two runway orientations. Therefore, for those airports with runway configurations involving three or more orientations, it is necessary to identify the runways in the two orientations used most frequently.
- (2) Missed approach protection is assumed for converging operations in IFR conditions.
- (3) Multiple arrival streams are only permitted on parallel runways.

Figure A1-1G. Preliminary analysis of capacity (continued).

CHAPTER V

Airport Peaks and Airline Scheduling / Case Studies

V.1 The Problem

Airport operators usually speak enthusiastically about the business of the airport in terms of the throughput of passengers and cargo, as represented by the annual number of passengers processed or the annual turnover of tons of air freight. This is entirely understandable because annual income is determined to a large degree by these parameters; moreover, the numbers are impressively large. However, it is important, when considering annual figures, to bear in mind that whereas annual flows are the prime determinant of revenue, it is the peak flows that determine to a large degree the physical and operational costs involved in running a facility. Staffing and physical facilities are naturally keyed much more closely to hourly and daily requirements than to annual throughput.

In common with other transportation facilities, airports display very large variations in demand levels with time. These variations can be described in terms of:

- Annual variation over time
- Monthly peaks within a particular year
- Daily peaks within a particular month or week
- Hourly peaks within a particular day

The first of these is extremely important from the viewpoint of the planning and provision of facilities. Air transportation still is considered the fastest growing mode, and there is little indication that this situation is likely to change. Consequently, operators of airport facilities often are faced with growing volumes that approach or exceed capacity. During the period 1970–2010, the average worldwide rate of air passenger growth was close to 7 percent. Even during the difficult period 2000–2010, which included the oil price increases during the period 2005–2008 and the subsequent recession, the average world air passenger growth rate also was approximately 5 percent. Air transport passenger travel is expected to continue to grow at 5.1 percent between the years 2010 and 2030 and air cargo to grow at 5.6 percent during the same period. Although the operator must be closely involved in the long-term planning of the airport. Emphasis here will be on the short-term considerations of day-to-day operation. Therefore, the discussion will concentrate on monthly, daily, and hourly variations of flows. In the operational context, this is natural because many of the marginal costs associated with the day-to-day provision of staffing and rapidly amortized equipment are not really related to long-term variations in traffic but rather to variations within a 12-month span.

At most, if not all, air transport airports, the major consideration must be passenger flow. At many of the larger airports, cargo operations are becoming increasingly important in part because cargo transport continues to outstrip passenger traffic in terms of growth rate. In the planning and operation of air cargo facilities, however, it must be noted that the peaks for air cargo operations do not coincide with those for air passenger transport. The two sub modes usually can be physically separated to the necessary degree, even though proximity of the freight and passenger aprons is desirable because much freight is carried in the bellies of passenger transport aircraft.

When considering the characteristics of the peaking of passenger flows, it is always important to bear in mind that the “passenger” is not a homogeneous entity. Passenger traffic is built up from the individual journey demands of many passengers. These passengers are traveling under different conditions, they

have different needs, and consequently, they place different overall demands on the system. Not surprisingly, this is reflected in different peaking characteristics, depending, for example, on whether the passenger is domestic or international, scheduled or charter, leisure or business, full fare or special fare.

Complicating the whole matter of peaking is the fact that unlike the situation in most other modes of transportation, where the passenger is dealing with only one operator, in air transport, there is the complex interrelationship of the passenger, the airport, and often several airlines. In the matter of peaking, the aims of the airline and the airport operator do not necessarily coincide. The airport operator would like to spread demand more evenly over the operating day in order to decrease the need for the supply of facilities governed by the peak. The airline, on the other hand, is looking to maximize fleet utilization and to improve load factors by offering services in the most attractive time slots. There is therefore a potential conflict between the airline satisfying its customer, the passenger, and the airport attempting to influence the demands of its principal customer, the airline.

V.2 Methods of Describing Peaking

Even the busiest airport operates over a wide range of traffic flows. Many of the world's largest air transport terminals are virtually deserted for many hours of the year; these same facilities only a few hours later may be operating at flows that strain or surpass capacities. Few facilities are designed to cope with the very highest flow volume that occurs in the design year of operation. Most are designed such that for a few hours of the year there will be an acceptable level of capacity overload. Different airport and aviation authorities approach this problem in different ways. Figure V.1 shows one of the characteristics of traffic peaking for a typical airport, that is, the curve of passenger traffic volumes in ranked order of magnitude. It can be seen that for a few hours per year there are very high peak volumes of traffic. Operational practice tends to accept that for a few hours of each year facilities must be operated at some level of overload (i.e., volumes that exceed physical and operational capacity) with resulting delays and inconvenience. To do otherwise and to attempt to provide capacity for all volumes would result in uneconomical and wasteful operation.

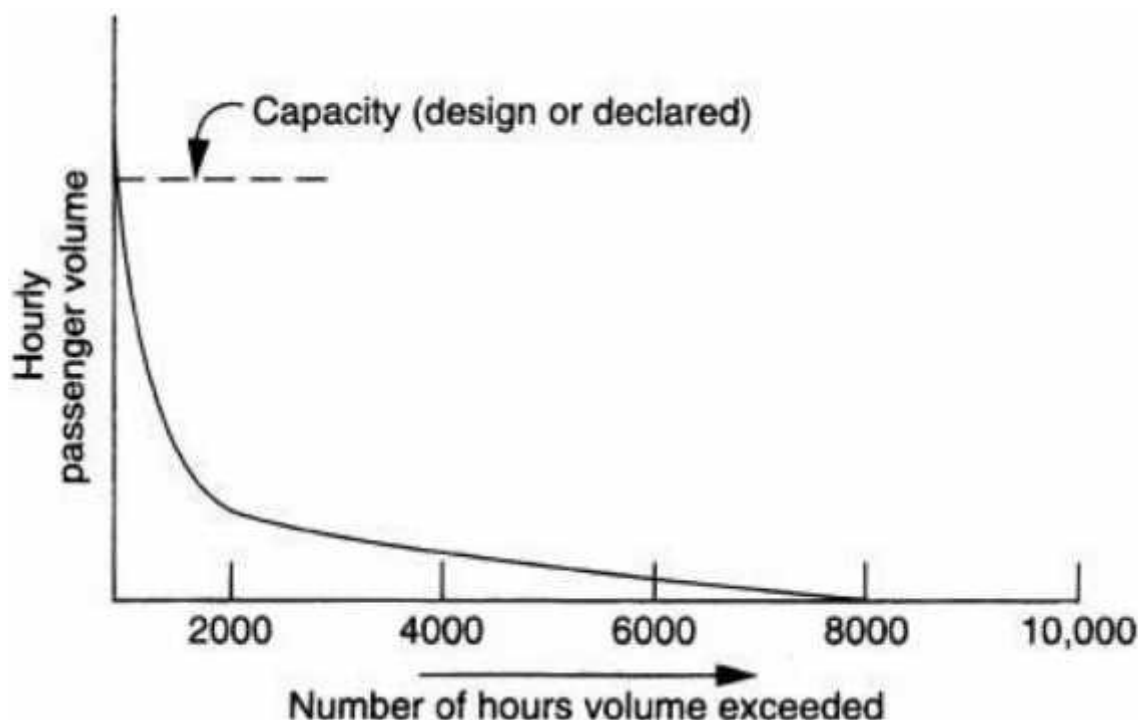


Figure V.1 : Typical distribution of hourly passenger traffic volumes at an air transport airport throughout the year.

V.2.a The Standard Busy Rate

The standard busy rate (SBR) measure or a variation of it is a design standard that has been used in the United Kingdom and elsewhere in Europe, most notably by the former British Airports Authority (BAA). It is frequently defined as the thirtieth highest hour of passenger flow, or that rate of flow that is surpassed by only 29 hours of operation at higher flows. The concept of the thirtieth highest hour is one that is well rooted in civil engineering practice in that this form of design criterion has been used for many years to determine design volumes of highways. Design for the SBR ensures that facilities will not operate at or beyond capacity for more than 30 hours per year in the design year, which is felt to be a reasonable number of hours of overload. The method does not, however, take explicit note of the relationship of the SBR to the actual observed annual peak volume. In practice, this relationship is likely to be on the order of Absolute peak-hour volume = $1.2 \times \text{SBR}$, but there is no guarantee that this will be so.

Table V.1 shows that in terms of aircraft movement, the ratio of the SBR to the absolute peak increases with increasing annual volume. This reflects the fact that as the traffic of an airport develops, extreme peaks of flows tend to disappear.

Annual Movements	Peak Day		Peak Hour		SBR	
	To Average Day Ratio	Number	To Peak Day Ratio	Number	To Peak Hour Ratio	Number
10,000	2.666	73	0.1125	8	0.688	6
20,000	2.255	124	0.1051	13	0.732	10
30,000	2.045	168	0.1011	17	0.759	13
40,000	1.907	209	0.0983	21	0.779	16
50,000	1.807	248	0.0961	24	0.794	19
60,000	1.729	284	0.0944	27	0.807	22
70,000	1.666	320	0.0930	30	0.819	24
80,000	1.613	354	0.0918	32	0.828	27
90,000	1.568	387	0.0908	35	0.837	29
100,000	1.529	419	0.0898	38	0.845	32
110,000	1.494	450	0.0890	40	0.852	34
120,000	1.463	481	0.0883	42	0.859	36
130,000	1.435	511	0.0876	45	0.865	39
140,000	1.409	541	0.0869	47	0.871	41
150,000	1.386	570	0.0863	49	0.876	43
160,000	1.365	598	0.0858	51	0.881	45
170,000	1.345	626	0.0853	53	0.886	47
180,000	1.326	654	0.0848	55	0.891	49

Annual Movements	Peak Day		Peak Hour		SBR	
	To Average Day Ratio	Number	To Peak Day Ratio	Number	To Peak Hour Ratio	Number
190,000	1.309	681	0.0844	57	0.895	51
200,000	1.293	708	0.0840	59	0.899	53
210,000	1.278	735	0.0836	61	0.903	55
220,000	1.264	762	0.0832	63	0.907	57
230,000	1.250	788	0.0828	65	0.910	59
240,000	1.237	814	0.0825	67	0.914	61
250,000	1.225	839	0.0821	69	0.917	63
260,000	1.214	864	0.0818	71	0.920	65
270,000	1.203	890	0.0815	73	0.924	67
280,000	1.192	914	0.0812	74	0.927	69
290,000	1.182	939	0.0810	76	0.929	71
300,000	1.172	964	0.0807	78	0.932	72
310,000	1.163	988	0.0804	79	0.935	74
320,000	1.154	1012	0.0802	81	0.938	76
330,000	1.146	1036	0.0799	83	0.940	78
340,000	1.137	1060	0.0797	84	0.943	80
350,000	1.130	1083	0.0795	86	0.945	81
360,000	1.122	1106	0.0793	88	0.948	83
370,000	1.114	1130	0.0791	89	0.950	85
380,000	1.107	1153	0.0788	91	0.952	87
390,000	1.100	1176	0.0786	92	0.954	88
400,000	1.094	1199	0.0785	94	0.957	90
410,000	1.087	1221	0.0783	96	0.959	92
420,000	1.081	1244	0.0781	97	0.961	93
430,000	1.075	1266	0.0779	99	0.963	95
440,000	1.069	1288	0.0777	100	0.965	97
450,000	1.063	1311	0.0776	102	0.967	98
460,000	1.057	1333	0.0774	103	0.969	100
470,000	1.052	1354	0.0772	105	0.971	102
480,000	1.047	1376	0.0771	106	0.972	103
490,000	1.041	1398	0.0769	108	0.974	105
500,000	1.036	1420	0.0768	109	0.976	106

Table V.1 Relationship Between Annual, Peak-Hour, SBR and Peak Day Aircraft
(Source: UK Civil Aviation Authority).

