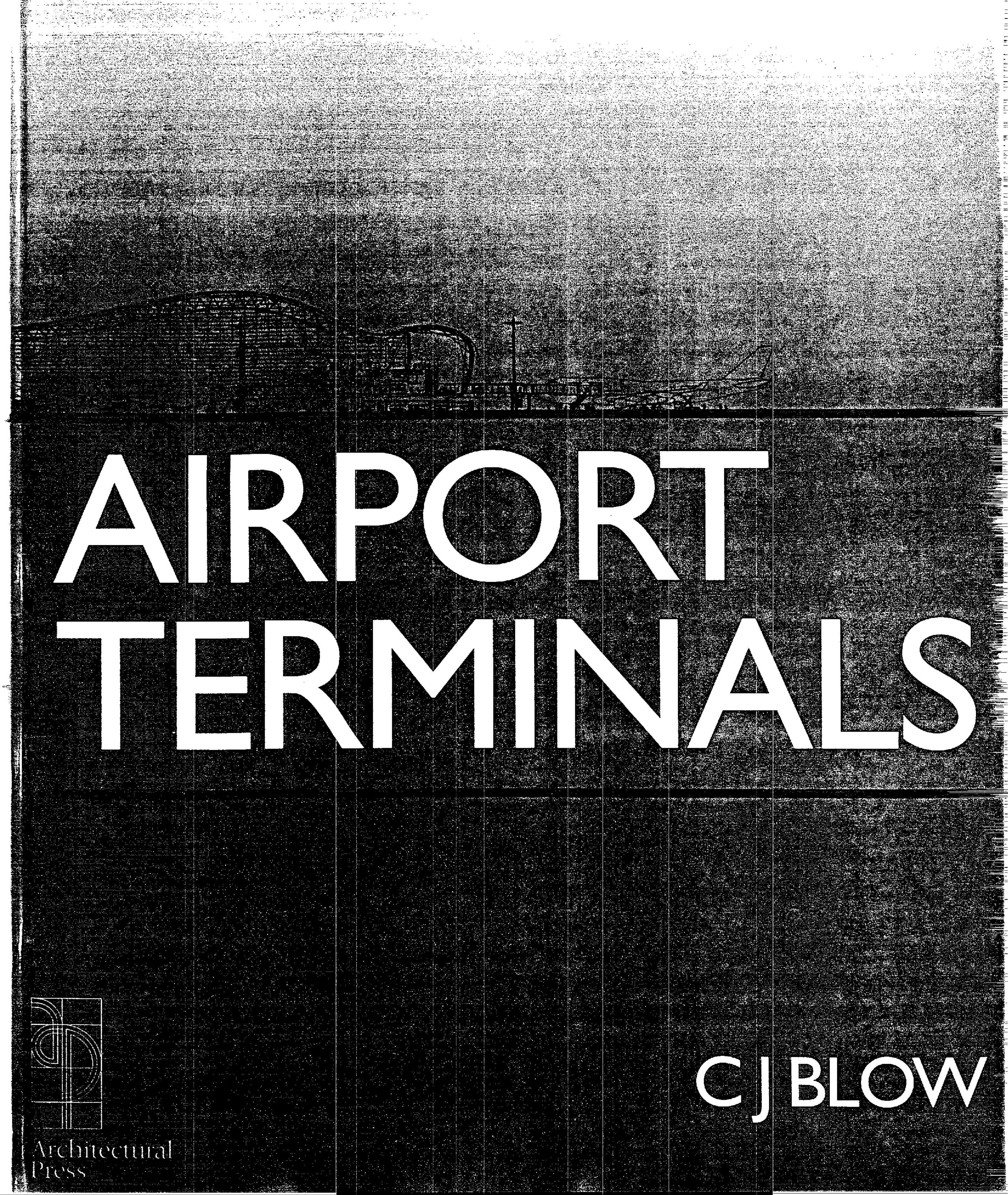
SECOND EDITION



AIRPORT TERMINALS

C J BLOW

Architectural Press

Airport Terminals

Airport Terminals

Second edition

Christopher J. Blow
MA(London) RIBA

Architectural Press

Architectural Press
An imprint of Butterworth-Heinemann
Linacre House, Jordan Hill, Oxford OX2 8DP
225 Wildwood Avenue, Woburn, MA 01801-2041
A division of Reed Educational and Professional Publishing Ltd

A member of the Reed Elsevier plc group

OXFORD BOSTON JOHANNESBURG
MELBOURNE NEW DELHI SINGAPORE

First published 1991
Second edition 1996
Reprinted 1997, 1998

British Library Cataloguing in Publication Data
A catalogue record for this book is available from
the British Library

Library of Congress Cataloguing in Publication Data
A catalogue record for this book is available from
the Library of Congress

ISBN 0 7506 2585 6

Composition by Genesis Typesetting, Laser Quay, Rochester, Kent
Printed and bound in Great Britain by Bookcraft (Bath) Ltd.

Contents

Part I Terminal design principles

Part II A taxonomy of airport terminal forms

Part III External landside factors

Part IV Terminal design details

Part V External airside factors

Part VI Redevelopment of existing airport terminals

Part VII Postscript

**Note: many chapters and subsections also conclude with specific references*

Acknowledgements

The author wishes to acknowledge help and encouragement from the following:

Architects and representatives of airport and transport authorities (for visits and illustrations – note that permission to reproduce drawings and photographs has been sought from the copyright holders in all cases).

Professor Norman Ashford
Geoffrey Crook
Maurice Hudson
Fred Lawson
Geoff Muirhead
and, at Scott Brownrigg & Turner, my colleagues David Aplin and Pat Barker and my wife Sheila.

Christopher J. Blow

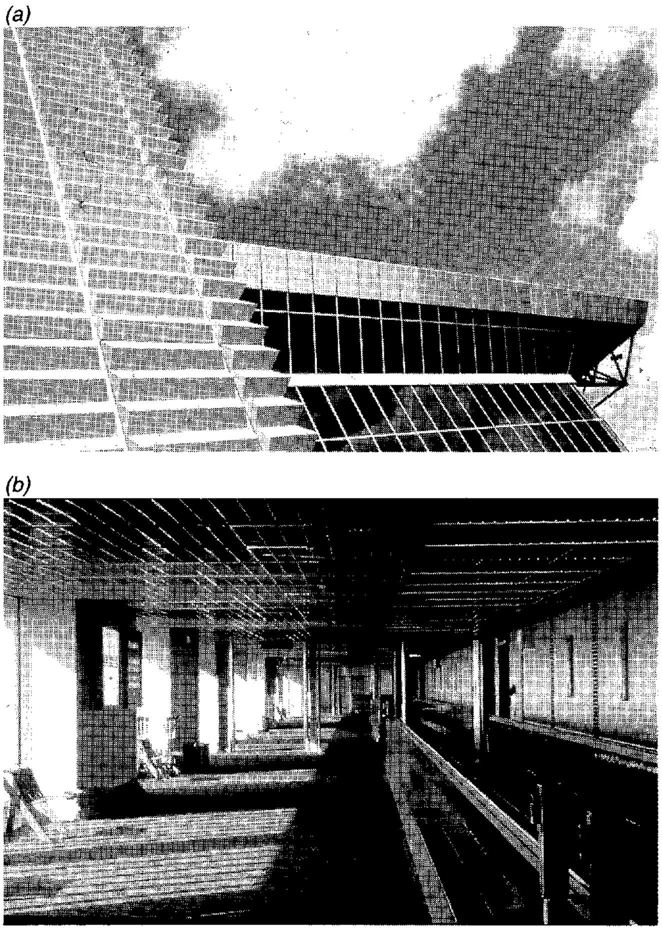
Preface

The business of airport terminals, and the politics of design

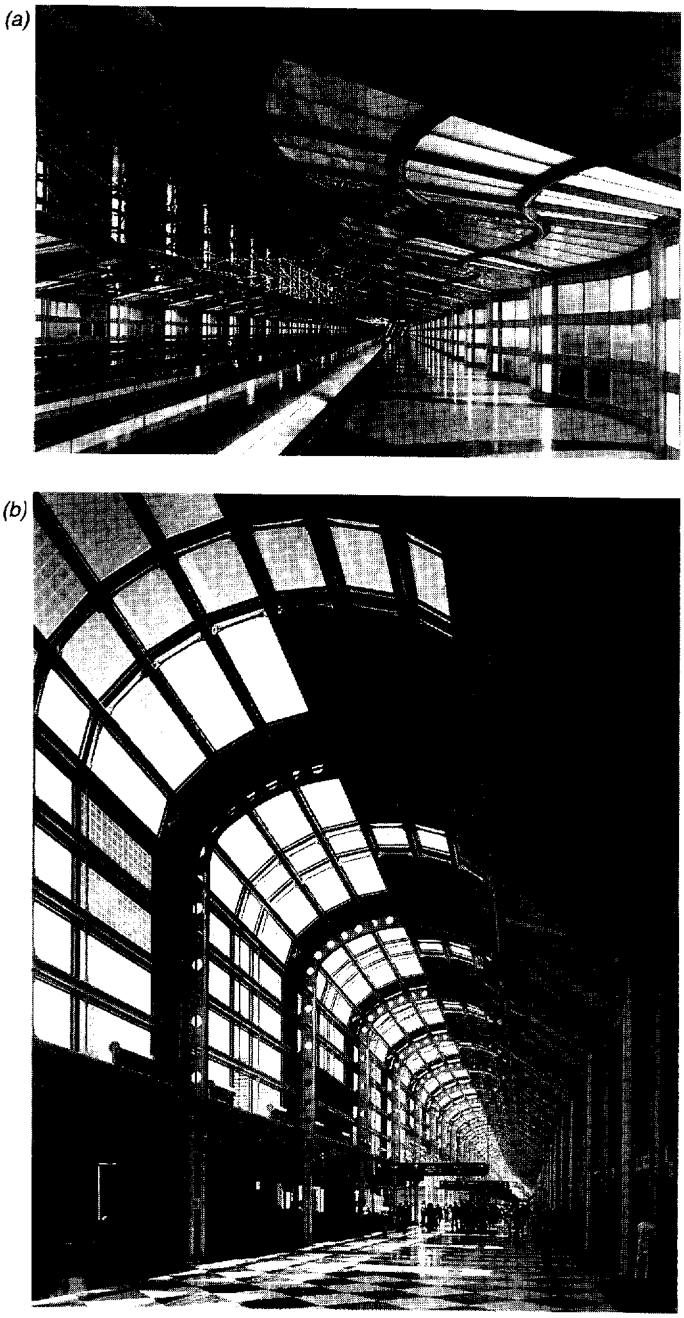
In this age, as in the age of steam, long distance travel is a special experience. Arrivals and departures are events, and points of arrival and departure are assembly places for large numbers of people. The great railway station was a symbolic showplace for the company that owned the railway, and one day may be so again, as illustrated in this book by examples in France. While airlines came and went, the international airport terminal was not so much a showplace for the airlines but established itself in the 1960s for the most part as a national showplace, the first point of contact with the country in question. Since then, commercial pressures have remodelled the terminal, and it has become a revenue earner. The comparison between the fortunes of airports and airlines has become an interesting one. An eminent observer of the aviation industry opened his address on economics to the Tenth World Airports Conference with the tip 'Buy airports, sell airlines'.

The fact that airlines have in many cases not been profitable is a result of a combination of world economic forces, over-capacity and fuel prices, and not as a result of lack of demand, which has usually continued to grow steadily. It is that growth which has sustained, and continues to sustain, the world's airports with constant design and construction challenges. The airport business plan has become as important as the floor plan, and terminal facilities can be profitable.

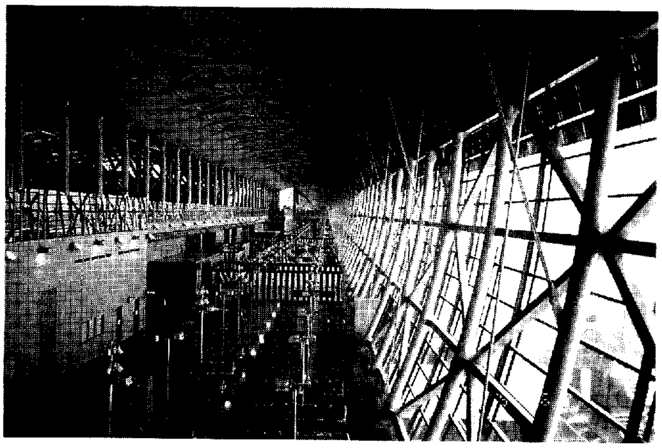
In any event, as a statement of the spirit of the age, a Victorian railway terminus has been replaced by an international airport terminal. When we think about the activities in an international airport terminal, the comparison with a railway station breaks down. International travel, which accounts for the majority of air travel (although the world's total figures are distorted by enormous volumes of domestic travel in the USA), involves border controls on customs and immigration. These processes, when combined with those relating to passengers' baggage – international travel involves stays of such duration that significant volumes of baggage are carried and need to be stowed in the hold of the aircraft – involve time delay and centralization. The distances which passengers have to travel inside airport terminals mean that some passengers may be forgiven for thinking that the terminal is organized for the benefit of the staff concerned with these processes rather than for them.



P.1 Heathrow Terminal 4 aluminium cladding; (a) external; (b) internal. Architects: Scott Brownrigg & Turner, Guildford. Client: Heathrow Airport Ltd (part of BAA plc).



P.2 Chicago O'Hare United Airlines Terminal: (a) passenger tunnel; (b) departures concourse. Architects: Murphy & Jahn, New York.



P.3 Kansai International Airport, terminal interior. Architects: Renzo Piano Building Workshop and Nikken Sekkei. Courtesy of Japan Airport Consultants.

The general themes of this book are capacity and the future of airport terminals. In 1993, nearly 2000 million passengers went through the world's airports on 40 million aircraft movements, and estimates of annual traffic growth rates at 5 per cent are conservative in some parts of the world. This traffic will not so much be met by new airports but by new terminals, replacement terminals and expanded terminals. One hundred million passengers give rise to terminal construction costs of up to $5 billion, and $50 billion is likely to be spent worldwide in the next decade on terminals alone. Master plans are to be worked within rather than created from scratch.

In preparing the second edition of this book, several shifts of emphasis since the late 1980s have been acknowledged. It is a matter of pressure points: commercial and global. It is retailers rather than airlines that have determined much development within airport terminals. High revenue sites within the terminal have been taken up by international names in retailing, and airport owners have been able to cash in on the value of their prime sites. Meanwhile, it is noteworthy that half of the world's aviation activity will be concentrated in the Asia/Pacific region by 2010. I have therefore introduced projects illustrated in Part II from the Asia/Pacific region, 4 out of 24.

Prior to the opening of Denver Colorado's new airport in 1995, the last new US airport to be built was Dallas Fort Worth in 1974. Europe will for certain have gained only one new airport, Munich (see Chapter 12) before the year 2000, although another site is being considered outside Athens. The Asia/Pacific region sees certain or projected new airports at Sydney, Kansai (see Chapter 9), Bangkok and Hong Kong (see Chapter 10), Macau (see Chapter 2), Kuala Lumpur, Seoul and in the Philippines, China and Indonesia.

Nevertheless, new terminals and redeveloped old ones will generally be the order of the day, and designs have to accept the constraints of siting resulting in most cases from several decades of airport development. Airport terminals can be compared to biological organisms, and like them they take on organic forms with elongated or detached extensions of many shapes and sizes.

Architectural quality is demonstrated by practical terminal buildings which respond to the conflicts of commercial pressure and, at the same time, represent the spirit of the aviation age in their form and external and internal detail. They do not have to blend with the landscape. They can assert themselves.

Christopher J. Blow 1995

Part I Terminal design principles

1 An overview of airport terminals

1.1 Pressures on design: demands on designers to innovate

There are five sources of demand which are combining to make the airport terminal of the early 1990s a very different animal from its predecessor. The term 'animal' is not inappropriate, for the shapes of terminals, piers and satellites now evolving would do credit to a bioscientist's taxonomy.

Security, density, commercial factors, traffic patterns and government controls combine to tax a designer's ingenuity.

1.1 London Heathrow Terminal 4 airside concourse. Architects: Scott Brownrigg & Turner, Guildford. Client: Heathrow Airport Ltd.

Security

Since recent terrorist atrocities have demonstrated the need to check rigorously for dangerous substances in baggage, check-in procedures are having to allow for the immediate X-ray of baggage or even more sophisticated electronic checks. Thermal neutron analysers (TNA) costing about $1 million each were being installed in US airports in 1990. The TNA system emits low energy neutrons around the item of baggage which will interact with any explosives present and sound the alarm if any offending gamma rays are detected. Bulky new equipment and the circulating baggage belts to feed it make special space demands in the check-in area.

Secondly, passenger and hand-baggage searching and segregation have taken on additional importance. Effective segregation of arriving and departing passengers on the landside of terminal buildings has long been provided by the design features of ground level arrivals forecourts and elevated departures forecourts. Only with the advent of airside concourse structures which segregate arriving from departing passengers can the benefits of centralized security control of departing passengers be achieved.

Segregation of passengers in multi-level systems needs to be complemented by controlled routes for transfer passengers entering the secure airside departures concourse for example. This situation is arising more and more, especially as airports acquire multiple terminals between which airside passenger transfers are taking place, Figures 1.1 and 1.2.

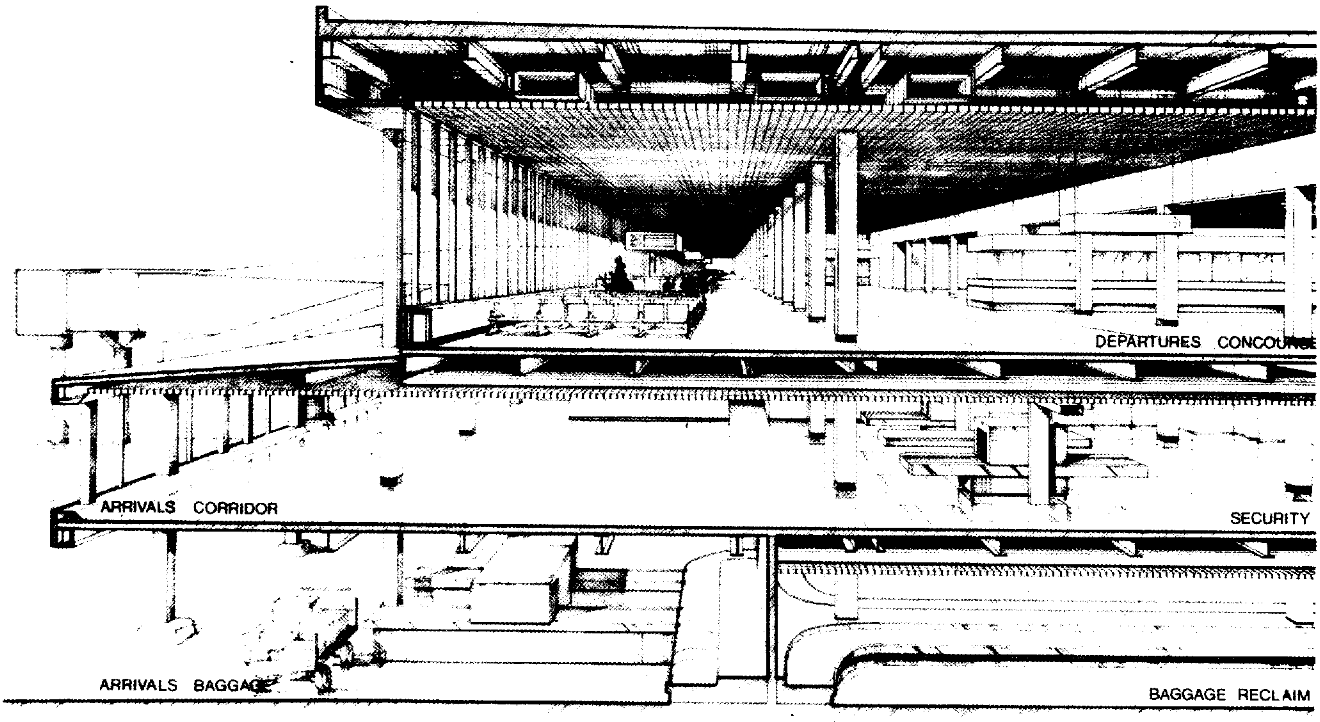
Density of traffic

As more and more passengers pace the floors of the world's airport terminals, operators seek efficiency of space standards. The prime manifestation of this is the fact that density of traffic now justifies one-way passenger flows, segregation and clarity of passenger movement.

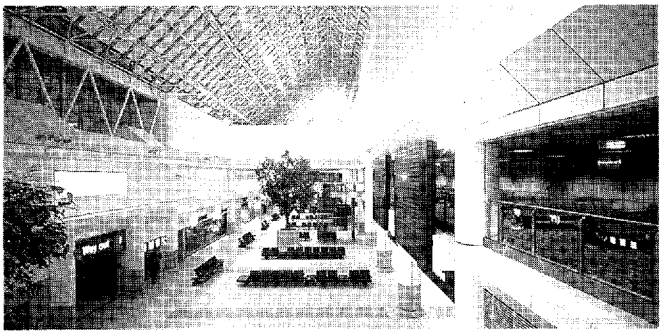
Sustained peak hourly flows of the order of 3000 passengers call for a very different type of circulation design, with moving pavements and wide concourses. Disabled people are travelling much more, and facilities are to be provided to make this possible. Ramps, and downwards-only ramps at that, are preferrable to lifts for large flows of passengers where changes of level are inevitable.

Commerce

Airport terminals, for the reasons already outlined and as illustrated by the new generation of buildings such as Gatwick North opened in 1988, are shopping centres and places of entertainment as well as large



1.2 Bahrain International, airside concourse. Architects: Scott Brownrigg & Turner, Guildford, with Scott Wilson Kirkpatrick & Co. Ltd. Client: State of Bahrain.



1.3 Manchester Terminal 2 departures, landside concourse view. Architects: Scott Brownrigg & Turner, Guildford. Client: Manchester Airport plc.

scale public catering facilities. Fashions change, and these commercial facilties need to be responsive to the speed of such change.

Within the complex airside and landside circulation systems of an international airport terminal, provision needs to be made for goods delivery routes and storage in such a way that facilities can grow and change. The advent of fast food chains in the high street has been followed by fast food for airline passengers. When establishing a new chain of orange juice and health food outlets, Grand Metropolitan Hotels (with the brand Healthworks) used Heathrow and Gatwick Airports as its launching pad, with 10 out of their 19 stalls there in the first wave. With or without duty-free shops, airport concourses are established as merchandising centres, Figure 1.3.

Airline traffic patterns

Some variability and diversity in traffic can be catered for in terminal design and some requires specific design features. Terminal buildings need to be able to serve different aircraft sizes, and with the advent of the Boeing 747 series 400 in 1989 the range of sizes increases further. Linear parking patterns with either or both moveable fixed gate positions and multiple aircraft centrelines are the order of the day. The provision of apron-drive loading bridges offers apron planning and operational flexibility which complements the desired flexibility of the internal organization of the terminal building itself, Figure 1.4.

Transfer traffic cycles also affect the demands on layout as demonstrated by the newly evolving 'hubs'. A terminal designed predominantly for transfer traffic within itself requires concentrated airside facilities and circulation in order to achieve the short interchange times which airline marketing and passengers both need. Vast though they may be, such US domestic transfer hubs as Atlanta, Georgia are very different from transfer hubs involving mixed domestic and international traffic.

The multiplicity of secure holding areas and circulation routes involved in a mixed hub are illustrated by the schematic design for Birmingham International Airport. Two-level circulation routes have been adopted for domestic and international/EC post-1992 traffic in lieu of arrivals and departures. This allows passenger routes to complement airline operational patterns whereby aircraft come in as domestic flights and go out as international flights from the same stand and vice versa.

Government controls

The politics of international travel have their effect on terminal design and flexibility. The distinction between domestic and international traffic at European airports is changing dramatically in the European Union since 1992. Most terminal buildings presently handling European and non-European international traffic are unable to divide into dual terminals with European traffic segregated from non-European. There is even the interim phase created by the timing of the Schengen agreement which removes barriers of all types between certain EU countries but not all.

Even without increase in traffic, extra space will be needed for dual facilities and functions. This is proving in some cases to be the severest test of the robustness and flexibility of design concepts evolved in the 1970s and 1980s. The feature on Schiphol Airport (Amsterdam) in Chapter 4 illustrates one airport authority's plan.

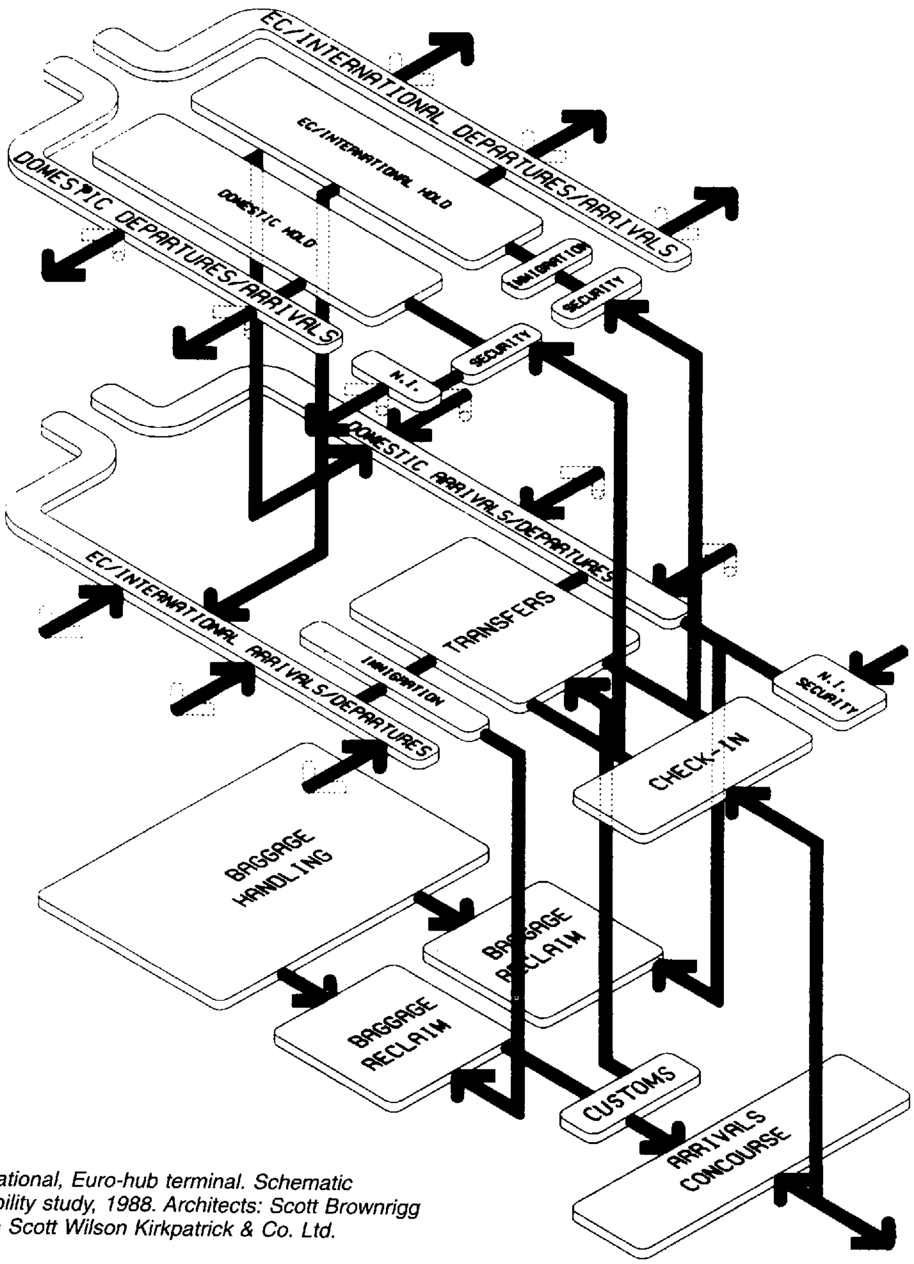
1.2 The balancing act

Experience over the last three decades shows that some terminal designs and airport planning concepts have adapted to change and others have not. Going even further back to pre-war days, the circular 'beehive' terminal at the original Gatwick Airport was all too soon obsolete. Quite apart from its siting, the small circular terminal, apparently ideal for nose-in parking and extremely short walking distances in 1936, was totally unsuited to the needs of the larger aircraft which so rapidly replaced the DH 86 biplane. Few, if any, pre-war terminal buildings serve present needs or have even retained their function through many cycles of change and reconstruction.