The table indicates that use of the SBR method in low-volume airports could result in high (peak/SBR) ratios that, in turn, could lead to severe overcrowding for a few hours per year. The location of the standard busy hour is shown in Figure V.2.

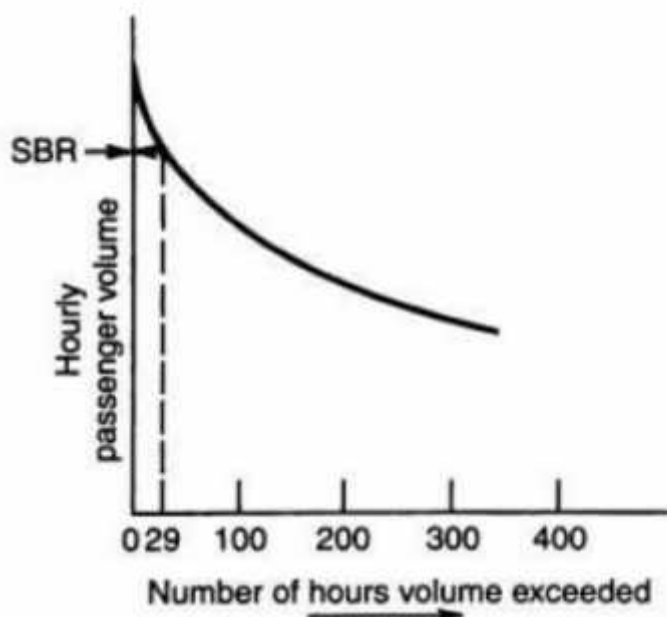


Figure V.2 Location of the standard busy rate.

V.2.b Busy-Hour Rate

A modification of the SBR that also has been used for some time is the busy-hour rate (BHR), or the 5 percent busy hour. This is the hourly rate above which 5 percent of the traffic at the airport is handled. This measure was introduced to overcome some of the problems involved with using the SBR, where the implied level of congestion at the peak was not the same from airport to airport. The BHR is easily computed by ranking the operational volumes in order of magnitude and computing the cumulative sum of volumes that amount to 5 percent of the annual volume. The next ranked volume is the BHR. This is shown graphically in Figure V.3.

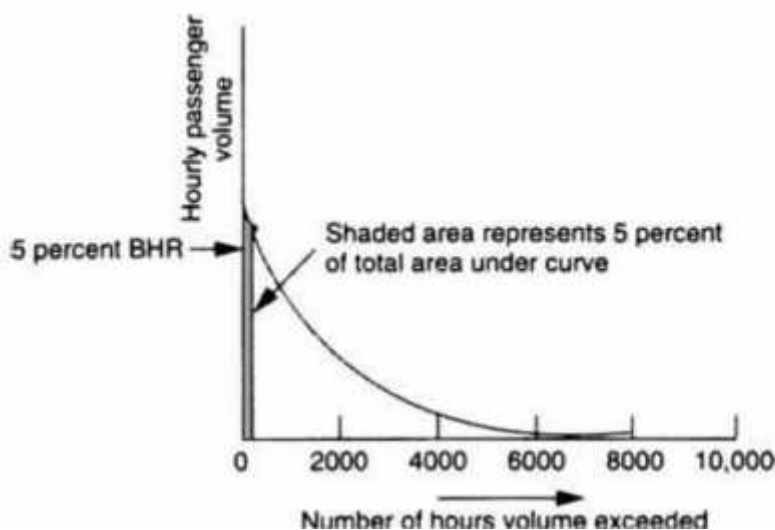


Figure V.3 The 5 percent busy-hour rate.

V.2.c Typical Peak-Hour Passengers

The Federal Aviation Administration uses a peak measure called the typical peak hour passengers (TPHP) that is defined as the peak hour of the average peak day of the peak month. In absolute terms, this approximates very closely the SBR. To compute the TPHP from annual flows, the FAA recommends the relationships shown in Table V.2. Stated in this form, it is apparent that the peak is more pronounced with respect to annual flows at small airports. As airports grow larger, the peaks flatten, and the troughs between peaks become less pronounced.

Total Annual Passengers	TPHP as a Percentage of Annual Flows
30 million and over	0.035
20,000,000–29,999,999	0.040
10,000,000–19,999,999	0.045
1,000,000–9,999,999	0.050
500,000–999,999	0.080
100,000–499,999	0.130
Under 100,000	0.200

Table V.2 FAA Recommended Relationships for TPHP Computations for Annual Figures(Source: FAA).

V.2.d Busiest Timetable Hour

This simple method is applicable to small airports with limited databases. Using average load factors and existing or projected timetables, the busiest timetable hour (BTH) can be calculated. The method is subject to errors in forecasting, the rescheduling and reequipping vagaries of the airlines and variations in average load factors.

V.2.e Peak Profile Hour

Sometimes called the average daily peak, the peak-profile-hour (PPH) method is fairly straightforward to understand. First, the peak month is selected. Then, for each hour, the average hourly volume is computed across the month using the actual length of the month (i.e., 28, 30, or 31 days as applicable). This gives an average hourly volume for an “average peak day.” The peak profile hour is the largest hourly value in the average peak day. Experience has shown that for many airports, the PPH is also close to the SBR.

V.2.f Other Methods

Although many outside the United States use some form of the SBR method to define the peak, there is little uniformity in method. In West Germany, for example, most airport authorities have used the thirtieth highest hour. Prior to introduction of the BHR, the BAA used the thirtieth highest hour or the PPH, whereas most other British airports used the thirtieth highest hour. In France, Aeroports de Paris based its design on a 3 percent overload standard. (In Paris, studies have shown that the thirtieth busy hour tends to occur on the fifteenth busiest day.) Dutch airports use the sixth busiest hour, which is approximated by the average of the 20 highest hours.

V.2.g Airport Differences

The shape of the volume curve shown in Figure V.1 differs among airports. The nature of these differences can be seen by examining the form of the curves for three airports with widely differing functions, as shown in Figure V.4.

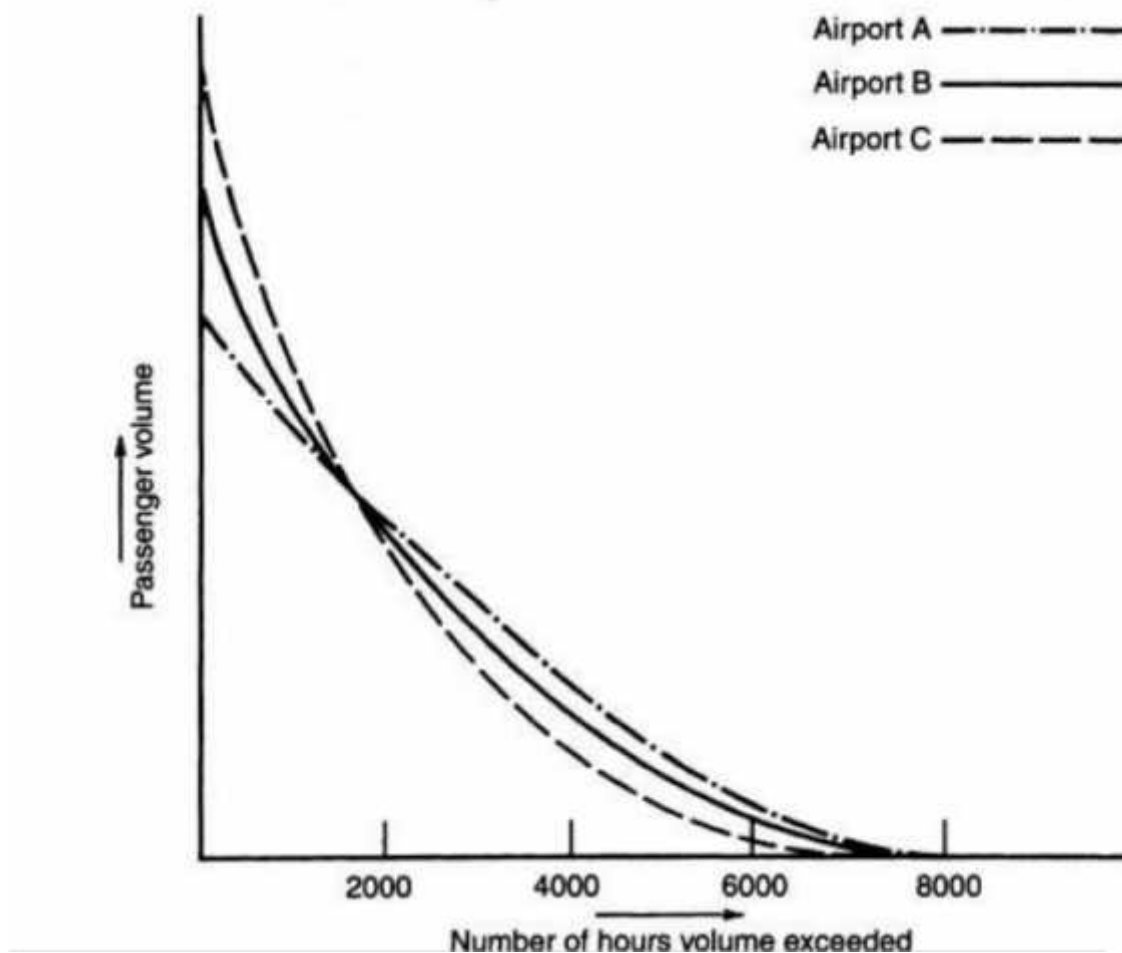


Figure V.4 Variation of passenger volume distribution curves for airports with different traffic characteristics.