Two notable British examples illustrate the sheer robustness of post-war adaptable design:

London Gatwick, South Terminal

Over a period of thirty years this terminal has been expanded on three sides and its original finger piers replaced, in one case by a circular satellite not dissimilar from the original 1936 'beehive' on a distant site. The building still straddles the London–Brighton road, long since virtually replaced by a motorway well to the east. The original forecourt for vehicular set-down and pick-up has also long since been

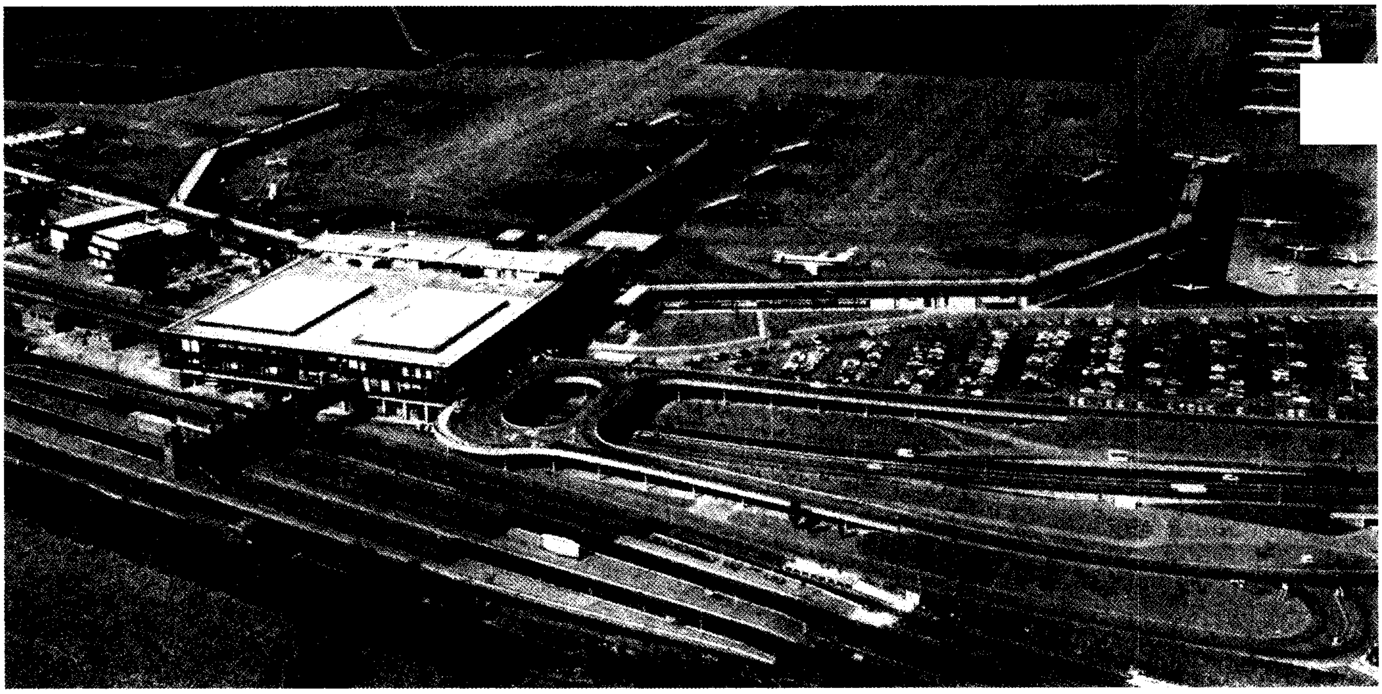


1.4 Birmingham International, Euro-hub terminal. Schematic passenger routes, feasibility study, 1988. Architects: Scott Brownrigg & Turner, Guildford, with Scott Wilson Kirkpatrick & Co. Ltd.

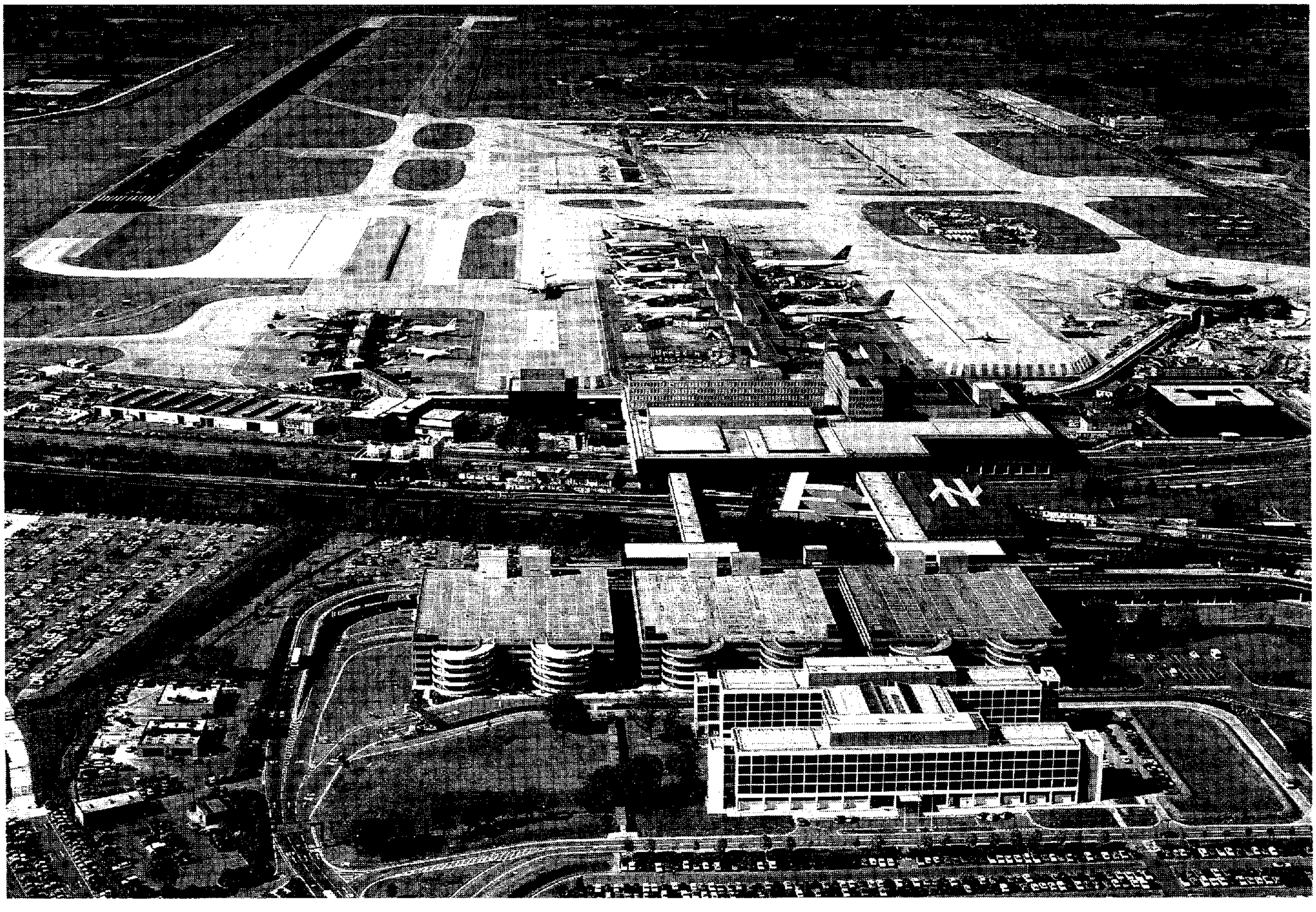
transposed to the other side of the railway line and linked with not only multi-storey short-term car parks but also a hotel, Figure 1.5.

London Heathrow, Terminal 3 Departures building

This terminal started life over thirty years ago as the Heathrow Oceanic terminal for both arriving and departing passengers with ground level parking at the front door on the landside and with only an open apron strip on the airside, Figures 1.6 and 2.5. Now, thanks to a combination of good siting and rethinking of surrounding land uses, the building is the centrepoint of a very different set of facilities. Those for arriving passengers have been removed to a separate building next door and a multi-storey car park built in front. A whole series of pier structures have thrust out on the airside, encroaching upon the original alignment of one of Heathrow's three redundant runways. As a final act of transformation, the landside portion of the building itself was in 1989 gutted down to the bare steel skeleton for the insertion of a completely new check-in configuration with shopping and catering facilities: see Chapter 27. The important thing is that it has been possible to keep the landside space and the airside space in balance; but for how much longer?



(a)



1.5 Aerial views of London Gatwick South: (a) in 1965, courtesy of Architects' Journal; *(b) in 1983, courtesy of architects: YRM Architects and Planners, London. Client: Gatwick Airport Ltd.*

(b)

1.6 Aerial view of London Heathrow Terminal 3 in 1961. Architects: Sir Frederick Gibberd & Partners. Courtesy of British Airways.

1.3 Progress

While concentrating on the form and content of terminal buildings, this book also puts them in context. To start within a historical context, it is interesting that although we have only had airport terminals as such since the mid 1920s, we have actually had replacement airport terminals since the 1930s. Commercial flying started immediately after World War I and terminal facilities improved rapidly. Although a wooden hut made an acceptable terminal in 1919, by 1925 passengers were coming to expect a building and facilities not unlike a railway terminus. Berlin, Paris (Le Bourget), Amsterdam and Croydon (London's international airport at that time, where the terminal opened on 30 January 1928), all offered waiting rooms and bureaux de change.

The reputations of airlines started to be linked to the airports: airlines were already competing against surface transport and airports were in fact competing against railway stations. Thus began the constant process of improvement and replacement of airport terminals. At Le Bourget the original buildings were pulled down and replaced in 1936, whereas those at Amsterdam (Schiphol) and Croydon were improved and modernized. Passenger numbers were still small and in the late 1930s Croydon and Le Bourget only handled about 2000 passengers each day.

For London, Gatwick (see Chapter 3) and Croydon did not meet post-war needs. After a short period of glory as London's international airport, Hurn, near Bournemouth, was replaced by the former RAF field at Heathrow. Heathrow's life as a civilian airport began on 31 May 1946. In the first six months the numbers of aircraft movements and passengers were 2000 and 63000 respectively. By 1950, these figures had risen to 38000 and 523000 in the whole year. The growth of Heathrow Airport is featured in Chapter 4.

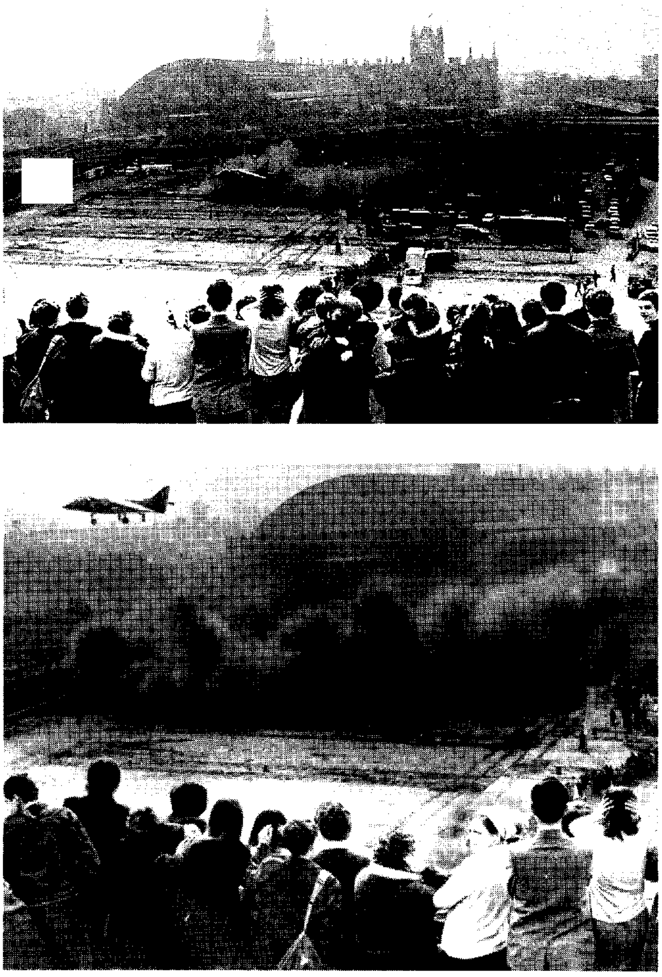
Yet much of the activity we associate with airport terminals has developed even since 1950. The first duty-free shop in the world opened at Shannon in Ireland in 1951, extending maritime habits for the benefit of the flying public. Some could be forgiven today for thinking that the duty-free shop is the most important part of the airport.

The role of the airport passenger terminal and its designers and owners is to provide a facility balanced for present and future needs of passengers, baggage and aircraft. 'Space, speed, simplicity and service' was the maxim for Heathrow Terminal 4. This must be the objective of every new and remodelled terminal in face of continually changing demands of traffic, commerce and security and of airlines, airport authorities and politicians.

2 Why airports as we know them?

2.1 Scale: the reasons for airport location and growth

Present day aircraft need runways suited to their power, loads and sizes. With the exception of airports built exclusively for short-take-off-and-landing aircraft (STOLports), international airports need 4000 metre runways to handle the largest commercial jet aircraft.



2.1 Harrier jump-jet at St Pancras Station. Courtesy of Daily Mail library.

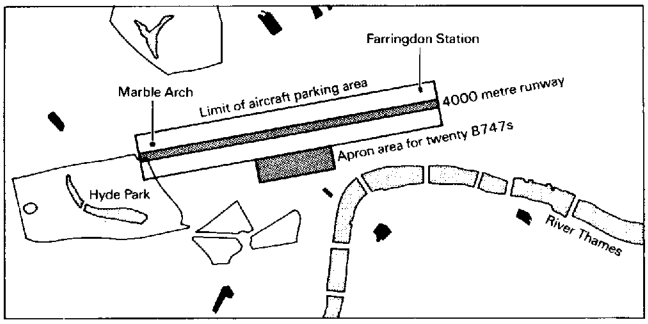
A dream of the possibility of the same aircraft that can carry several hundred passengers for several thousand miles in the most economic way being able to fly direct from city centre to city centre is some way off.

A London-to-Paris air race in the 1960s simultaneously highlighted the difficulties and the possibilities of high speed centre-to-centre travel: despite the noise and dust one team was permitted to fly into one of the London railway termini with a jump-jet – a poignant juxtaposition. If airports had come earlier to the world's cities, what a different pattern of development there would have been. However, as quieter aircraft are developed, so incompatibility with neighbouring development is reduced (see Section 5.2), Figure 2.1.