Airport A: A high-volume airport with a large amount of shorthaul domestic traffic (typical U.S. or European hub).

Airport B: A medium-volume airport with balanced international/domestic traffic and balanced shorthaul/long-haul operations (typical Northern European metropolitan airport).

Airport C : A medium-volume airport with a high proportion of international traffic concentrated in a vacation season (typical Mediterranean airport serving resort areas).

Airport C will carry a higher proportion of its traffic during peak periods and, therefore, there is a leftward skew to the graph in comparison with Airport B. A typical U.S. or European hub, on the other hand, with larger amounts of domestic shorthaul traffic carries more even volumes of passengers across the period 0700 to 1900 hours, decreasing the leftward skew of the graph.

V.3 Nature of Peaks

Airport traffic displays peaking characteristics by the month of the year, by the day of the week, and by the hour of the day. The form and time of the peaks very much depend on the nature of the airport traffic and the nature of the hinterland served.

The following factors are among the most important affecting peaking characteristics:

1. Domestic/international ratio. Domestic flights will tend to operate in a manner that reflects the working-day pattern because of the large proportion of business travelers using domestic flights.
2. Charter and low-cost carrier (LCC)/scheduled ratio. Charter flights are timetabled for maximum aircraft usage and are not necessarily operated at the peak periods found most commercially competitive by scheduled airlines. Low-cost carriers also strive for maximum aircraft usage and tend to schedule flights in hours not commercially attractive to full-fare passengers.
3. Long-haul/shorthaul. Shorthaul flights are frequently scheduled to maximize the usefulness of the day either after or prior to the flight. Therefore, they peak in early morning (07:00 to 09:00) and late afternoon (16:30 to 18:30). Long-haul flights are scheduled mainly for a convenient arrival time, allowing for reasonable rest periods for travelers and crew and to avoid night curfews.
4. Geographic location. Schedules are set to allow passengers to arrive at a time when transportation and hotels are operating and can be used conveniently. For example, the six-to eight-hour eastward transatlantic crossing is most conveniently scheduled for early-morning arrivals at the European airports, avoiding curfews. Allowing for the time differences between North America and Europe, this means an evening departure from the eastern seaboard.
5. Nature of catchment area. The nature of the region served has a strong influence on the nature of traffic peaking throughout the year. Areas serving heterogeneous industrial-commercial metropolitan areas such as Chicago, Los Angeles, London, and Paris show steady flows throughout the year, with surges at the Christmas, Easter, and summer holiday periods reflecting increased leisure travel. Airports in the vicinity of highly seasonal vacation areas, such as the Mediterranean and the Caribbean, display very significant peaks in the vacation months.

Figure V.5 shows the monthly variations in traffic at several airports serving widely different geographic areas in both the northern and southern hemispheres. Daily variations in the peak week are shown in Figure V.6. The analysis is carried further by Figure V.7, which shows hourly passenger movements for two congested airports. London Heathrow's runways are operating most of the day at capacity, whereas the capacity limitation at São Paulo Guarulhos is in the terminals. The extreme peaks in São Paulo's flows are associated with severe crowding and a lowering of level of service (LOS).

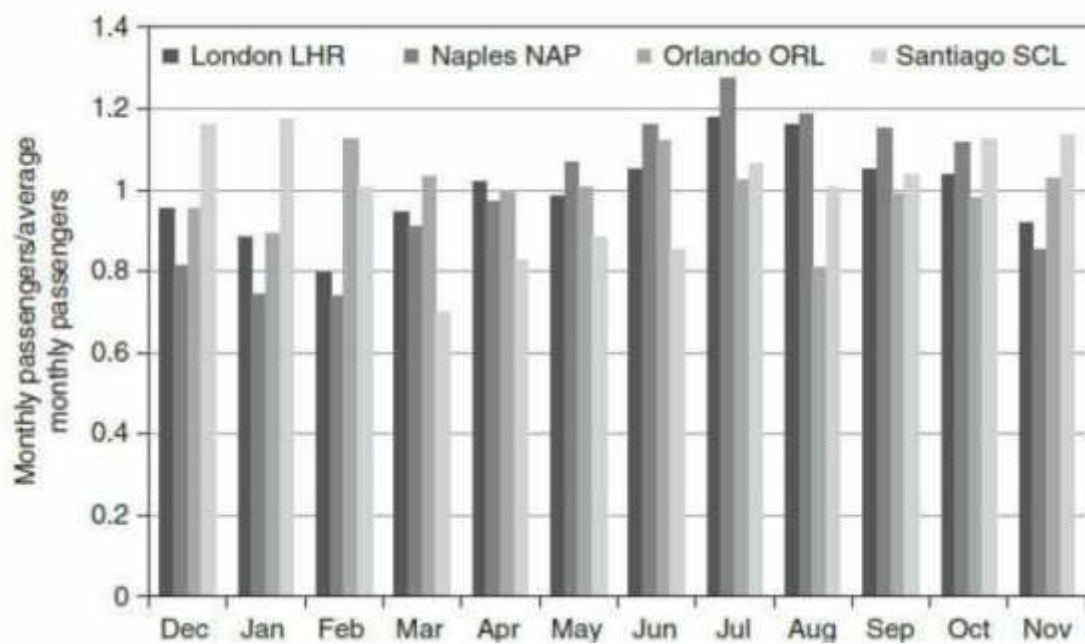


Figure V.5 Monthly variations in passenger traffic at selected airports. (Source: Reporting airports.)

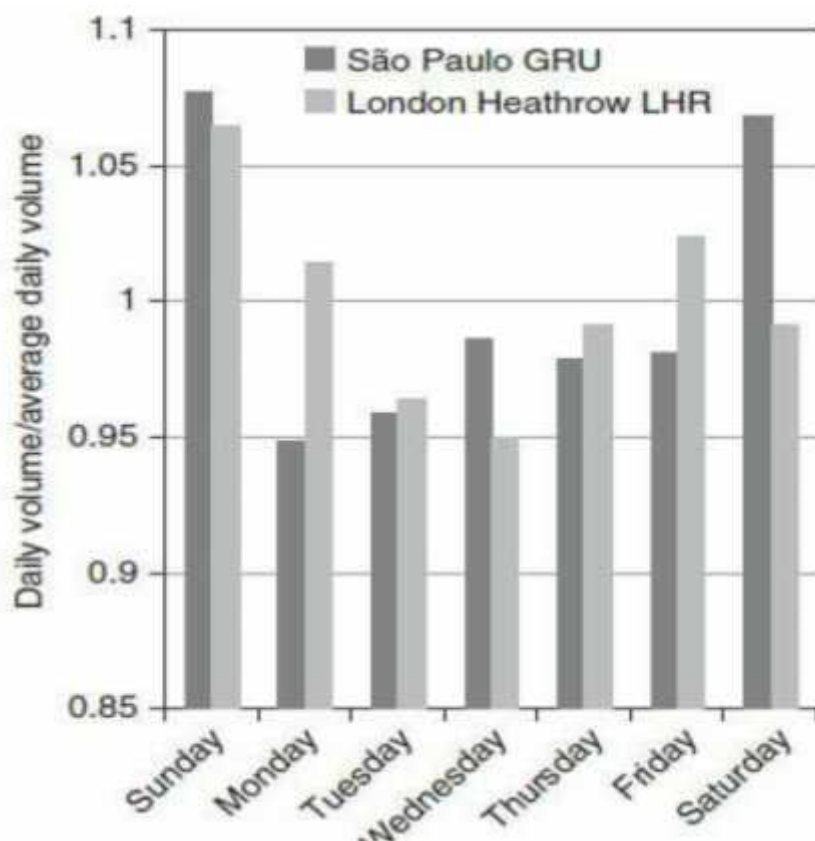


Figure V.6 Variations in passenger flows in a peak week.

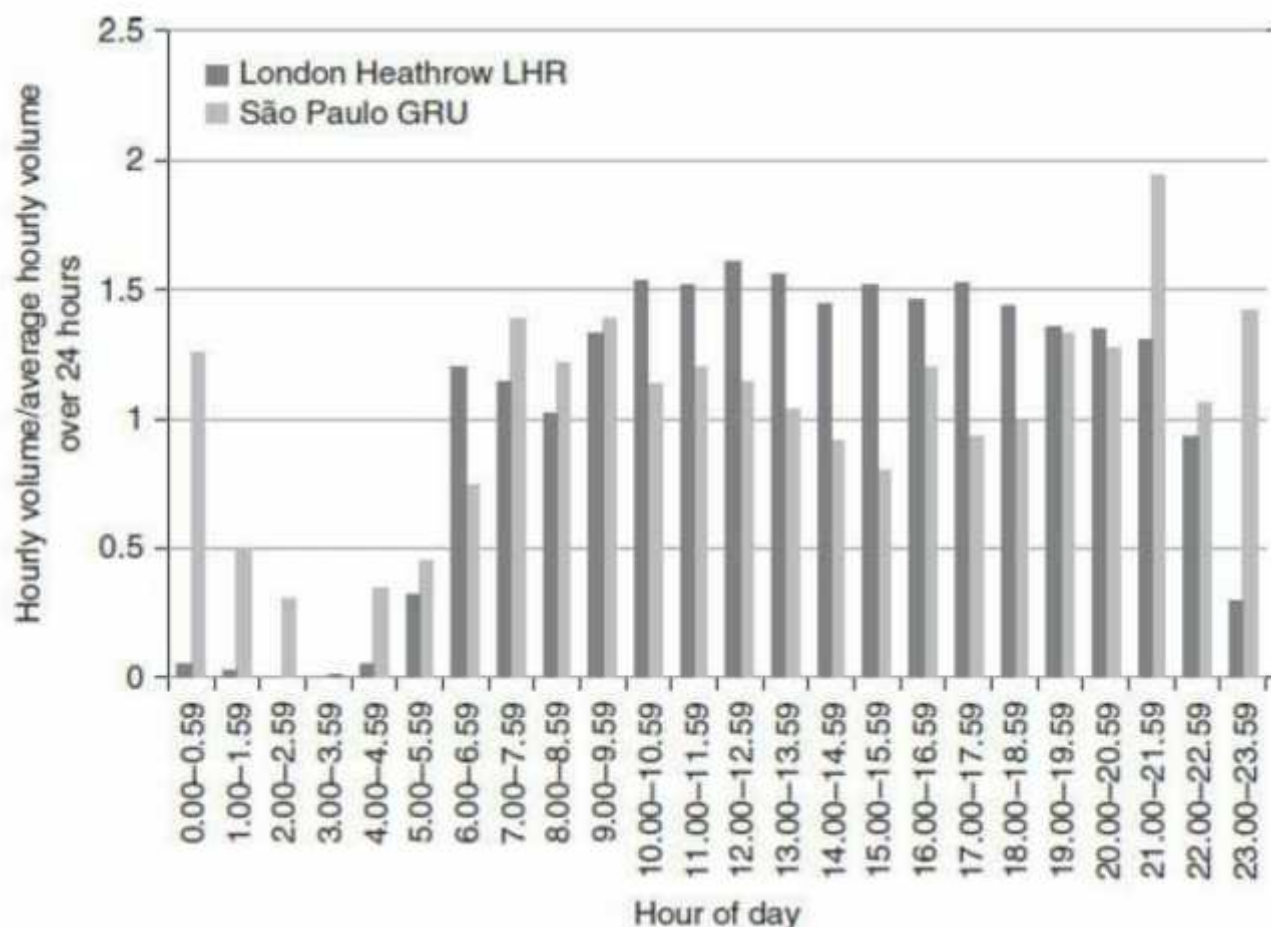


Figure V.7 Variations in hourly traffic volumes. (Source: BAA).