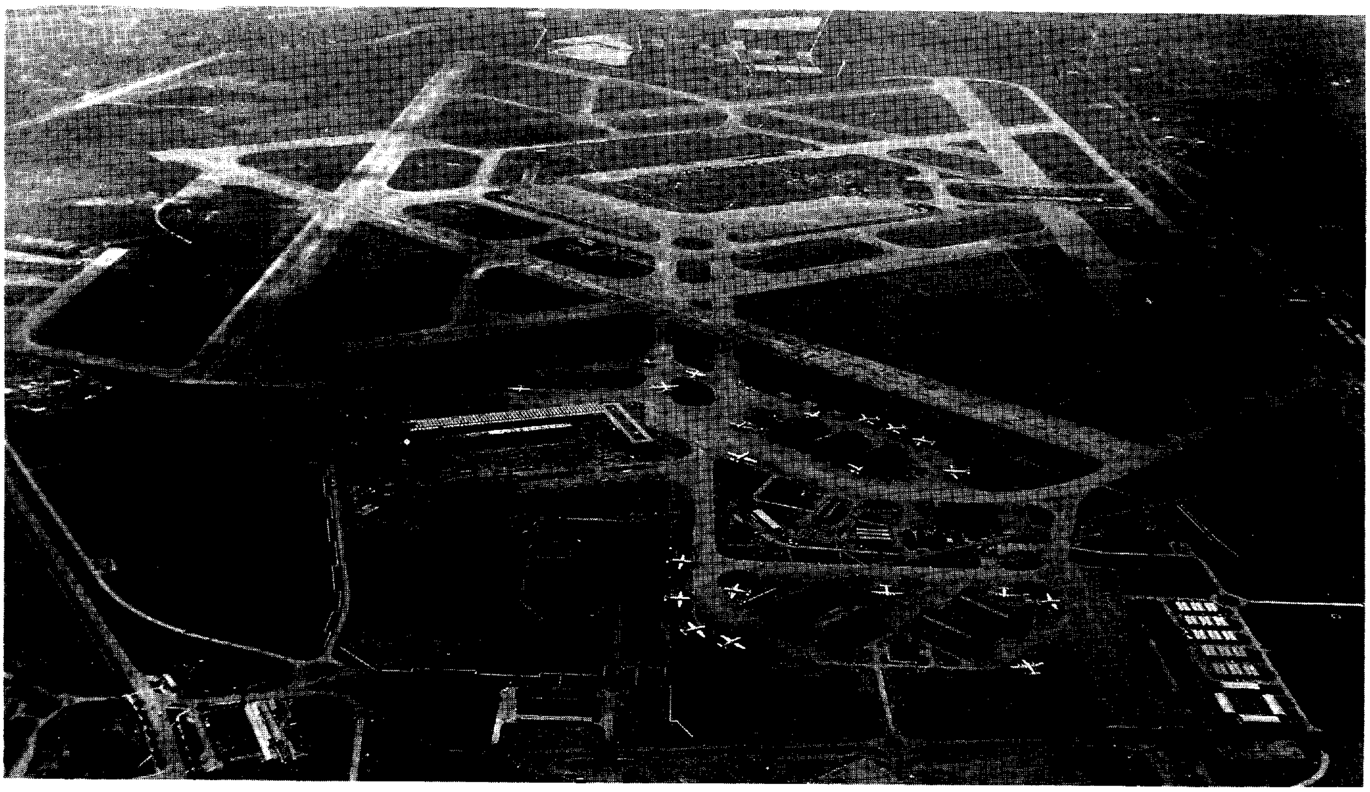
Even in the 1920s and 1930s city airport sites were being chosen on the fringe of the developed area: the right balance between convenience for passengers and inconvenience for non-passengers. As cities expanded and runway lengths increased the competition started in earnest – should passengers' convenience be sacrificed in favour of the community?

A striking illustration of scale is provided by overlaying a 4000 metre runway on central London, or any other city, together with parking area for 20 or so jumbo jets, Figure 2.2.

More often than not the airport terminal is a centre of urban activity (large numbers of people, public transport, private transport, commercial activity, offices, etc.) far removed from the metropolitan centre.



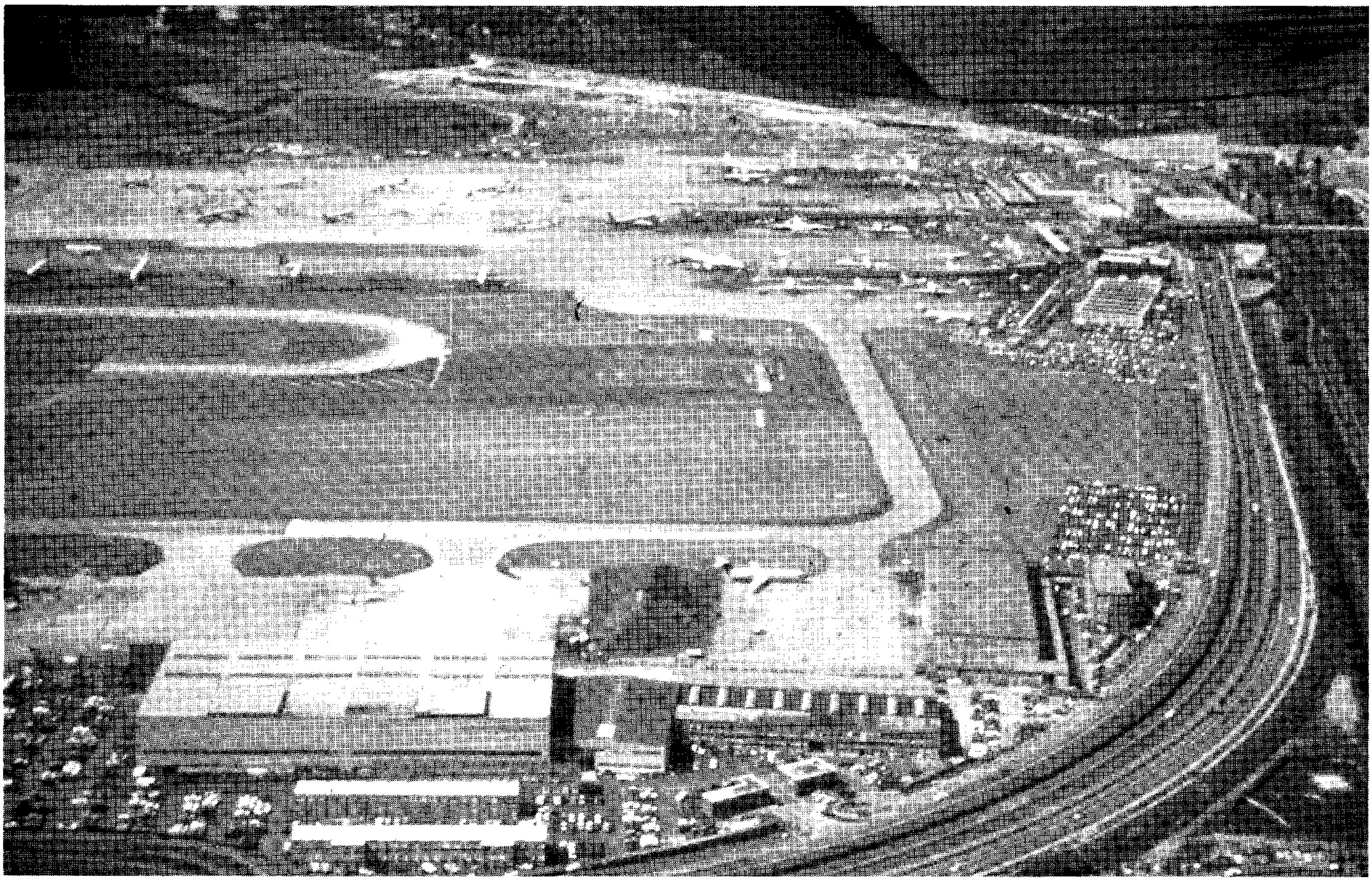
2.2 4000 m runway superimposed on central London.



(a)

2.3 London Heathrow: (a) 1952 view of runway star and Central Terminal; (b) current aerial view. Courtesy of Heathrow Airport Ltd.

(b)



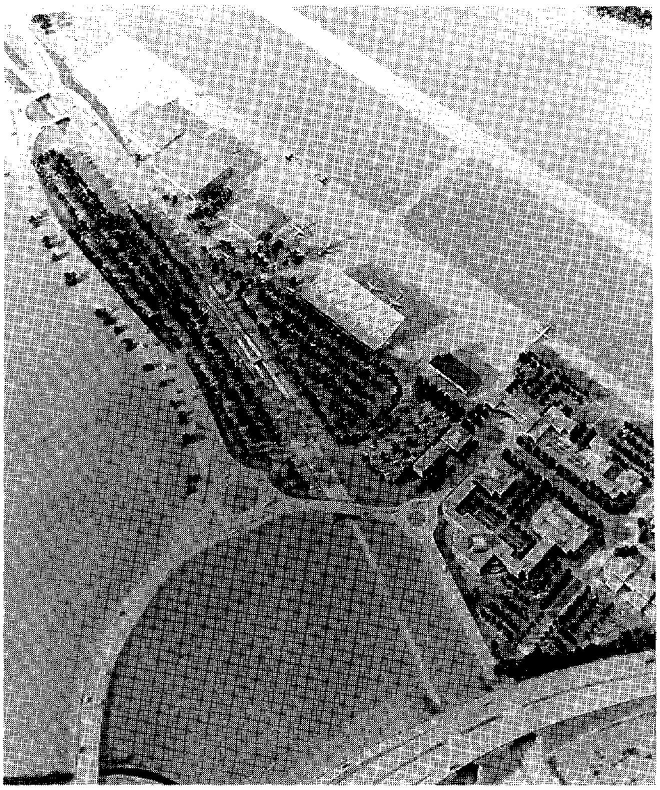
2.4 *Aerial view of Gatwick, 1979. Courtesy of Gatwick Airport.*

2.2 Airports as activity centres

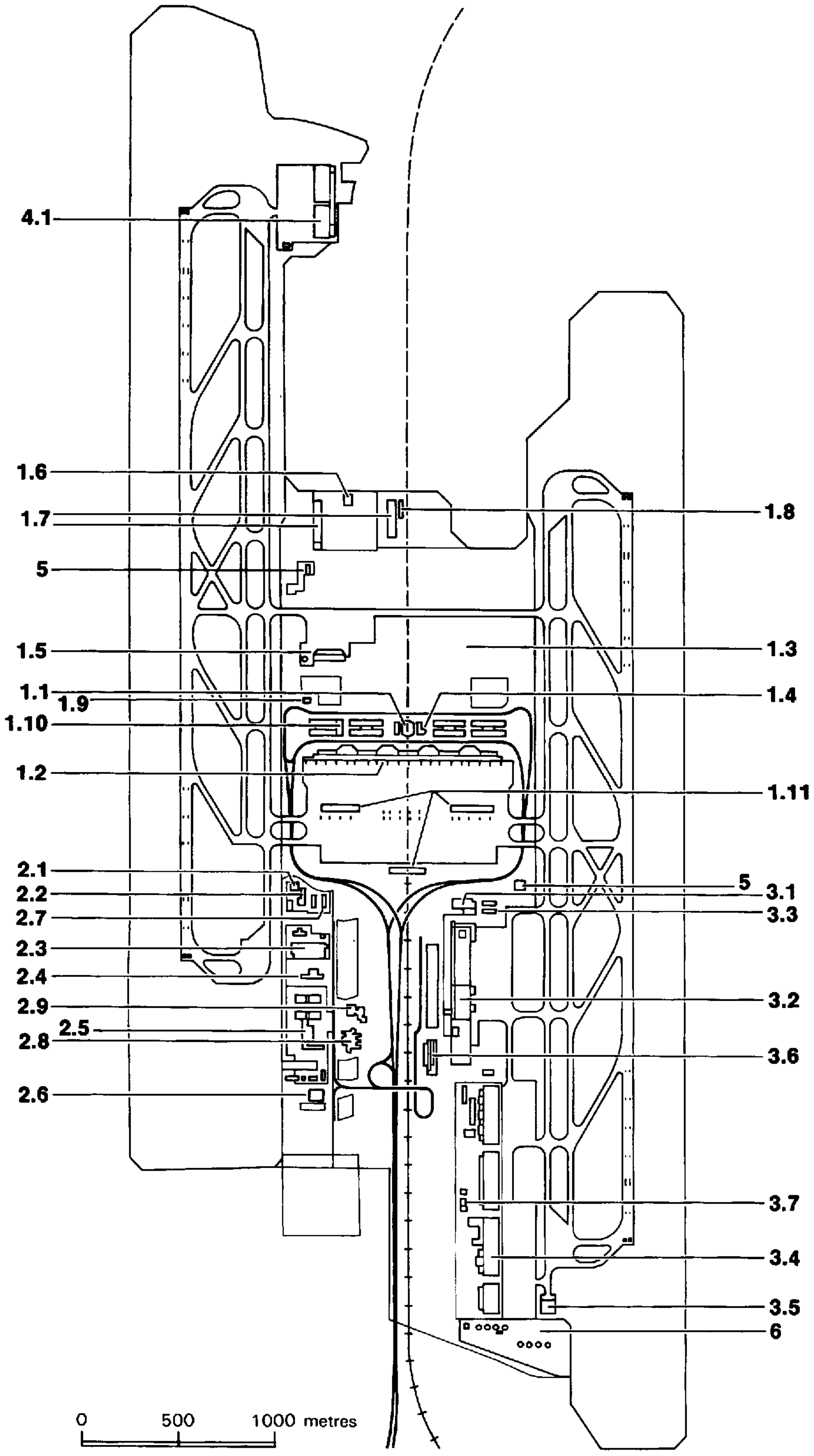
What has started as an interchange point for airline passengers is already becoming a great deal more. Just as nineteenth-century railway termini and railway junctions spawned hotels and shops and even, in the case of many larger railway junctions, industrial towns, so airports, and particularly their terminal areas, combined with transport interchange points to become growth points for all sorts of other activity. The following examples illustrate the airport as a centre of activity.

London Heathrow

Heathrow has grown within west London's suburban structure, but its presence has reinforced multi-use surrounding development. It still lacks ideal public transport interchange and connection to central London, but this will be partially remedied by the proposed Heathrow Express dedicated rail link to Paddington: see Chapter 22. Heathrow Airport provides immediate employment for nearly 80 000 people, has over 5000 hotel rooms and parking for 20 000 cars, Figure 2.3.