Despite the difference between peaks caused by the many factors that affect peaking, there is in some aspects, in fact, great overall similarity between airports. It is therefore possible to deduce general relationships between peak and annual flows at airports largely because no airport is entirely unfunctional, just as no town is entirely industrial, governmental, educational, or leisure-structured in its makeup.

Figure V.8 shows the relationship between peak flows as represented by SBR and annual flows for a number of rather diversely selected airports. Also shown on this graph are the FAA peak/annual recommended ratios, as embodied in the TPHP concept. The great similarity of the two approaches becomes apparent when they are presented graphically.

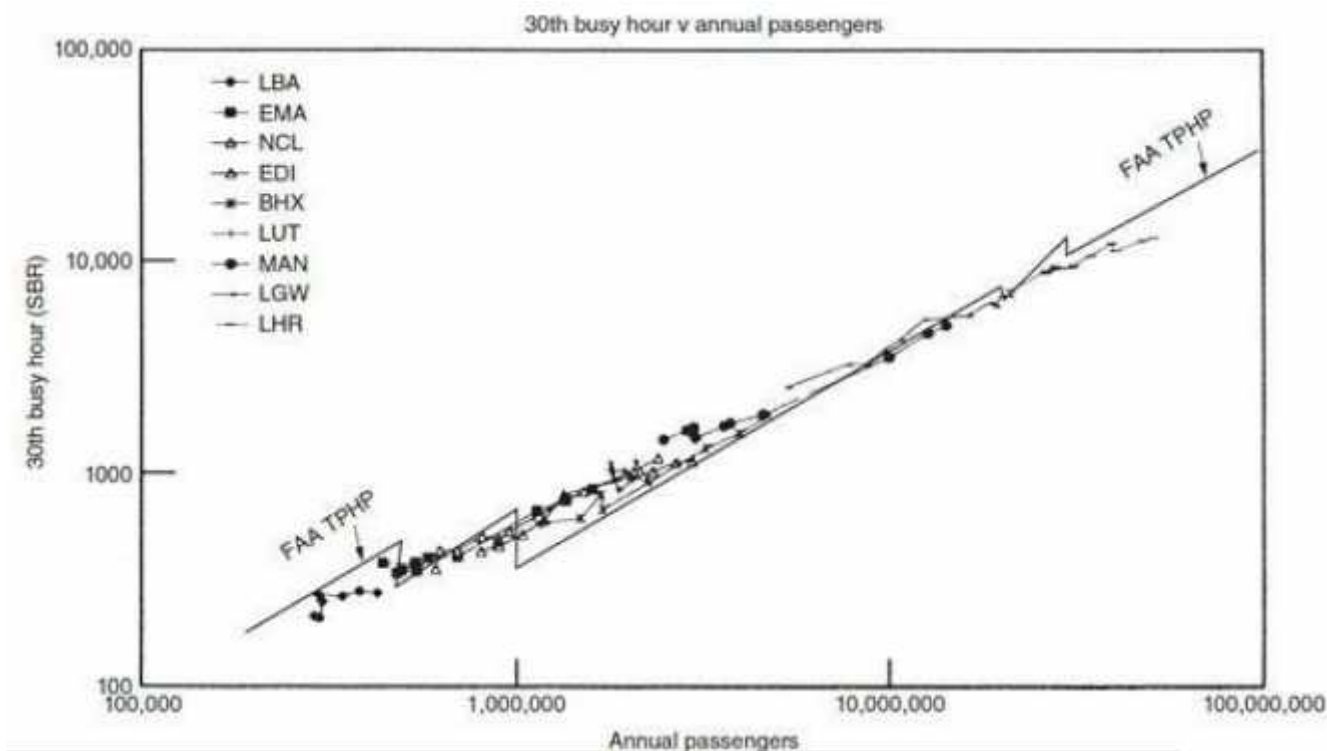


Figure V.8 Relationships among standard busy rate (SBR), typical peak-hour passenger volume, and annual passenger volume.

V.4 Implications of Variations in Volumes

It can be easily demonstrated that the demand for peak-hour schedules affects the amount of infrastructure that must be supplied by the airport. Whereas the need to implement service in an off-peak period will not necessarily involve the airport in significant marginal costs, at a crowded airport, the decision to take another service in the peak hour might well add significant marginal costs. There are, however, economies of scale that result from peak-hour operations.

Figure V.9 shows the relationship between passenger flows and air carrier aircraft operations. It can be seen that whereas passenger volumes vary significantly between peak and nonpeak hours, the same scale of variation is not observed in aircraft movement volumes. This reflects the fact that during off-peak periods, aircraft operate at lower load factors than during the attractive peak-hour slots. The implications in terms of costs and revenues need to be considered.

Services such as ramp handling, emergency services, air traffic control, runway and taxiway handling, and even some terminal services (e.g., announcements and baggage check) are based on the aircraft unit rather than on the number of passengers it carries. In off-peak hours, these services are provided at a less economic rate per passenger than during peak periods owing to low load factors during offpeak periods.

Therefore, the airport is faced with a dilemma. Although peak operations would appear to involve high marginal costs in terms of infrastructure, operation at close to peak volumes is highly economic once this infrastructure is provided. There is even a temptation for the airport to operate at flow levels above the design rate. This inevitably leads to reduced LOS in terms of processing delays and overcrowding.

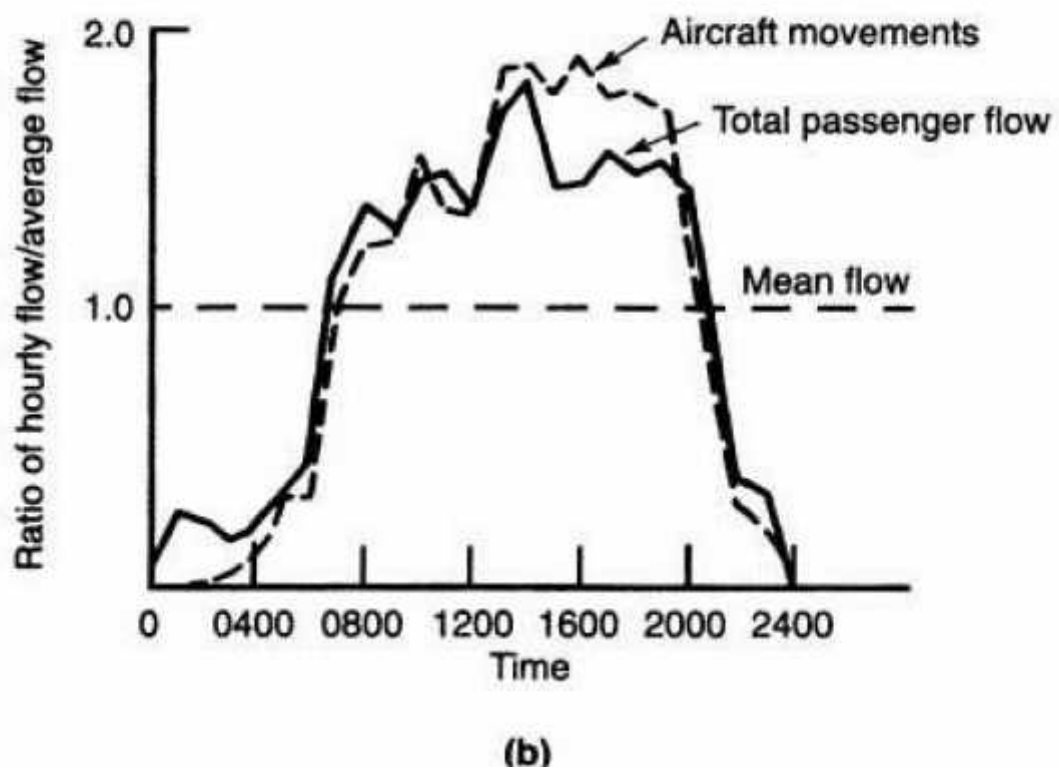
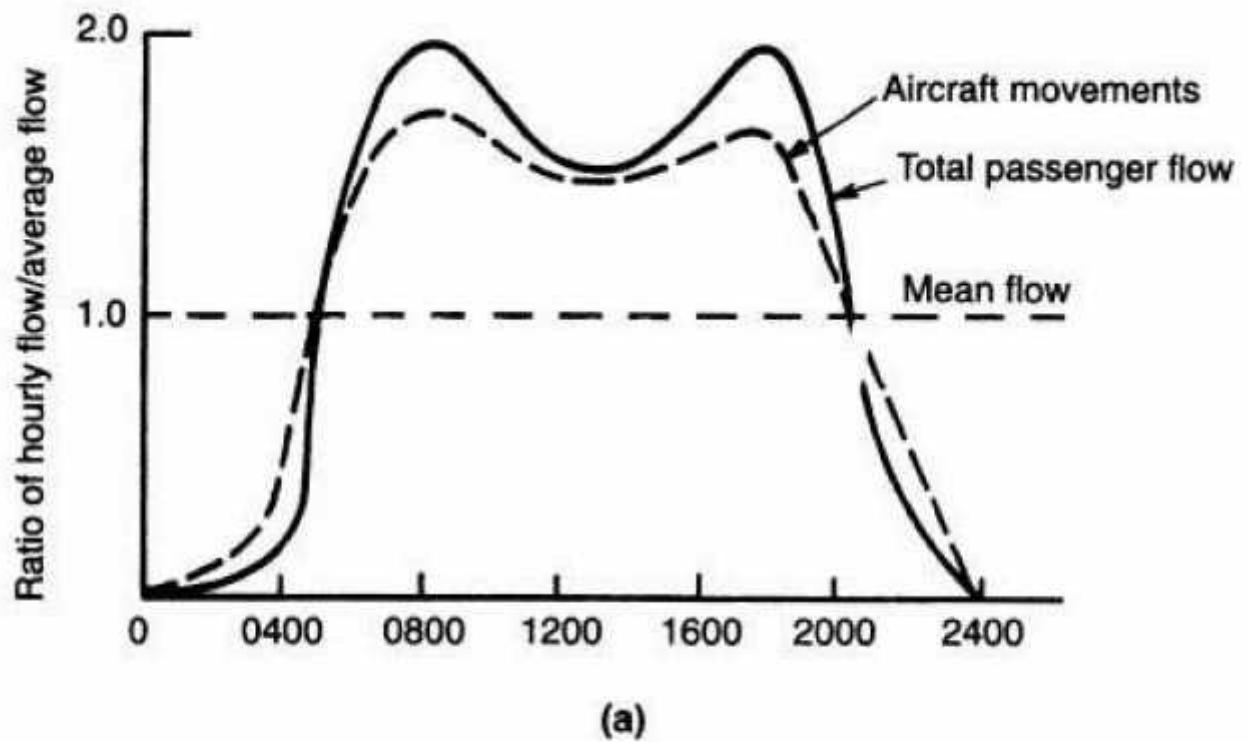