2.5 *Eastleigh Airport site development model. Architects: Scott Brownrigg & Turner, Guildford. Client: Southampton Eastleigh Airport Developments Ltd.*



Key

1	Passenger handling and general aviation facilities
1.1	Central building with railway station
1.2	Terminal west
1.3	Development area east
1.4	Tower
1.5	Special terminal
1.6	General aviation terminal
1.7	General aviation hangar
1.8	Helicopter shelter
1.9	Waste disposal
1.10	Car rental centre
1.11	Apron buildings
2	Technical region north
2.1	Police
2.2	Fuel
2.3	Catering
2.4	Central power plant
2.5	Airport authority technical services
2.6	ATC regional control
2.7	Security
2.8	Airport authority administration
2.9	Central canteen
3	Technical region south
3.1	Airmail
3.2	Cargo
3.3	Cargo apron buildings
3.4	Hangars
3.5	Engine test run area
3.6	DLH flight operations centre
3.7	Maintenance canteen
4	Technical region east
4.1	Hangars
5	Fire stations
6	Fuel farm

2.6 Munich master plan. Courtesy of Flughafen München GmbH.

London Gatwick

Gatwick has a cluster of hotels, off-airport carparking, offices (for the Civil Aviation Authority and for British Airports), and warehousing (at Lowfield Heath, where it is in association with a major airline base). All have benefited from the through-rail interchange (see also Chapter 3), Figure 2.4.

Southampton, UK

For many years the former Eastleigh airport had been under-developed, though well located on the M27 south coast motorway. The Development Brief by Eastleigh District Council in 1988 proposed retail warehousing, a high-technology business park and a motel or hotel, all linked to a railway station interchange with fast links to both London and Southampton, Figure 2.5. The airport component has been bought by BAA plc: see Section 7.3.

Munich, Germany

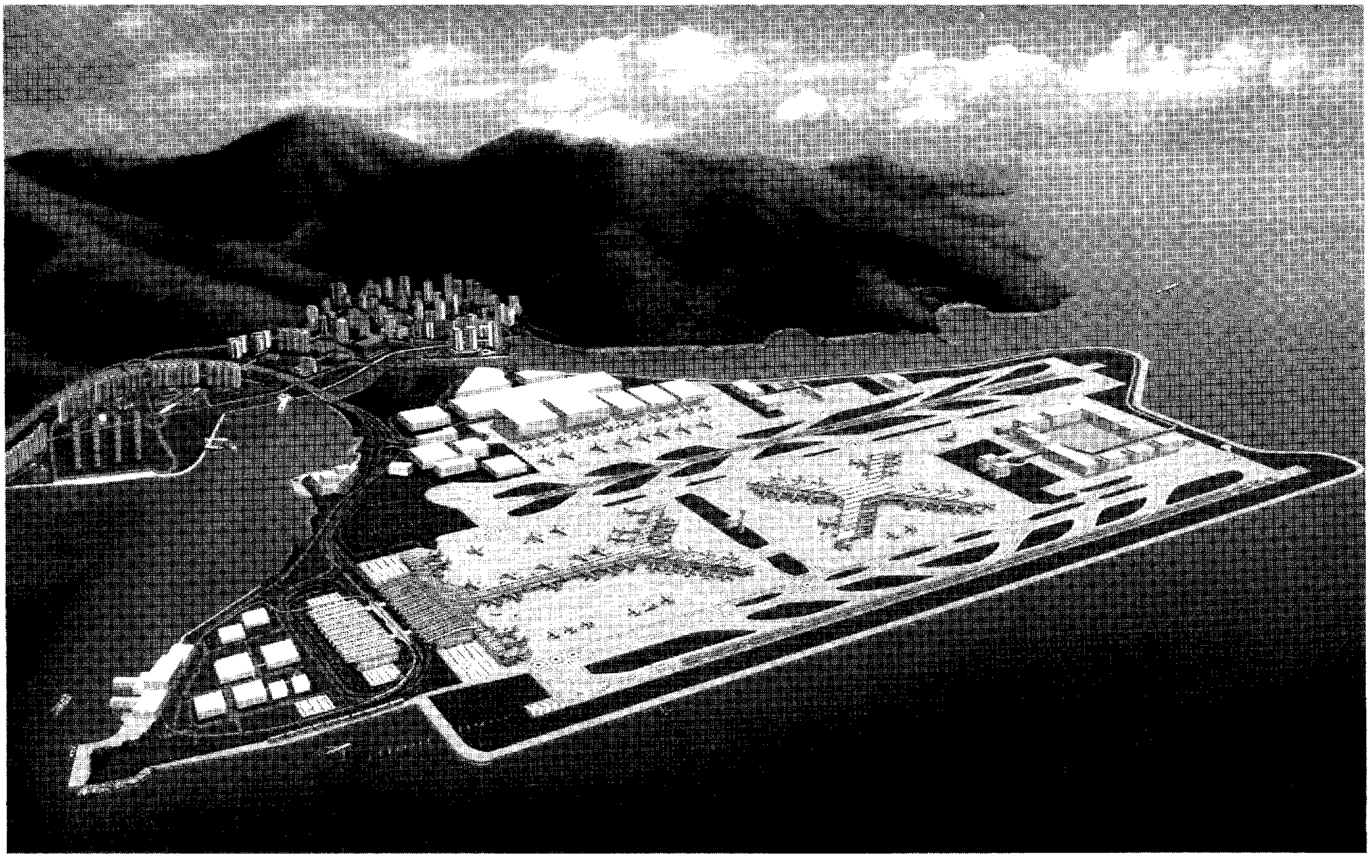
In the case of Munich's new airport, the only completely new airport in Europe in the 1980s, the planners have created a particular 'green area' concept, and surrounding development is being strictly controlled, Figure 2.6.

Osaka Bay, Japan (Kansai)

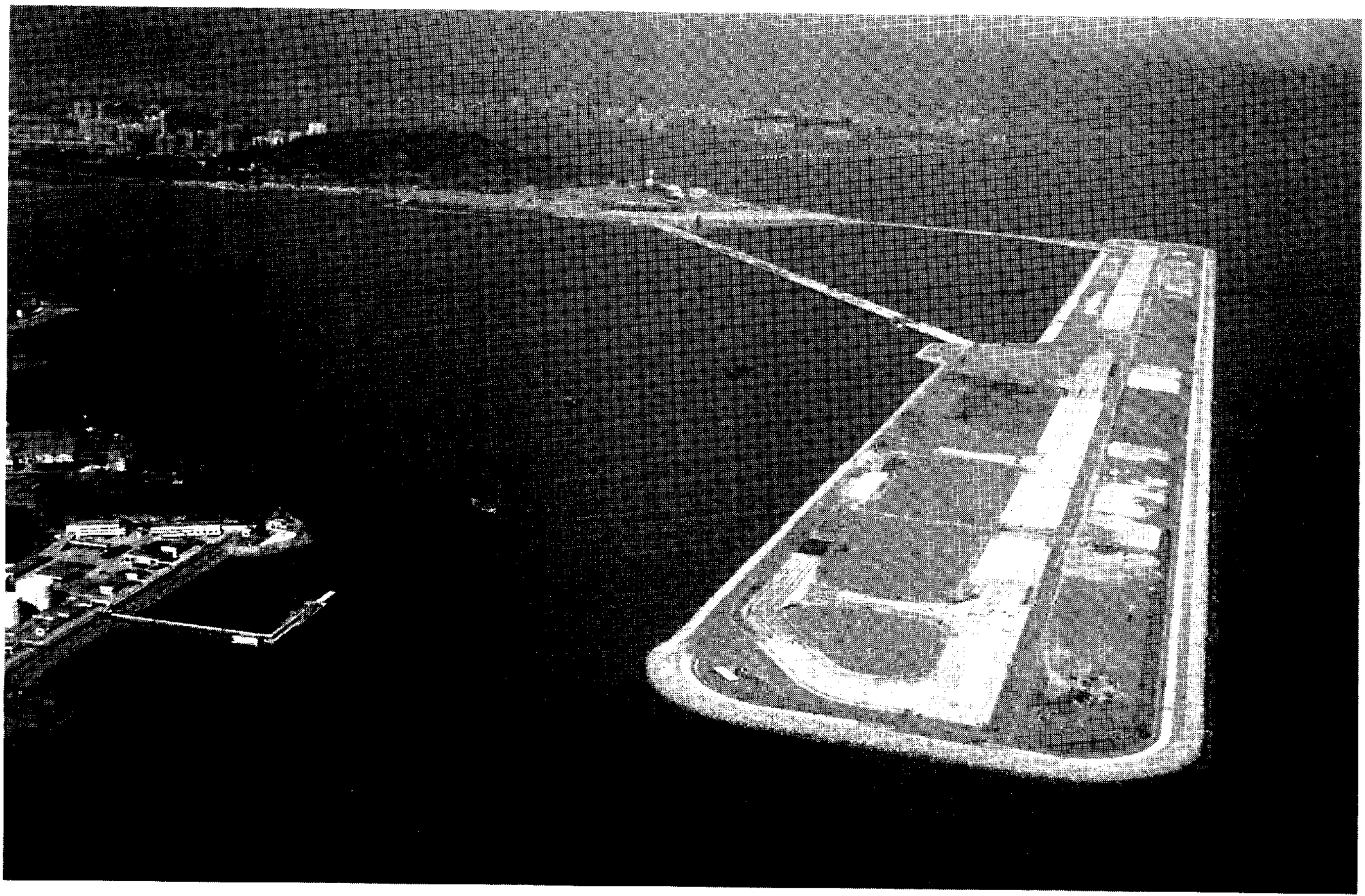
Kansai International Airport, Japan's second major international airport and the world's first virgin offshore airport, was planned as such in 1974 but work did not start until January 1987. The offshore location is designed to permit 24-hour operation and to minimize noise pollution in a densely populated region. The 500-hectare man-made island on which the first of three runways and the terminal are sited is 5 kilometres from the coast. It is linked to the coast by a road and rail bridge. The single runway has a target capacity of 160 000 movements per year and the airport opened in 1994. See Section 9.4 for information about the notable terminal.

The new Hong Kong Airport

Hong Kong's giant twin-runway replacement airport, the first phase of which is due to open in 1997, is situated on a new island formed partly from a small



2.7 Impression of Hong Kong's new airport in the year 2040. Courtesy of Provisional Airport Authority, Hong Kong.



2.8 Aerial view of Macau Airport. Courtesy of CAM, Sociedade do Aeroporto Internacional de Macau SARL.

existing one called Chek Lap Kok, Figure 2.7. With this new airport, replacing the congested and potentially dangerous site at Kai Tak, come a vital series of tunnels, bridges, road, rail and port projects, which in turn open up develoment potential in previously isolated parts of the colony. Furthermore, a whole new community will be developed on the neighbouring island of Lantau, largely to support the airport with manual workers. See Section 10.3 for information about the terminal.

Macau

This much smaller single-runway offshore airport, also at the mouth of the Pearl River in southern China, is designed to serve as an entry point to both the city of Macau and to southern China, and may well have a short-term role as an entry point to neighbouring Hong Kong. The terminal building, located on the corner of an existing island, is planned to be handling 4 million passengers per year by 2000, and considerable apron expansion is envisaged by more local reclamation, Figure 2.8.

Offshore airports such as Kansai, Chek Lap Kok and Macau offer potential integration with sea travel too. Ironically, this type of airport development militates against clustered commercial development.

Offshore airports were first proposed in an article in *Fortune* magazine in June 1961. They make a lot more sense now than they did then. Over the years serious proposals have emerged first for Chicago (Lake Michigan), then for New York (Long Island Sound), London (Maplin Sands), Cleveland, Ohio (Lake Erie), Los Angeles (San Pedro Bay), Copenhagen (Saltholm), Tokyo (Haneda), Hong Kong (Chek Lap Kok), Macau and Kansai. Floating runways and terminals have also caught the imagination of engineers and architects.

Further reading

Allen, R. (1971) Water-based airports. *Airport Forum*, **4**.

Beechener, J. (1995) Macau – a new airport surfaces. *Airport Support*, March.

Gethin, S. (1993) Making waves in Macau. *Airport Support*, June and sequel.

3 A cameo

The original satellite at London's Gatwick Airport is a generic form of circular building serving parked aircraft. A fascinating story surrounding the design of an airport terminal in 1934 is told in *Gatwick – the evolution of an airport* by John King. It concerns the birth of the idea of a circular terminal building by Morris Jackaman, the developer of the original Gatwick Airport in Sussex.

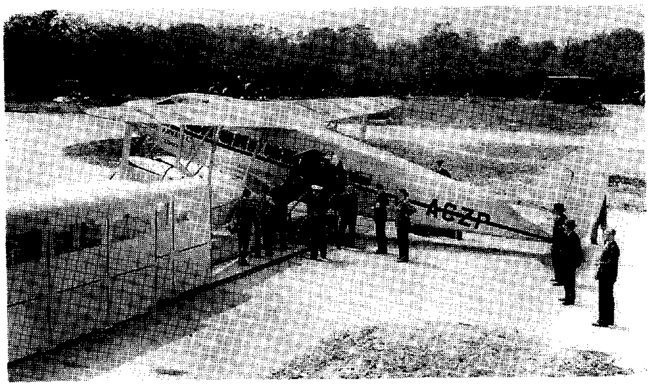
> One problem which particularly concerned Morris was the design of the passenger terminal. He considered that conventional terminal buildings such as Croydon which had been described as only fit for a fifth rate Balkan state, were inefficient and not suited to expansion of passenger traffic . . . It is believed that one idea he considered was building the terminal over the adjoining railway. The result of his deliberations was ultimately the circular design which is a feature of the 1936 passenger terminal, now generally known as the Beehive. How this came about is intriguing. Morris was working late one night at his parents' Slough home when his father came into his study. 'Oh, for heaven's sake, go to bed', his father urged. 'You're just thinking in circles'. Instantly Morris reacted 'That's it, a circular terminal' . . . Morris quickly put his thoughts on the advantages of a circular terminal on to paper. Using the patent agents E.J. Cleveland & Co., a provisional specification was submitted to the Patent Office on 8 October 1934. Entitled *Improvement relating to buildings particularly for Airports*, the invention sought 'to provide a building adapted to the particular requirements at airports with an enhanced efficiency in operation at the airport, and in which constructional economies are afforded'.

Various advantages of a circular terminal were detailed. They included:

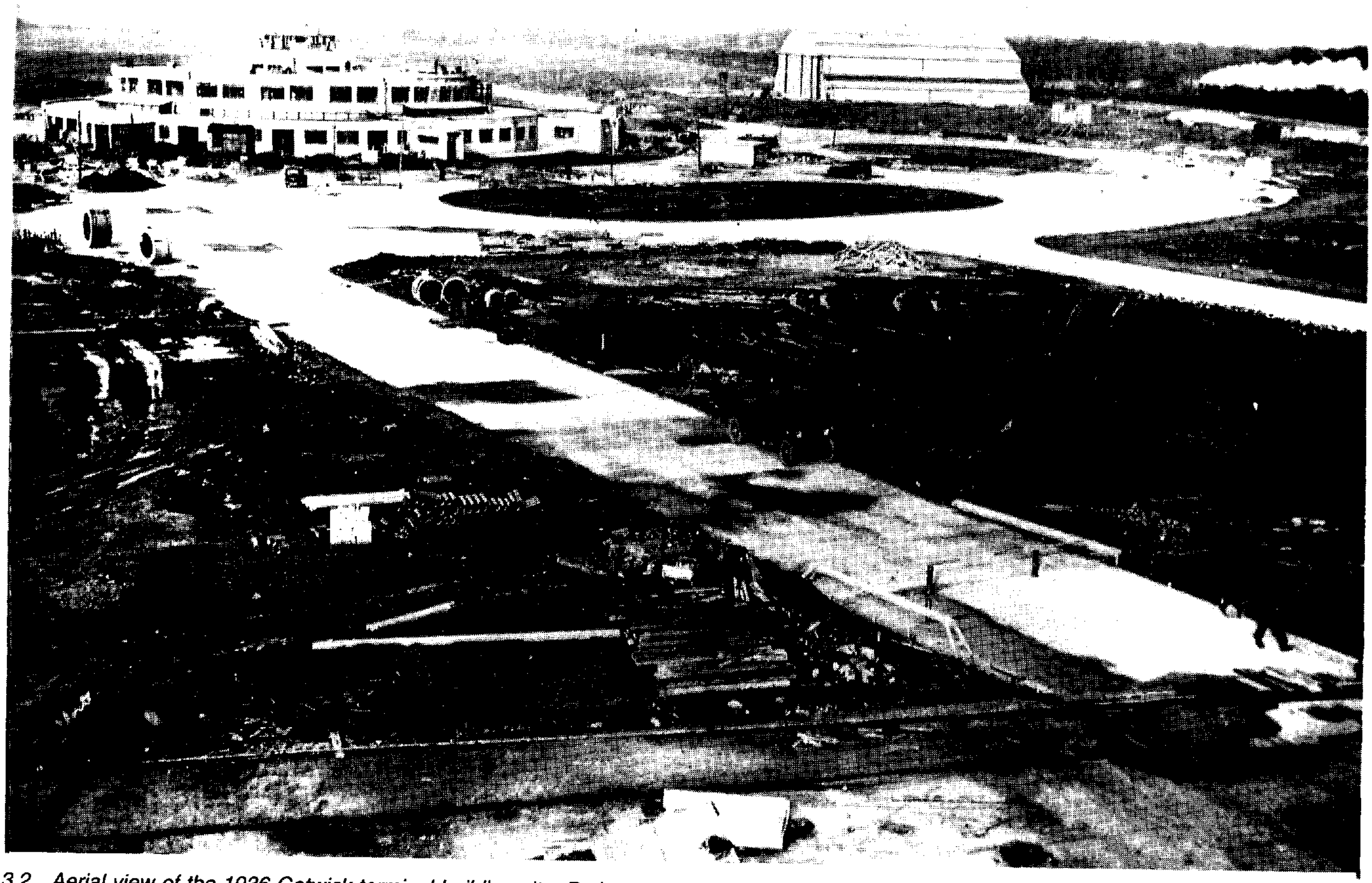
1. Certain risks to the movement of aircraft at airports would be obviated.
2. More aircraft, and of different sizes, could be positioned near the terminal at a given time.
3. A large frontage for the arrival and departure of aircraft would be obtained without the wastage of space on conventional buildings.

Morris' application went on to describe the terminal as 'arranged as an island on an aerodrome' and

> The building thus has what may be termed a continuous frontage and the ground appertaining to each side of it may be provided with appliances such as gangways, preferably of the telescopic sort, to extend radially for sheltered access to aircraft. It will be observed that by this arrangement the aircraft can come and go without being substantially impeded by other aircraft which may be parked opposite other sides of the building, and this not only ensures efficiency of operations with a minimum delay, but also ensures to some extent at any rate that the aircraft will not for example, in running up their engines, disturb other aircraft in the rear, or annoy the passengers or personnel thereof. In order to give access to the building without risk of accident or delay of aircraft, the building has its exit and entrance by way of a subway or subways leading from within it to some convenient point outside the perimeter of the ground used by aircraft, leading to a railway station or other surface terminal.



3.1 *Gatwick Airport, the first flight boarding.*



3.2 Aerial view of the 1936 Gatwick terminal building site. Both photographs courtesy of John King and Mrs Reeves (neé Desoutter).

In fact Morris Jackaman's concept was built at Gatwick to a detailed design by architect Frank Hoar, complete with the telescopic walkways referred to in the patent application and adjacent to and linked by tunnel to the Southern Railway station. The first service operated on Sunday 17 May 1936 to Paris: passengers caught the 12.28 train from Victoria, arriving at Gatwick Airport station at 13.10. They mounted the stairs of the footbridge, crossed to the up platform, walked through the short foot tunnel and completed passport and other formalities in the terminal ready for the 13.30 departure of British Airways' DH86. They left the terminal through the telescopic canvas-covered passageway to board the aircraft steps. Ninety-five minutes later they reached Paris. The whole journey from Victoria had taken two and a half hours and cost them £4 5s 0d including first class rail travel from Victoria.

Further reading

Hoar, H. F. (1936) Procedure and planning for a municipal airport. *The Builder,* 17 April – 8 May.

King, J. (1986) *Gatwick – the evolution of an airport.* Gatwick Airport Ltd/Sussex Industrial Archaeological Society.

King, J. and Tait, G. (1980) *Golden Gatwick, 50 years of aviation.* British Airports Authority/Royal Aeronautical Society.

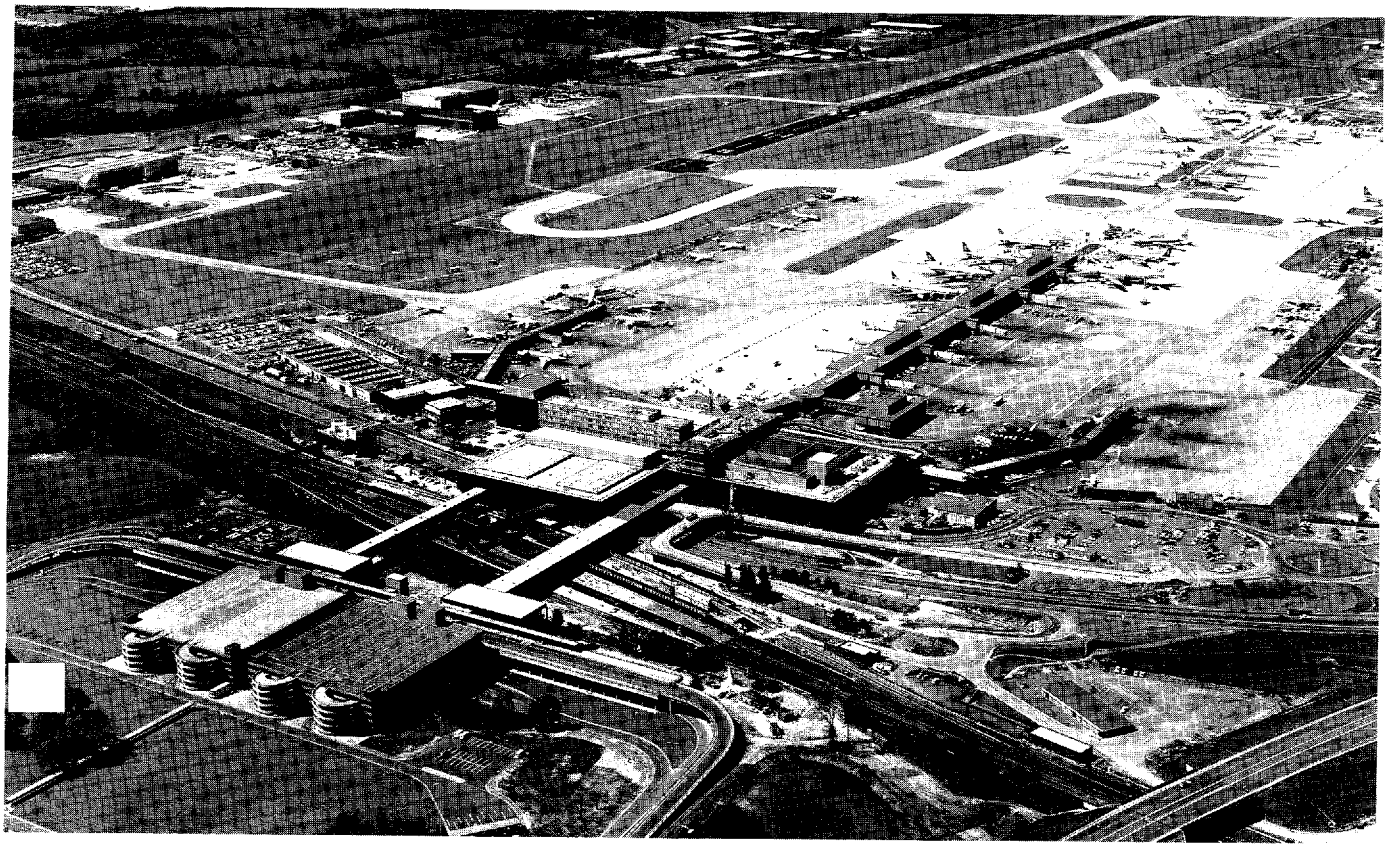
4 A review of overall size factors and capacity

4.1 Growth

There are two major influences on airport size; population demand and airline traffic scheduling. Every world metropolis and population centre has by now a giant airport in its vicinity and most cities have airports appropriate to their local needs. Either because the numbers of passengers, flights and choices of destination have increased to a certain level or because of its 'crossroads' location, a particular airport and its one or more terminals can take on a secondary growth pattern.

Traffic attracts more traffic, since a wide range of airlines and destinations in turn attracts passengers from a larger area, possibly away from what would otherwise be their nearest airport, and also attracts airlines to feed connecting flights. Ultimately, high volumes of traffic attract airlines to use their routes and facilities to the maximum by creating 'hubs', junctions for radiating routes with convenient flight-changing or transfer facilities for passengers. See Section 6.5 for more about hub terminals.

Since the previous chapter concentrated on Gatwick Airport and traffic to Paris, this chapter takes as its



4.1 Gatwick Airport South Terminal aerial view, 1980. Architects: YRM Architects and Planners, London. Photograph: Chorley and Handford Ltd.

first examples the terminal systems of Gatwick, as one of London's post-war airports, and Charles de Gaulle, as Paris's new airport for the twenty-first century, which in turn has two very different terminal buildings. Features on London Heathrow and Amsterdam Schiphol follow these.

Gatwick South Terminal (with new satellite 1983)

Gatwick South Terminal is based on small but increasingly large increments of growth as the response to change. Paris Charles de Gaulle is based on a grand design which also has to be responsive to change, but by allowing giant new elements of different design to be added.

Type: owned, with six other airports, by public company.
Form: satellite and pier-form terminal, single main level.
Architect: YRM Architects and Planners, London, and others.

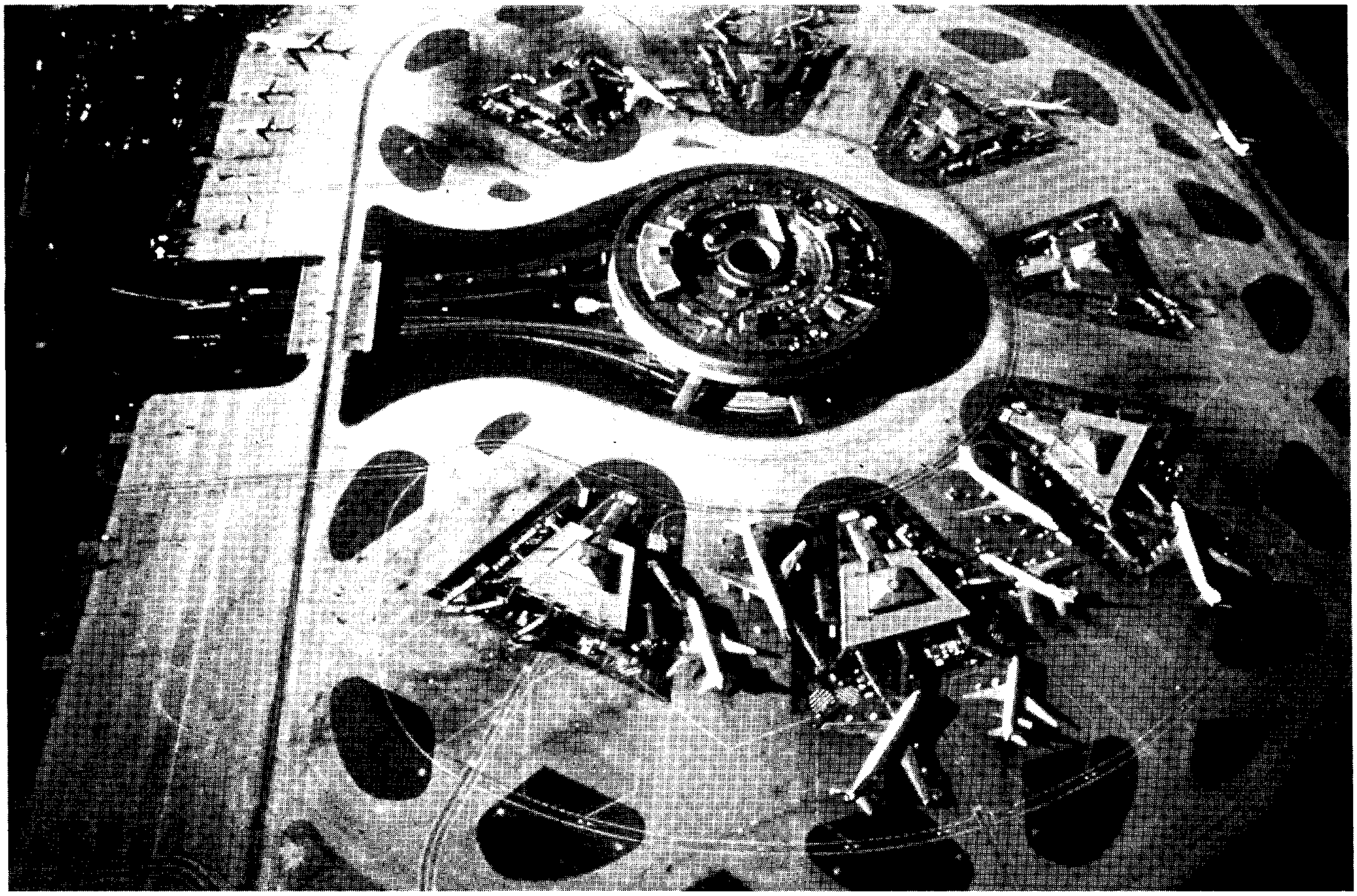
Design standards:
Passengers per year: capacity 16 million (including 5 million through satellite).
Aircraft stands: 69 plus 8 on satellite.