FIGURE V.9 (a) Idealized relationship between air carrier movements and passenger flow. (b) Observed relationship between air traffic movements and passenger flow at Chicago O'Hare Airport.

V.5 Factors and Constraints on Airline Scheduling Policies

The development of a schedule, especially at a major hub with capacity problems, is a complex problem for the airline. The process involves considerable skill and a clear understanding of company policies and operating procedures. Among the factors to be considered, the following are most important.

V.5.a Utilization and Load Factors

Aircraft are expensive items of equipment that can earn revenues only when being flown. Clearly, all other factors being equal, high utilization factors are desirable. However, utilization alone cannot be used as the criterion for schedule development; it must be accompanied by high load factors. Without the second element, aircraft would be scheduled to fly at less than breakeven passenger payloads, which typically are close to 70 percent on long-haul operation of a modern wide-bodied aircraft.

V.5.b Reliability

No airline would attempt to schedule using the sole criterion of maximizing utilization of aircraft. Utilization can be maximized, however, subject to the double constraints of load factors and punctuality. As attempted utilization increases, the reliability of the service will suffer in terms of punctuality. Schedule adherence is a function of two random variables: equipment serviceability and late arrivals or departures of aircraft owing to en-route factors.

Computer models are used to predict the effect of schedules on punctuality, and the result is compared with target levels of punctuality set in advance for each season.

V.5.c Long-Haul Scheduling Windows

A schedule must take into account the departure and arrival times at the various airports at origin, en route, and at destination. In 2012, Qantas offered a service between London and Sydney that called at Frankfurt, Singapore, and Melbourne. Leaving London at 18:30, the flight first called at Frankfurt 21:15/23:50, local time, avoiding the landing at Frankfurt from 01:00/04:00. The next stop on the following day was Singapore, 18:00/19:45, on the evening of the next day, followed by a call at Melbourne, 05:00/06:45, the morning of the day after that. The final leg of the flight landed at Sydney at 08:10, well after the end of the night curfew, which ran from 23:00 to 06:00. If the same service were to be attempted with a schedule to land at Sydney at least an hour and 20 minutes before the beginning of the curfew, it would have to leave London at 08:00 two days before. This is a poor time to begin a long flight because of problems accessing London Airport at such an early hour.

Departure times must be set recognizing that many passengers must travel from city centers to the airport and must arrive at the airport some reasonable time before the scheduled time of departure. The landing time at Sydney also gives too small a margin for error.

Figure V.10 provides examples of scheduling windows for flights to and from London. Eastbound transatlantic flights from New York JFK to London Heathrow take approximately seven hours, and there is a time difference of five hours between the two cities. The Heathrow night jet ban, which has few exceptions, commences at 00:00 hours and ends at 06:00 hours. Eastbound flights are therefore scheduled to take off before 12:00 hours or after 18:00 hours. Zurich has a no-exception night jet ban between 23:00 hours and 06:00 hours. Eastbound flights from New York JFK must leave either before 09:00 hours or after 16:00 hours.

Westbound flights into London Heathrow also must be scheduled to arrive outside the hours of curfew. Flights from Cairo, two hours ahead of London in time, must leave before 20:50 hours to arrive before 00:00 hours or after 02:50 hours to arrive after 06:00 hours. For flights between Cairo and Zurich, the departures are restricted to hours outside the hours between 19:50 and 02:50 hours.

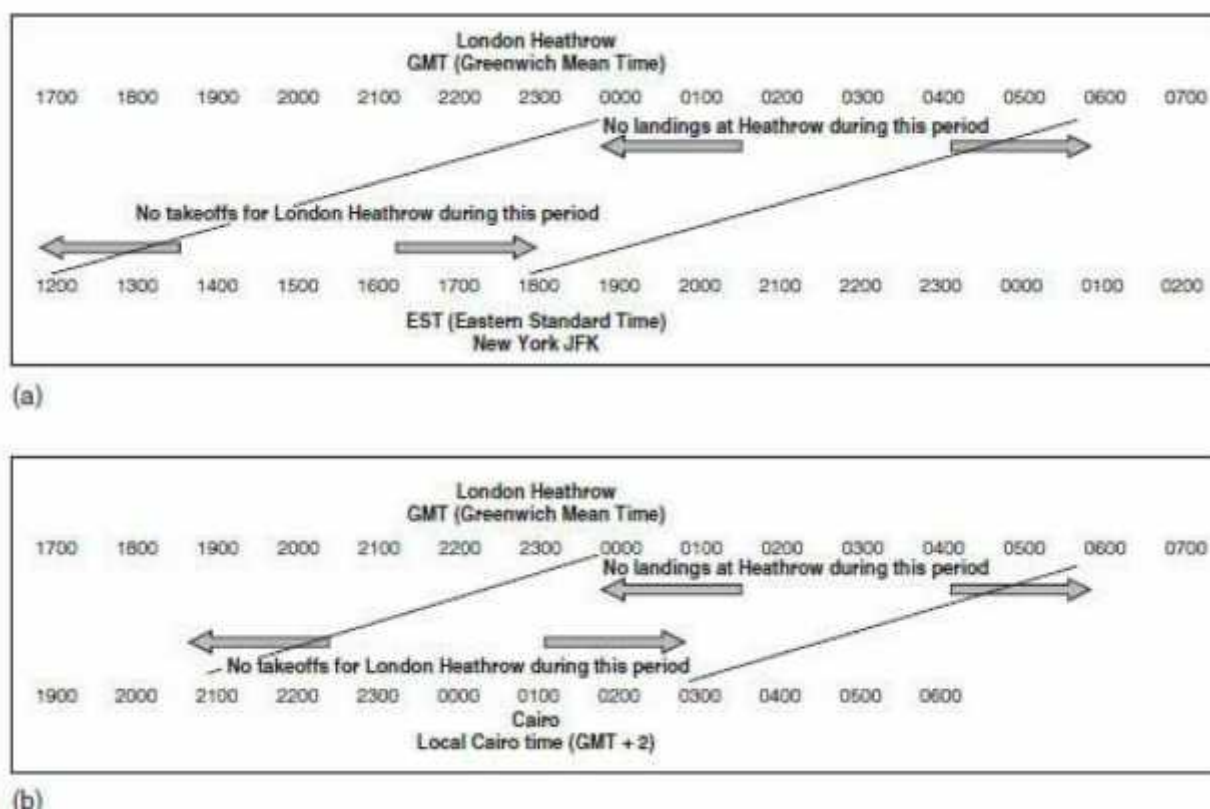


Figure V.10 Scheduling windows for eastbound and westbound flights into London Heathrow Airport.

In 2008, 53 African states complained that the night bans in Europe discriminated against their services to Europe, which were precluded by night bans on landing. It was claimed that the night bans such as those in Zurich severely restricted their services by making early morning connections in Europe possible only with very unsatisfactory takeoff times at the African departure airport.

V.5.d Airport (Runway) Slots

Runway takeoff and landing slots also must be considered. In many airports, especially in Europe, North America, and Asia, existing runways are running near to capacity during peak periods of the day. This capacity is limited owing to the necessary safety margins required in the separation of arriving and departing aircraft. Many airports near their slot capacity are coordinated. This means that a regulatory authority such as the FAA or the Civil Aviation Authority (CAA) has to determine and allocate a number of slots as being available to arriving or departing flights. Actual coordination is carried out semiannually at International Air Transport Association (IATA) slot conferences. A carrier often will have the right only to its historical slots, provided that these are being used. Consequently, at a coordinated airport, any carrier will be uncertain whether it will be possible to move from its historic slots or gain more slots. This situation poses problems to schedulers, who must make assumptions on the likely slots available to them.

V.5.e Terminal Constraints

Another constraint faced by schedulers is that of airport passenger apron and terminal capacity. Many airports are operating only slightly below the capacities of these facilities often as built 20 or more years earlier. In the case of terminals, authorities often limit the number of passengers that can pass through a terminal during a half-hourly period, stating that this flow is the “declared capacity.” This obviously sets a limit on the number of arrivals, departures, or combinations of aircraft apron movements that can be scheduled in capacity constrained periods, presenting schedulers with yet another hurdle.

V.5.f General Crewing Availability

In addition to the special problems associated with layovers of long haul flight and cabin crews at slip airports, all schedules must be built around the availability of maintenance, ground, air, and cabin crews. There is clearly a very strong interrelationship between the numbers of various crew personnel required and the operations to be scheduled, especially in terms of mixed short-and long-haul flights.

V.5.g Aircraft Availability

Airlines must schedule the use of their aircraft in a manner that reflects the needs of routine maintenance checks. The individual manufacturers provide advice on aircraft maintenance programs, but each operator needs approval of its continuous inspection program from its appropriate airworthiness regulatory authority, for example, the FAA, Transport Canada, or the European Aviation Safety Agency (EASA). Most aircraft maintenance organizations use an approach based on Boeing’s Maintenance Steering Group recommendations, which require four different kinds of checks:

- A Check. This is a light check carried out every 500 to 800 hours, usually overnight at an aircraft stand.
 - B Check. This is also a light check usually carried out overnight at the aircraft stand, usually every three to five months.
 - C Check. This is a heavy-maintenance check carried out in a hangar at approximately 15 to 21 months.
 - D Check. Also known as a heavy maintenance visit (HMV), this check is carried out every four to six years and requires several months in a hangar.
- On a large aircraft, as many as 100 technicians may be involved.

V.5.h Marketability

The scheduled times of departure or arrival must be marketable by the airline. Connections are especially important at major transfer points, such as Atlanta, London, and Singapore. Whenever possible, passengers avoid long layovers at an airport. Other factors that the airline considers are that departure and arrival times at major generating hubs must be at times when public transport is operating and may have to coincide with hotel checkin and check-out times and room availability. It is also important to have continuity of flight times across the days of the week if the flight operates several times a week.

V.5.i Summer-Winter Variations

Where there is a large amount of seasonal traffic, usually vacation related, there can be substantial differences in scheduling policies between summer and winter operations. The large variation in demand that can occur at airports serving such areas as Florida and the Bahamas, the Caribbean, and the

Mediterranean resort areas is substantial, and this will affect the schedules of airports with which their services link. Seasonal variations also are large at airports such as Munich that serve ski resorts.

V.5.j Landing-Fee Pricing Policies

At some airports, an attempt has been made to vary landing and aircraft-related fees in order either to use a pricing policy to spread peaking or to recoup extra finance for operations carried out in the uneconomic night hours. An example of the former policy is that which was used by the former BAA, which at a stroke adopted punitive peak-hour tariffs at London Heathrow to encourage airlines to transfer operations from Heathrow to Gatwick airports and to move operations from the peak period. Under this policy, a typical turnaround of a long-range B747 at Heathrow during the peak period was 2.8 times the cost for an operation outside the peak tariff times and 183 percent of the cost that would have been involved had the operation taken place at the less popular London Gatwick airport at the same peak time. The effect of this peak tariff was not large, as can be seen in Table V.3, which shows the observed operational impact of this particular differential tariff.

	London Heathrow Airport: Peak Passengers as a Percentage of Total Passengers			
	July	August	September	October
1976 (prepeak tariffs)	30.7	30.8	30.4	30.5
1977 (postpeak tariffs)	29.7	26.3	24.5	24.3

Table V.3 Effect of Peak Tariffs on Traffic.

In general, there is little evidence to indicate that airlines do reschedule significantly to avoid such tariffs. Airline operators claim that there are far too many other constraints precluding massive rescheduling outside peak-demand periods and that, therefore, such tariffs are almost entirely ineffective in achieving their proclaimed purpose.

The truth would appear to lie somewhere between these two positions. Where there is no differential peak pricing, airlines have no particular incentive, other than congestion induced delay costs, to move operations from the congested peak period. On the other hand, the commercial viability of a flight and its ability to conform to bans and curfews might necessitate operations in peak hours.

High differentials for peak operations might appear at first to be a reasonable step for the operator to take to spread congestion.

However, any such action should be evaluated in light of the impact on the based carriers whose operations inevitably represent a very large proportion of the airport's total movements. The short-term economic gain to the airport could put a long-term economic strain on the finances and competitiveness of the based carriers. Withdrawal of services, movement of the airline base, or even collapse of the carrier will have a serious financial impact on the airport.

The second type of tariff that was instituted to support uneconomic operations during slack night hours is exemplified by a surcharge on handling fees formerly levied at Rome for arrivals and departures between 19:00 and 07:00. This amounted to a 30 percent surcharge if operations occurred within the period. A tariff of this nature has the bizarre effect that a transiting aircraft arriving and departing in a period that is partly within the surcharge period can in fact halve the surcharge by remaining on the stands for five more minutes, consequently using more airport resources.

There is in fact a very wide variation in the manner in which airports structure landing fees. Table V.4 shows that for the major airports, landing fees are often computed from some combination of :

- Aircraft weight.
- Apron parking requirements.
- Passenger load.
- Noise level created.
- Emissions charge.
- Security requirement.
- Peak surcharge.

Airport	Country	Landing Charge		Parking Charge		Passenger Charge	
		Fixed	Variable	Fixed	Variable	Arrival	Departure
Dusseldorf	Germany		X		X		X
Faro	Portugal		X		X		X
Miami	USA		X		X		X
Montego Bay	Jamaica		X		X		X
Orlando	USA		X		X		X
Bridgetown	Barbados		X		X	X	X
Athens	Greece		X		X		X
Manchester	UK		X		X		X
London Gatwick	UK		X		X		X
Madrid	Spain		X		X		X
Amsterdam	Netherlands		X		X		X
Brussels	Belgium		X		X		X
Frankfurt	Germany		X		X		X

TABLE V.4 Aeronautical Fee Structures at Selected International Airports, 2010

There is a very large variation among airports when it comes to the cost of a turnaround. Tables V.5 illustrates, for a selected number of airports, the large range of charges involved in the turnaround of a Boeing 737 under identical base assumptions.

These data are further illustrated by Figure V.11, which graphically shows the variation among the same airports. It is clear that most of the variation is caused by the introduction of passenger charges and government tax.

a. Turnaround Charges Classified by Area Incurred												
	USD KUL	USD MEX	USD DXB	USD MAD	USD WAW	USD AKL	USD SVO	USD DEL	USD LHR	USD JNB	USD ORD	USD NRT
Landing	\$80	\$217	\$414	\$824	\$1,361	\$1,126	\$1,390	\$508	\$1,076	\$2,579	\$963	\$3,991
Parking	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$101	\$0	\$0	\$203
Infrastructure/services	\$27	\$276	\$106	\$489	\$238	\$0	\$0	\$172	\$86	\$0	\$0	\$1,267
Passenger	\$2,369	\$2,474	\$2,693	\$2,323	\$2,350	\$3,011	\$3,072	\$3,867	\$6,222	\$5,102	\$6,879	\$4,174
TAX	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$11,117	\$0	\$4,336	\$0
b. Turnaround Charges Classified Description of Method of Charging												
	USD KUL	USD MEX	USD DXB	USD MAD	USD WAW	USD AKL	USD SVO	USD DEL	USD LHR	USD JNB	USD ORD	USD NRT
Landing	\$80	\$217	\$295	\$790	\$976	\$784	\$830	\$374	\$758	\$2,579	\$963	\$1,676
Noise Emissions									\$75			
Parking									\$101			\$203
Infrastructure/services		\$175		\$331	\$111			\$172	\$86			\$1,100
Airbridge	\$27	\$102	\$106	\$158	\$127							\$167
TNAV			\$120	\$34	\$384	\$342	\$561	\$134	\$242			\$2,315
Passenger	\$2,120	\$2,306	\$2,448	\$1,933	\$2,350	\$2,210	\$2,234	\$3,867	\$6,222	\$4,637	\$6,879	\$3,319
Security	\$249	\$167	\$245	\$389		\$801	\$838			\$465		\$855
TAX									\$11,117		\$4,336	
Total without tax	\$2,475	\$2,967	\$3,213	\$3,635	\$3,949	\$4,137	\$4,463	\$4,547	\$7,486	\$7,681	\$7,842	\$9,635
Total with tax	\$2,475	\$2,967	\$3,213	\$3,635	\$3,949	\$4,137	\$4,463	\$4,547	\$18,603	\$7,681	\$12,178	\$9,635

Table V.5 International Airport Charges for Selected Airports, 2010 (U.S. Dollars)

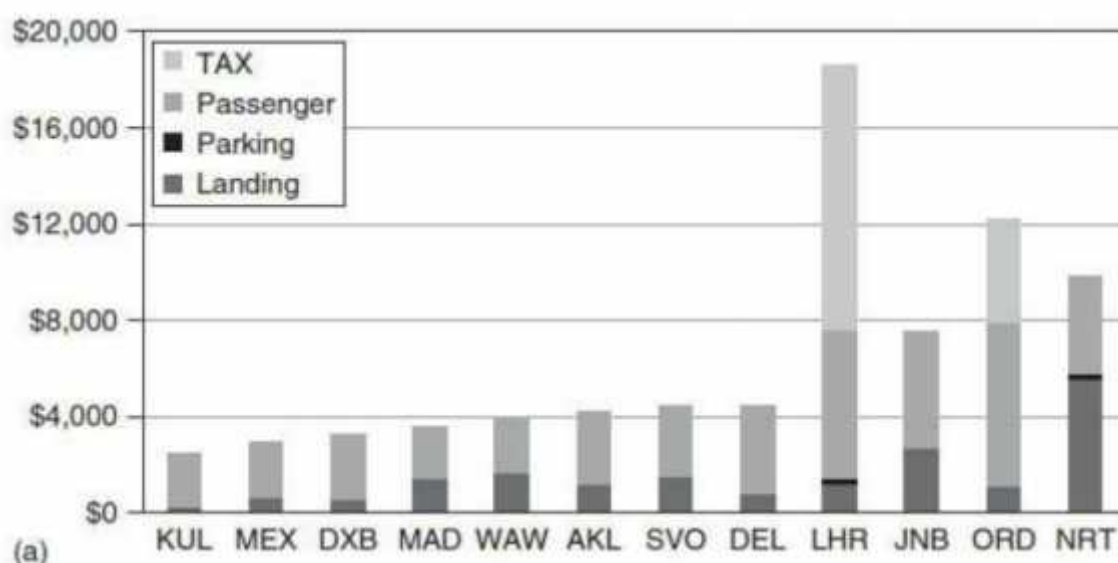


Figure V.11.a : Turnaround charges by type.

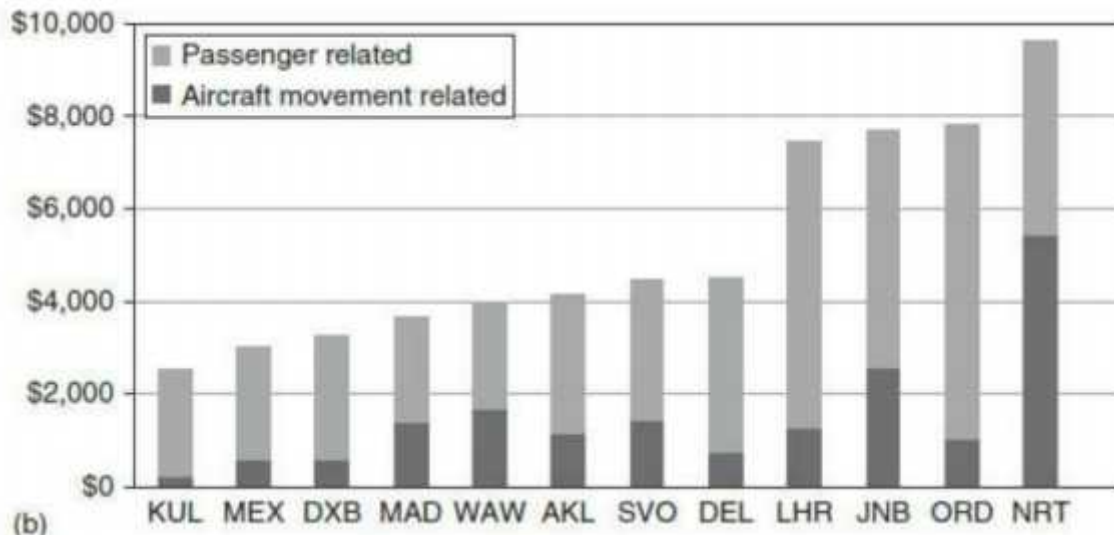


Figure V.11.b : Turnaround charges, passenger related/ aircraft-related.