Description: Between 1958 and 1977 Gatwick Airport's first terminal was developed as a three-pier terminal handling predominantly charter traffic. In fact, the post-war terminal replaced the original terminal described in Chapter 3 on a totally different site. The design capacity of the 120 m × 180 m central terminal building at the end of its growth cycle, including the enlarged Central Pier, was 11.2 million passengers per year. A key feature of the terminal is the link with the adjacent railway station, Figure 4.1.

The northern pier was replaced in 1983 by the eight-stand circular satellite which is linked to the central terminal by a rapid transit system. Many subsequent extensions have increased check-in areas and enhanced passenger lounges, catering and retail facilities, to the point where the number of shops has been increased from 5 to 35. See Section 9.2 for a description of the North Terminal.

Paris Charles de Gaulle, Terminal 1 (1974)

Type: owned by airport group.
Form: multiple island satellites, vertically stacked central terminal.
Architect: Aeroports de Paris.



4.2 Paris Charles de Gaulle Terminal 1; inflexible but originally intended to multiply.

4.3 Paris Charles de Gaulle Terminal 2; flexible and with intent to multiply. Architect: Paul Andreu. Client: Aeroports de Paris. Photographer: Jean Thomas D'Hoste.

Design standards:
Passengers per year: capacity 8–10 million.
Aircraft stands: maximum of 6 to each of 7 satellites.

Description: This terminal is such a dramatic example, and will always be so, by virtue of its non-extendable form. The central terminal shape is a hollow drum with a light well in the centre and car parking on top. The passenger kerbsides are on three levels around the drum. After check-in the passengers move through tubes across the light well to reach the appropriate entry point to the satellite connector. These connectors, with undulating moving walkways, link to the island satellites, Figure 4.2.

It is notable that the second terminal at Charles de Gaulle is of quite a different form.

Paris Charles de Gaulle, Terminal 2 (1982, 1989 and 1993)

Type: owned by government airport group.
Form: multiple linear units, vertically-stacked.
Architect: Aeroports de Paris.

Design standards:
Passengers per year: A, B, C and D: approx. 20 million.
Aircraft stands: up to 10 terminal-served per module plus mobile-lounge-served stands.

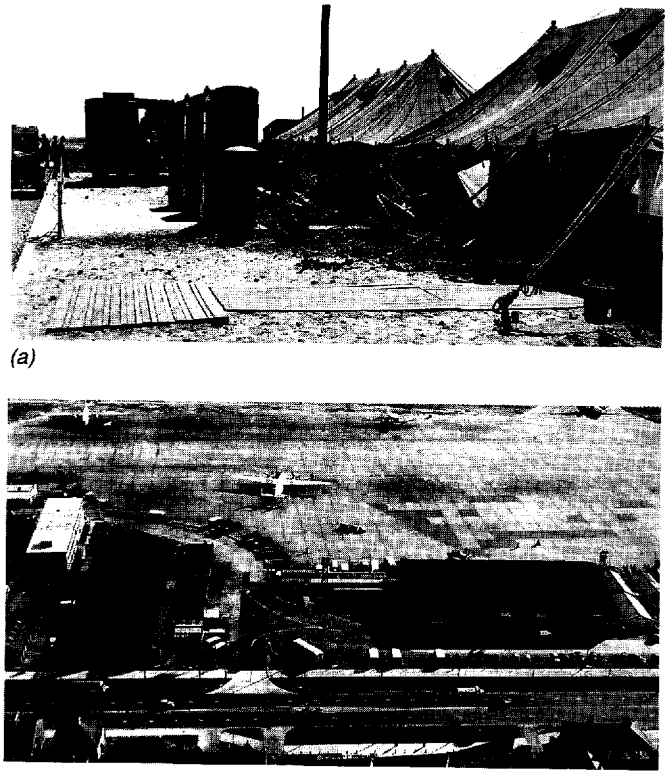
Description: This is in fact four unit terminals as the first three phases of a multi-phase modular concept. The curved two-level buildings have kerbsides and a multi-storey car park between and are divided into arrivals and departures units, Figure 4.3. The fourth to be completed, unit C, has luffing bridges, described in Chapter 26 and demonstrating the process of evolution of a design. Completion of Terminal 2 has now given way to the opening of a multi-level railway interchange station and plans for Terminal 3.

Features on two more giant airports now follow, both with early roots in constrained suburban locations and both having experienced particular growth and evolution of early master planning. London Heathrow started with a star shaped runway system with a central terminal area and Amsterdam Schiphol started with a tangential runway system. Heathrow has four terminals, with a fifth possible in the future. Schiphol has one giant terminal complex with piers constantly growing in number and length. Both have been able to respond so far to growth and change within the constraints of their early ground rules and land areas: Heathrow has a site area of only 1100 hectares and three remaining runways and Schiphol has 1700 hectares and four runways.

The growth of London Heathrow (1946–95)

Hounslow Heath's airport, ten miles west of London, really began on 25 August 1919 with the world's first sustained international air service. This service was initially operated to Paris by Air Transport and Travel and transferred to Croydon in March 1920. Heathrow itself started as a RAF station, and was chosen as a major airport site in 1944. The current history of the growth of Heathrow Airport is best charted by Figures 4.4 and 4.5 and the following chronology:

Ministry of Civil Aviation takeover of RAF station	1946
Annual number of passengers reaches 1 million using temporary terminal buildings	1953
Europa Building (Terminal 2) opened for Europe traffic with long-haul still using temporary buildings, and annual number of passengers at 3 million	1955
Oceanic Terminal (Terminal 3) for long-haul traffic total annual number of passengers at 7 million	1962
Operation by British Airports Authority starts	1966
Terminal 1 for British European Airways traffic: total annual number of passengers at 15 million	1969
Terminal 3 pier (pier 7) for Boeing 747s and new Terminal 3 Arrivals Building	1970
Terminal 2 modernized and extended: total annual number of passengers at 24 million	1976
London Underground extended to Heathrow Central	1977
Terminal 1 new International Arrivals Building and Eastern Satellite (Eurolounge) opened	1981
Terminal 4 (see Section 9.1), principally British Airways long-haul: total annual number of passengers at 31 million	1986
Refit of Terminal 3 completed (see Section 27.5): total annual number of passengers at 40 million	1990
Major changes to Terminal 1 (see Section 27.2): total capacity at 54 million passengers per annum	1994



(a)

(b)

4.4 London Heathrow: (a) tented accommodation in 1946; (b) early buildings on the north side. Courtesy of British Airways.

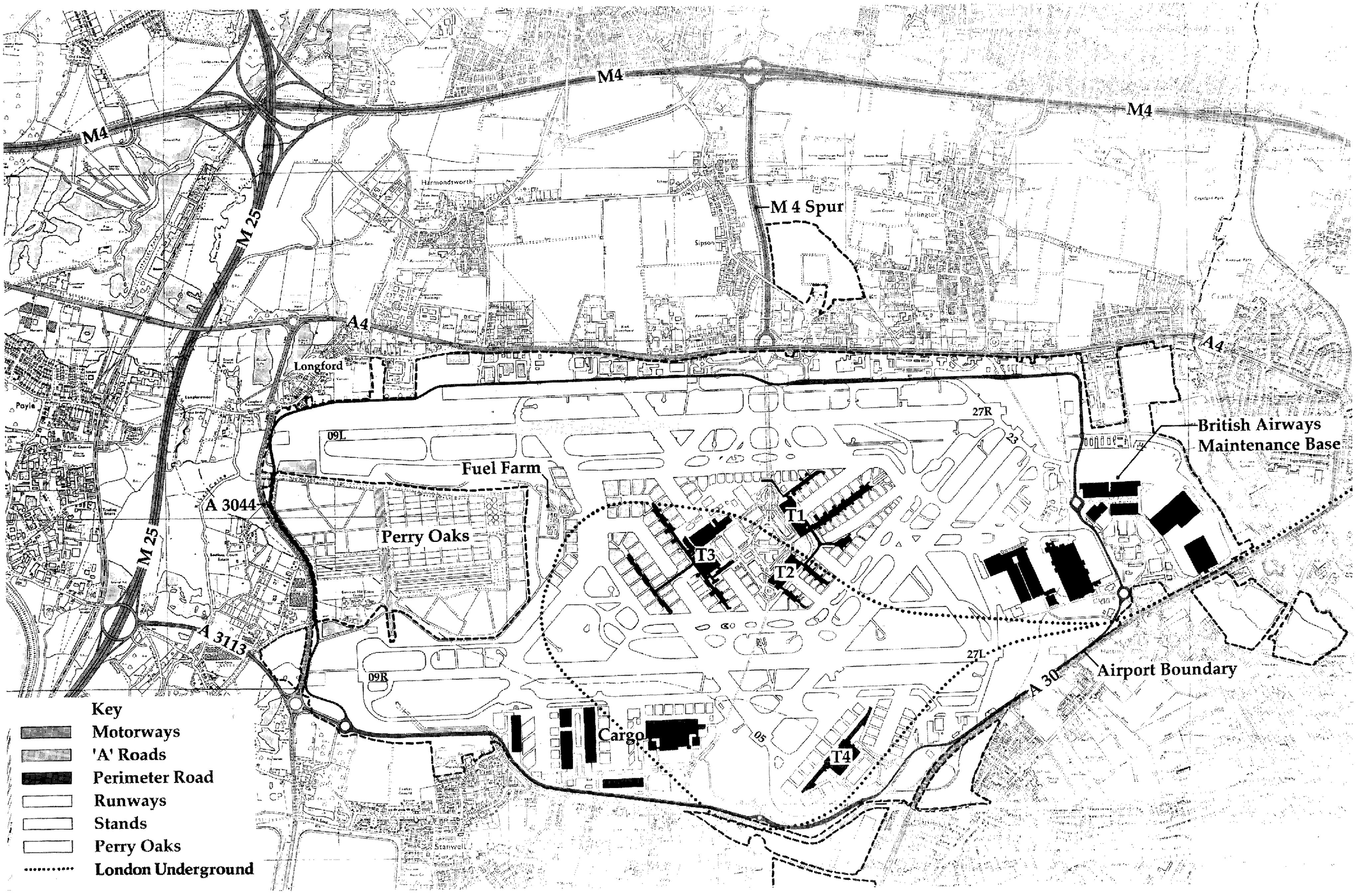
The strategy has been to provide separate terminals for different types of traffic and to link them as well as possible to allow convenient transfer arrangements for passengers changing planes. Heathrow's current intercontinental transfer percentage is running at 3 per cent. In other words, 14 million international passengers per year simply use Heathrow as a junction, taking advantage of the connections offered by 200 000 departing flights annually.

In future the opportunity exists to develop the central terminal area westwards by siting a fifth terminal on the site of the former Perry Oaks sewage works. For graphical representation of Heathrow's growth see Figure 4.10.

The growth of Schiphol (1920–95)

This airport site was first chosen for an airfield in 1919, on a reclaimed polder with the historical name of Schiphol (hell for shipping). Originally in the sea lanes 16 kilometres south of the city of Amsterdam, Schiphol was the point of departure for the first commercial flight from Amsterdam to London Croydon by the British airline Air Transport and Travel. The same airline was the operator of the first scheduled service of all, from London Hounslow to Paris in 1919, as described above. For twenty years, until destruction in 1940, Schiphol was the base both for the Dutch airline KLM and for the manufacture of Fokker aircraft. By 1938 it had become only the second airport in Europe with paved runways and was handling over 10 000 passengers per year.

Post-war rebuilding was led by the reconstruction and lengthening of the runways, followed by new terminal buildings. The following chronology charts the



4.5 London Heathrow site plan 1980s. Courtesy of Heathrow Airport Ltd.

post-war development of Schiphol Airport, using present pier designations:

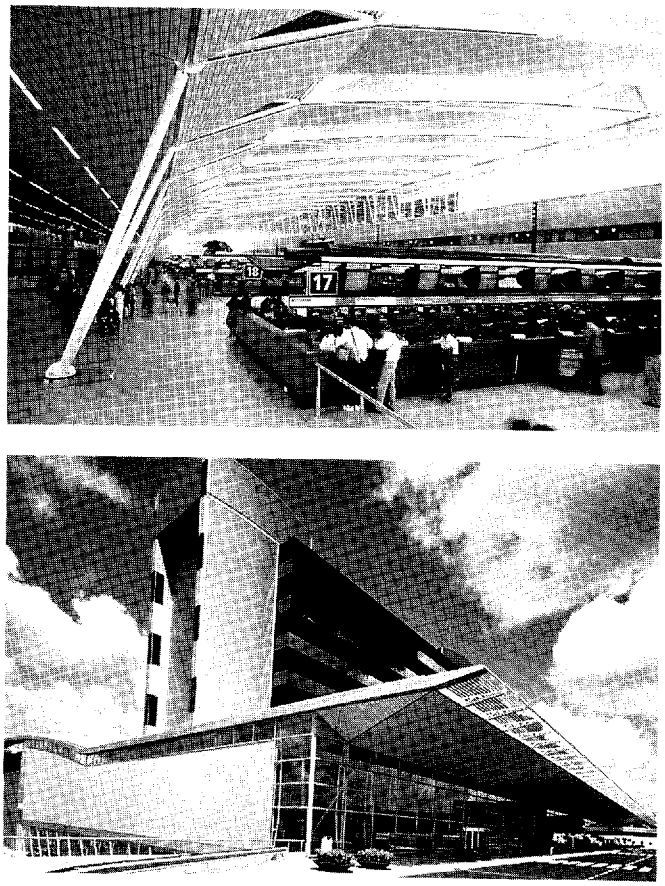
Post-war operations recommence	1945
Tangential runway master plan	1949
Two 3300 m runways open	1960
Terminal with C, D and E piers and 2 more runways, with 25 aircraft stands and capacity of 4 million passengers per year	1967
C Pier extended, 9 more aircraft stands and total capacity of 8 million passengers	1971
D Pier modernized	1974
New F pier, 8 wide-body stands and terminal extended, with total capacity of 18 million passengers per year (8 million handled)	1975
Railway link opened	1978
Ten million passengers per year mark passed	1980
E Pier rebuilt with 10 wide-body stands	1987
D Pier extension with 13 more MD80 or Boeing 737 stands and 16 million passengers per year handled	1990
Five-year plan raising capacity to 27 million passengers (Terminal extension and G Pier)	1993
Further plan to raise quality and service standards (B Pier and D Pier 'alternate' northern extension)	1995

The strategy has previously been to provide a single terminal complex, offering convenient transfer for the 37 per cent of passengers who now change planes at Schiphol. Now, with the splitting of European Community traffic, which will be treated as domestic traffic, from truly international traffic, a contiguous terminal extension has been demanded. The plan is that the existing terminal will be dedicated to EC traffic and the extension to non-EC traffic with the full range of customs and immigration facilities, Figures 4.6–4.8. The northern extension to D Pier, with a second circulation level, provides for alternating use between EC and non-EC, obviating the need for repositioning of aircraft.