V.6 Scheduling Within the Airline

As a fundamental element in the supply side of air transport, the question of scheduling involves a large number of persons and sections within the structure of the airline itself. A typical functional interaction chart is shown in Figure V.12. The commercial economist takes advice from market research and interacts with the various route divisions, which control the operations of the various groupings of the airline routes. In some airlines, there are no route divisions. The commercial economist and route divisions are both part of the commercial department in this case. In advising schedules planning, which is concerned with the overall planning of the airline's schedule, the commercial economist will take note of a number of factors that affect the decision as to whether or not to attempt to incorporate a service within a schedule. These factors could include some of the following:

- Currently available route capacity
- Fare structure (i.e., standby, peak, night, etc.)
- Aircraft type
- Competition

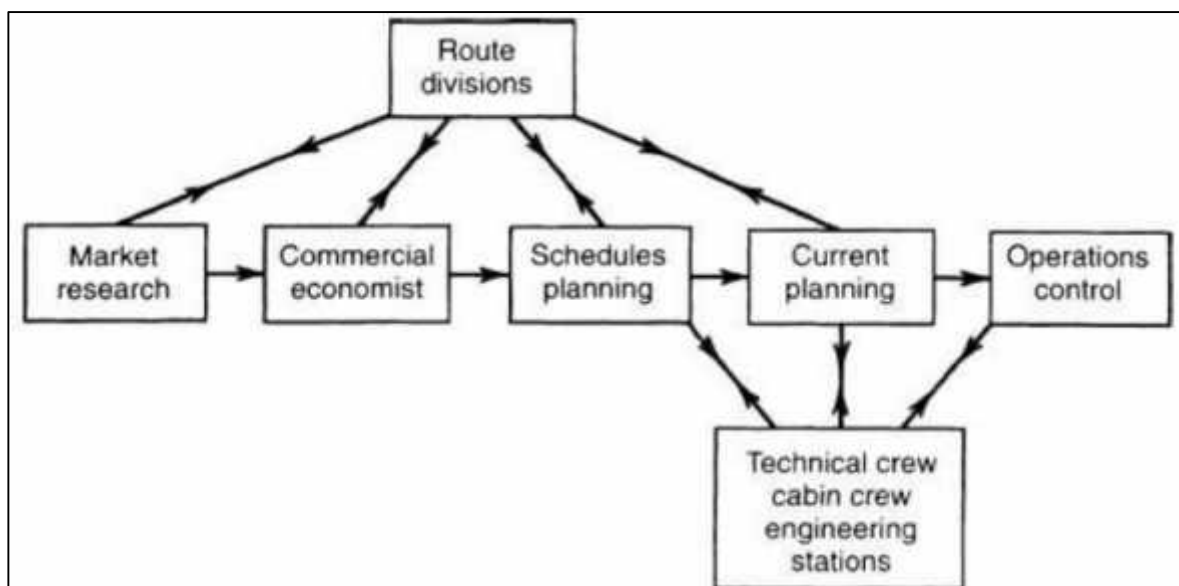


Figure V.12 Organization of scheduling within a typical airline.

Once the decision has been made that a service should be incorporated into the schedule, the schedules planning section of the airline, which is frequently divided into long-and shorthaul functions, will examine the scheduling implications of planning the service. At this stage, the factors that affect the planning include:

- Length of haul long or short.
- Availability of aircraft allowing extras for aircraft in maintenance and on standby.
- Acceptability of service schedule to the airport.
- Availability of technical, flight, cabin, and engineering crews.
- Clearances with countries concerned where there are no bilateral agreements to overfly or use airports for technical stops.

When schedules planning is satisfied that all overall planning considerations have been resolved satisfactorily, the service is passed to current planning, which is charged with the implementation of the particular service schedule. This is done in conjunction with input from the technical, cabin, engineering, and stations staffs. The final implementation of the service is carried out under operations control, which deals with daily operations and the need to provide service in terms of difficulties from crew sickness, fog, ice, delays, aircraft readiness status, and so on.

V.7 Fleet Utilization

Figure V.13 presents two fleet utilization diagrams for an airline using one smaller fleet of relatively new aircraft and another larger fleet of older aircraft. Several points are noteworthy. First, the aircraft in service are heavily used between the hours of 07:00 and 22:00; there is little use of these aircraft outside these hours because they constitute part of the short-and medium-haul fleet of this carrier. Second, where there is a small young fleet, there are no standby aircraft, and maintenance is carried out in the night time hours. For older and larger fleets, aircraft are withdrawn from service for maintenance, and several aircraft are held back as standby units for use should an aircraft have to be withdrawn for maintenance or repair. Low-cost carriers tend to have fewer standby aircraft, accepting that equipment failure will result in cancellation of services.

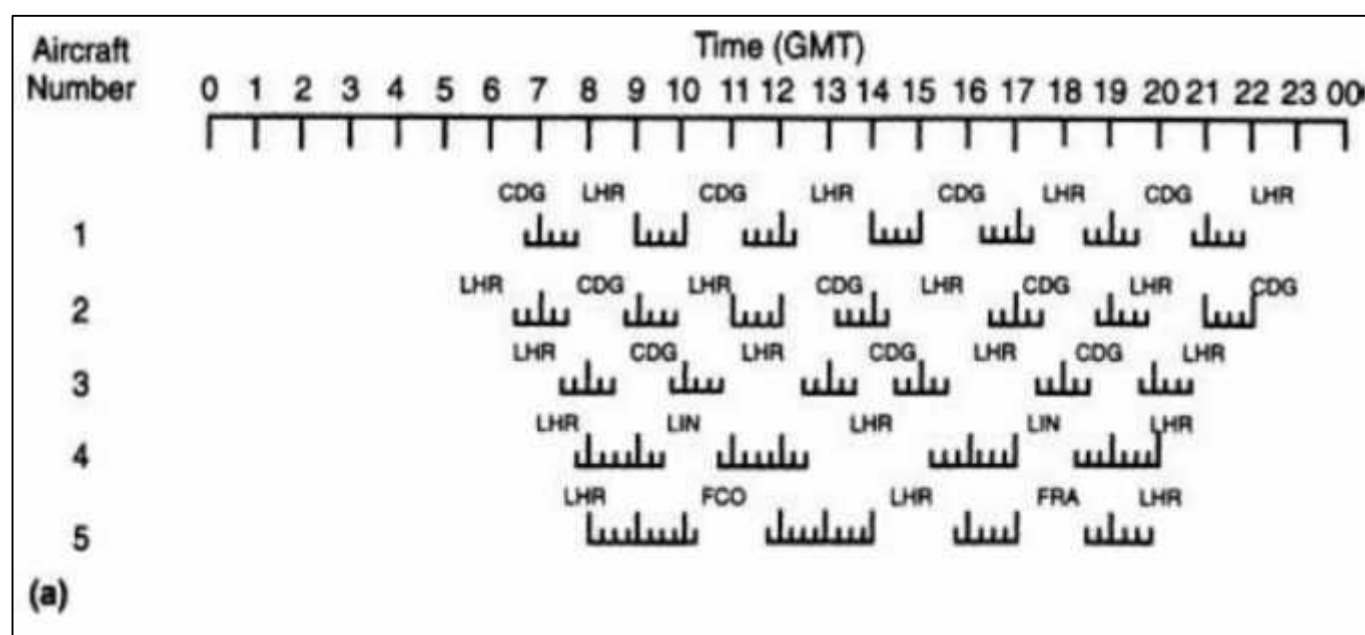


Figure V.13.a : Use of a small new fleet for shorthaul operations.

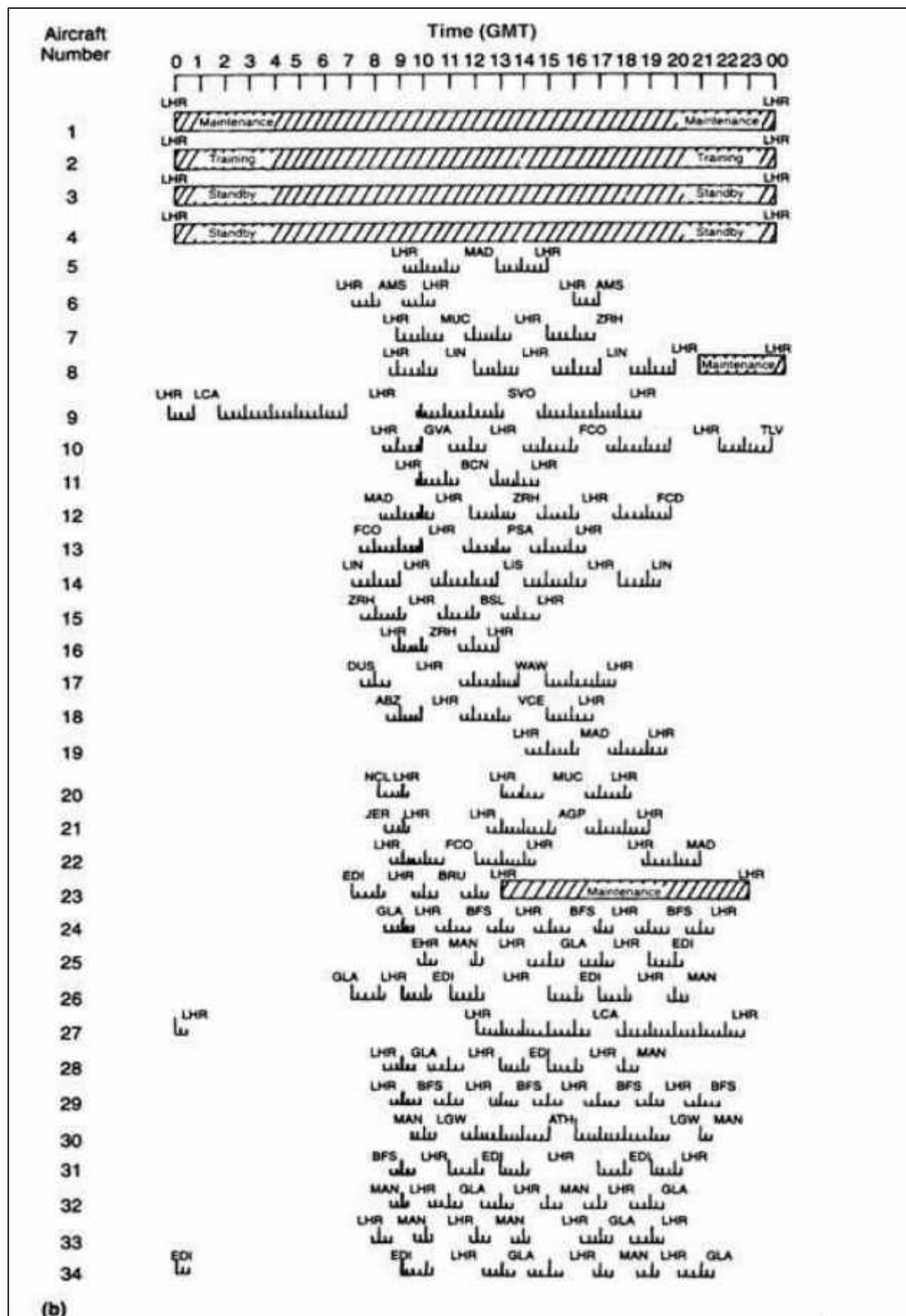


Figure V.13.b : Use of a large older fleet for short-and medium-haul operations.

V.8 IATA Policy on Scheduling

The scheduled airlines industry organization, IATA, has developed a general policy on scheduling that is set out in its Worldwide Scheduling Guidelines. At some airports, there are official limitations, and the coordination is likely to be carried out by general governmental authorities. Much more common is the situation where the airlines themselves establish an agreed schedule through the mechanism of the airport coordinator. It is recommended that the airport coordinator be the national carrier, the largest carrier or an agreed coordinating agent. Coordination compiles a recognized set of priorities that normally produce an agreed schedule with minimum serious disagreement.

These priorities include:

1. Historical precedence to slots in the next equivalent season.
2. Effective period of movement. Where two or more airlines are competing for the same movement slot, the airline intending to operate for the largest period of time has priority.
3. Emergencies. Short-term emergencies are treated as delays; only long-term emergencies involve rescheduling.
4. Changes in equipment, routing, and so on. Applications for a schedule of new equipment at different speeds or adjustments to stage flight times to make them more realistic have priority over totally new demands for the same slot.

Aviation is a mixture of a number of segments that can be broadly classified into regular scheduled, programmed charter, irregular general aviation, and military operations.

It is the function of the airport to arrange to afford appropriate access to any limited facility after consultation with the representative of the categories. IATA's policy states that the aims of coordination are :

- To resolve problems without recourse to governmental intervention.
- To ensure that all operators have an equitable opportunity to satisfy their scheduling requirements within existing constraints.
- To seek an agreed-on schedule that minimizes the economic penalties to the operators concerned.
- To minimize inconvenience to the traveling public and the trading community.
- To arrange for regular appraisal of declared applied limits.

Schedules are set on a worldwide basis at the semi annual IATA scheduling conferences for the summer and winter seasons. More than 100 IATA and non-IATA airlines meet at these huge conferences where, by a process of reiterated presentation of proposed schedules, the airport coordinators eventually are able to set an agreed-on schedule for the airports they represent.

V.9 The Airport Viewpoint on Scheduling

Most large airports with peak-capacity problems have strong and declared policies that affect the manner in which scheduling is carried out. The viewpoint of the airport operator is that which represents not only its own needs but also the interests of air travelers, the airlines as an industry group, and in some cases even the nontraveling public. These interests are protected by obtaining a schedule that provides for the safe and orderly movement of traffic to meet the needs of passengers within the economic and environmental constraints of the airport. The viewpoints of the various interested parties differ substantially. The airport operator seeks an economic and efficient operation within the constraints of the facilities available. Air travelers are looking for travel in reasonably uncongested conditions with a minimum of delays and a high frequency of service at desirable times unmarred by unreliability. As an

industry group, the airlines are also seeking efficiency of operation and high frequency and reliability of service. However, each airline quite naturally will desire to optimize its own position and will seek to gain its own best competitive situation. In the case of the airlines, the aims of the individual company are not necessarily the same as the interests of the industry group. At some airports, nontravelers become involved where limits have been set for environmental reasons on the number of air transport services that can be scheduled, such as at London Heathrow, where there was a limit of 275,000 air transport movements per year. This restraint was lifted in the mid-1980s, and by 2010, the number of annual movements had increased to more than 466,000 with very little increase in night time movements. The increased capacity was achieved almost entirely by peak spreading, or infilling the nonpeak troughs. Similar aircraft movement constraints exist at Ronald Reagan Washington National Airport. It is the custom of many airports to declare their operational capacities at six-monthly or annual intervals. This operational capacity is observed by the scheduling committee, which consists of representatives of the scheduled airlines serving the airport. Normally, the airport operator is not represented directly on this committee. As already stated, the airport's interests are represented by the major carrier at the airport. At Los Angeles, this is United Airlines; at Frankfurt, it is Lufthansa; and at London Heathrow, British Airways. Therefore, the airport that has capacity limitations is often in an arm's-length relationship with the individual airlines seeking additional services.

V.10 Hubs

There is some ambiguity in the term hub when used in the context of air transport. Prior to deregulation of the airlines, the FAA used the term to designate large airports serving as the major generator of services, both international and domestic, within the United States. With the advent of deregulation, airlines were able to control LOS in terms of routes and frequencies. This enabled the establishment of what the airlines designated as hubs, which provided services both to other major airports also designated as hubs and to smaller airports providing spoke services. The airline hubbing system was associated with much greater frequency of services between hubs and from the spoke airports, supposedly accompanied by higher load factors on the aircraft. Direct services between smaller nonhub airports generally were abandoned. Some airports operate as hubs for one airline only (e.g., Newark, NJ, for Continental and Rome Fiumicino, Alitalia). Others, such as New York JFK, London Heathrow, and Changi Singapore are hubs for two or more airlines. Hubbing presents airlines with the opportunity to use better their aircraft and passengers with many more flight combinations, although these combinations almost always require transfer at the hub. Flights from hubs are usually nonstop, and those to other hubs are usually in larger, more comfortable aircraft than formerly. Flights to spoke airports are often on smaller aircraft with capacities of fewer than 50 persons.

The effectiveness of a hub airport depends on :

- Its geographic location.
- The availability of flights to multiple destinations.
- The capacity of the airport system to handle aircraft movements and passenger volumes.
- The ability of the terminal layout to accommodate passenger transfers.

Hub airports have very different patterns from airports supporting long-haul flights on predominant sectors. When operating as an airport with a two-airline hub operation, Dallas–Fort Worth reported 12 peaks throughout the day during which aircraft are on the ground providing for transfers. Therefore, aircraft ... arrive and depart in 12 arrival and departure waves, which in FAA terminology are described as banks. Hub terminals in the United States typically have high terminal usage, with peaks occurring at roughly two-hour intervals between 07:00 and 22:00 hours. Similar successions of banks have been analyzed at the U.S. Airways hubs at Philadelphia, where 11 banks were recorded, and at Pittsburgh, PA and Charlotte.

Conclusion

- The future of airports as part of the civil aviation system is certainly an open book, with no foreseeable conclusion. However, much of the fundamentals that govern airports and airport management will, for the most part, remain a constant.
- The fundamental physics of flight will never change, nor will the fundamentals that govern air traffic operations. Technologies are sure to change, as are the regulations and funding mechanisms that facilitate the adaptation of technologies. The policies that direct the process of aviation are sure to change as well.
- It is the responsibility of airport management and others with interests in air-port operations to constantly evolve their knowledge of this ever-changing industry. A constant maturation of airport management from a business, operations, and public relations standpoint, along with a working knowledge of the fundamentals that form the foundation of the industry, will no doubt contribute to civil aviation being a most important part of our world's transportation and social framework.
- The link between air transport growth and economic and social development is becoming increasingly important as a result of the emerging global economy/society. Forecasts indicate a strong and sustained increase in demand over the next two to three decades, suggesting that the development of many city regions or even countries will be linked to the development of their airports.
- Sustainable development requires that this growth be compensated for through improving environmental performance, and this in itself will put new pressures on airport operators. But the challenge will be even more significant because it is clear that in the future, environmental pressures will build on the industry. These will arise from the changing climate, emerging science, new regulations, increasing costs, and changing public and political attitudes.
- Delivering ongoing environmental performance improvement and responding to emerging political pressures and regulations will have implications for all airport service partners, requiring a collaborative approach across the airport site.
- Environmental pressures are currently most evident at larger airports, in regions of the world where aviation is most mature, where environmental pressures and regulations are most onerous, and where quality-of-life expectations are highest. But future growth is forecast to be the strongest in the emerging economies and in particular the BRIC (Brazil, Russia, India, and China) countries, leading to massive infrastructure development, China plans to expand 91 airports, construct 56 new airports, and move 16 to new sites.
- In this context, it is critical that airport operators across all parts of the world (but particularly in regions of highest growth) have a good understanding of the principles of sustainable development of airports with environmental management at a strategic and operational level.
- Furthermore, airports need to develop cost-effective responses with their service partners to underpin ongoing growth.

Assignment

Assignment Title: Presentation on the Algerian Airport Network and EGSA

Objective:

To enable students to apply the theoretical knowledge acquired during the Airport Management course by analyzing the Algerian airport network and the role of EGSA (Airport Services Management Establishment). This activity also serves as preparation for the defense of the Master's final project.

Instructions:

-) Students must prepare and deliver a **30-minute presentation**.
-) The topic should cover:
 1. Overview of the Algerian airport network (infrastructure, main airports, traffic).
 2. Role and organization of EGSA in managing airport services.
 3. Challenges and opportunities in Algerian airport management.
-) The presentation must demonstrate both technical understanding and management perspective.

Expected Outcomes:

-) Application of course concepts to a real-world case.
-) Development of analytical and presentation skills.
-) Preparation for the Master's thesis defense.

Evaluation Criteria:

-) Clarity and structure of the presentation (25%)
-) Depth of analysis and use of technical knowledge (30%)
-) Relevance of information and examples (20%)
-) Presentation skills (15%)
-) Time management and respect of the 30-minute limit (10%)

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