A review of Schiphol's growth would not be complete without reference to the other major European hub at Frankfurt. In 1993 Frankfurt was a single-terminal airport handling 32 million passengers. The opening of a second but closely linked people-mover terminal in 1994 raised the annual capacity to 44 million passengers, Figure 4.9.

4.2 Demand and capacity

Passengers per hour and passengers per year: these two key factors in airport terminal design are related by traffic distribution. A peak concentration at certain hours of day will produce a high hourly demand in relation to annual traffic. A constant daily traffic level will produce a high annual rate in relation to the hourly demand.



4.6 Amsterdam Schiphol Airport. Interior and exterior of terminal extension. Courtesy of architects: Benthem Crouwel. Photographer: Jannes Linders.

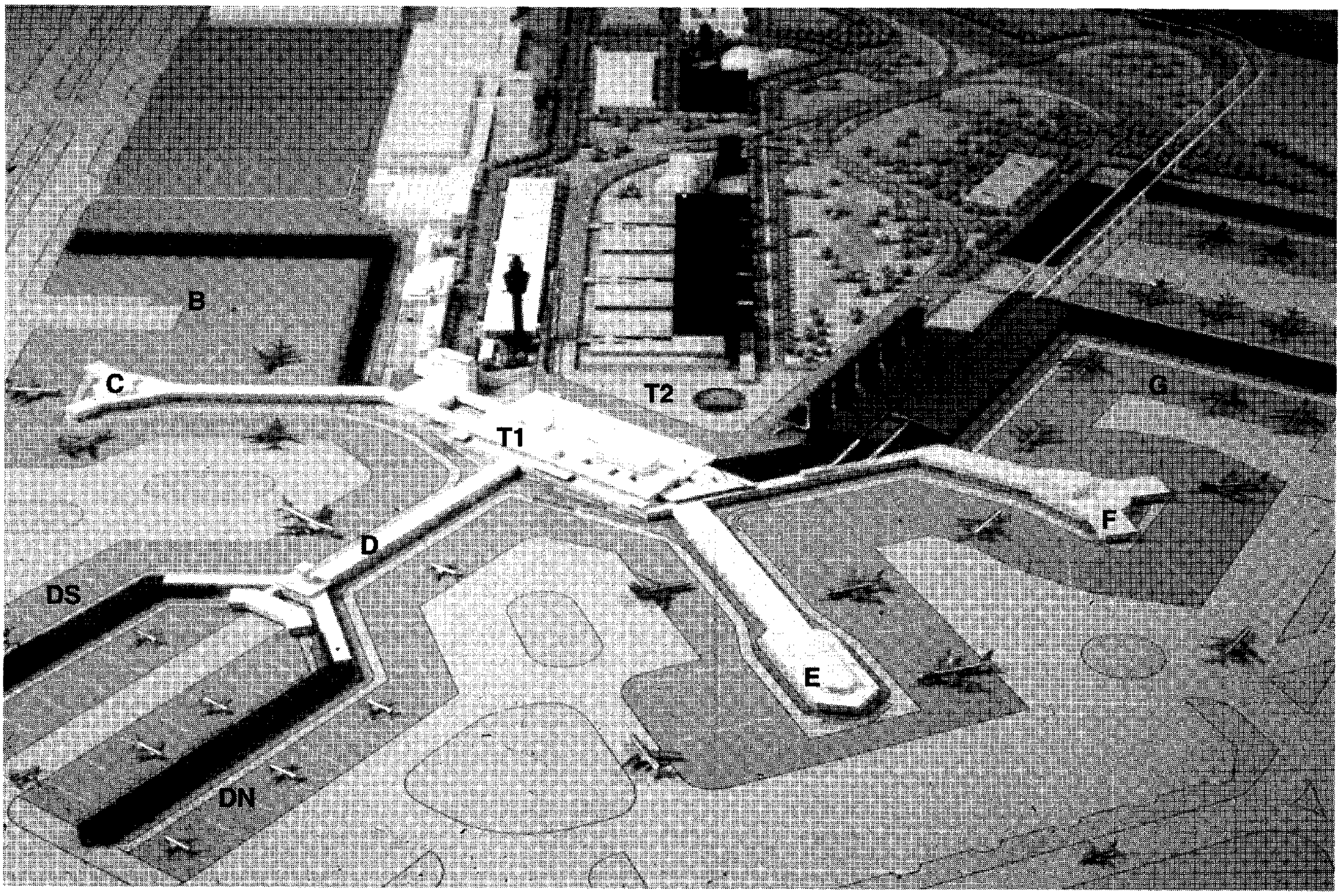
Overall ratios can be quoted as a range for the above reasons:

2-way peak hour flow = annual traffic × 0.03% to 0.04%, and
1-way peak hour flow = 2-way peak hour flow × 60% to 70% (the smaller the terminal the higher the percentage)

It would be useful to quote some specific examples of the relation between hourly and annual capacities, not as being experienced but as predicted and determining the design standards of some of the terminals described in this book:

(a) Manchester Terminal 2 Phase 1, Heathrow Terminal 4 and the full design for Gatwick North Terminal range from 1850 to 2500 passengers per hour each way and from 6 to 9 million passengers per year. They are international terminals with similar types of traffic.

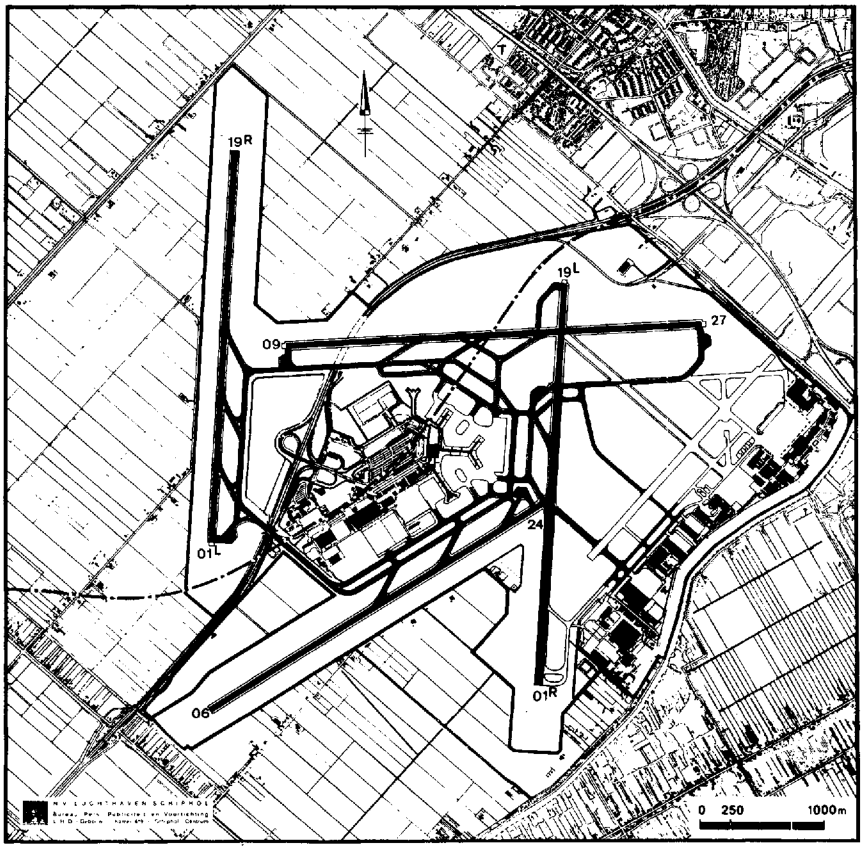
(b) Zürich Terminal B and Hanover, with less constant but high peak expectation, have hourly capacities of 3500 and 2000 respectively but annual capacities of only 6 and 4 million. Incidentally neither of these capacities has been matched by demand even in the second decade of use.



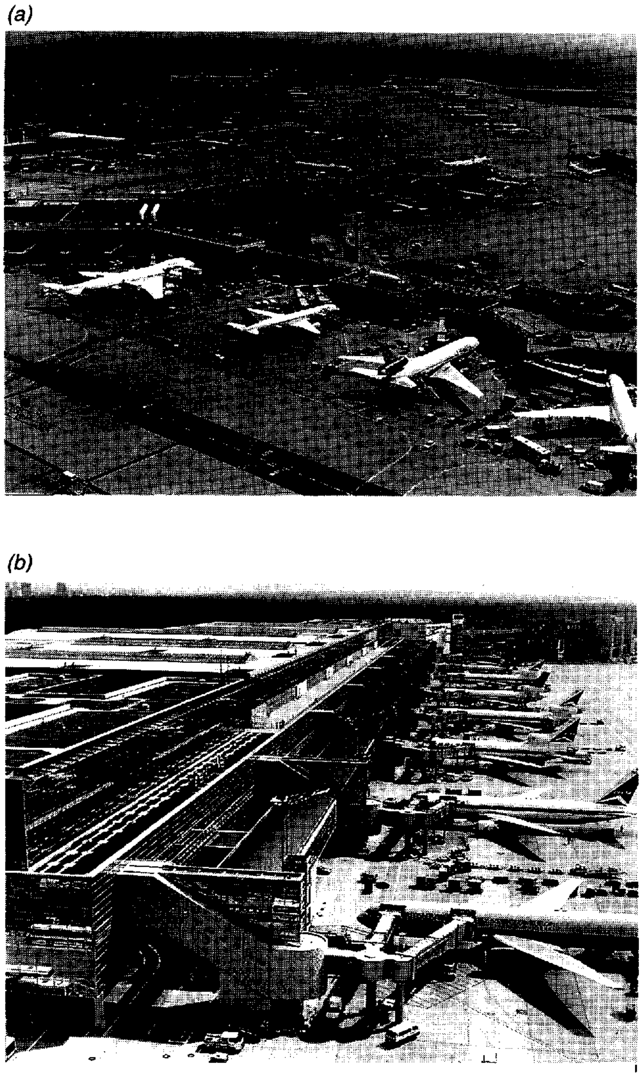
4.7 Schiphol, 1990 development model (updated).

Key

B	B Pier (regional airlines), 1994
C	C Pier, 1967 with 1971 A-head extension
D	D Pier, 1967
DS	D Pier southern extension, 1990
DN	D Pier northern extension, 1995
E	E Pier, 1967; rebuilt 1987; due for further extension post 1998
F	F Pier, 1975
G	G Pier, 1993
T1	Existing terminal
T2	Terminal expansion, first part 1993

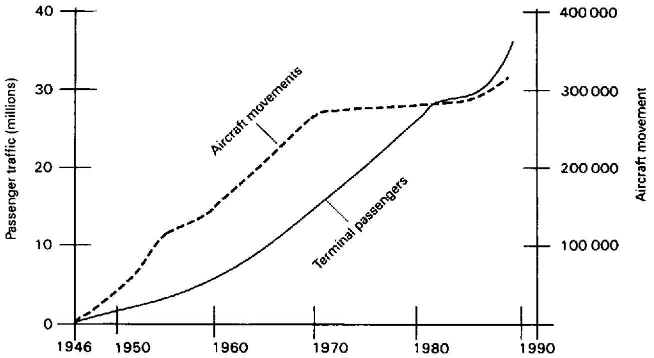


4.8 Schiphol, runway layout. All illustrations courtesy of NV Lufthaven Schiphol.



4.9 *Views of Frankfurt: (a) Terminal 1; (b) Terminal 2. Courtesy of Flughafen Frankfurt Main. Photographer: Stefan Rebscher.*

It has been common for terminal design criteria to be related to the hourly capacity or the number of passengers due to be handled in the thirtieth busiest hour of scheduled use. This means that during the 29 hours in the year in which demand is greatest the facilities will not match the requirement, but ensures reasonable standards and economy: see Section 17.6.



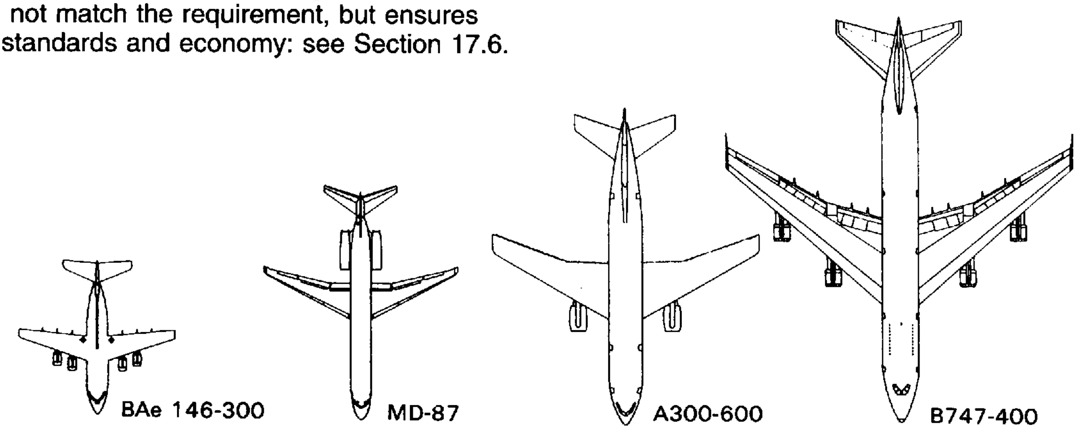
4.10 *Graph of London Heathrow passengers and aircraft movements. Adapted from BAA Consultancy data.*

4.3 Aircraft movements

The other key factor in design is the average number of passengers per aircraft. For example, at major long-haul (intercontinental) international airports like Heathrow and Gatwick, the number of passengers per aircraft is high at 115. Figure 4.10 illustrates the dramatic increase in passengers per aircraft in the 1970s and 1980s. Growth in the number of aircraft movements at Heathrow levelled off while the number of passengers handled rose from 20 million to nearly 40 million.

4.4 Aircraft size

Throughout the late 1950s and 1960s the largest commercial jet aircraft was the Boeing 707, with a wingspan of 44.4 m (145 ft 9 in), length 46.6 m (152 ft 11 in) and maximum capacity of 219 passengers. Then in January 1970 came the Boeing 747, with a wingspan of 59.6 m (195 ft 8 in), length 70.5 m (231 ft 4 in) and a maximum capacity of 550 passengers. This has now been augmented by the Boeing 747-400, an



4.11 *Sizes of representative aircraft up to Boeing 747-400.*

even larger aircraft, and many terminals have been designed to anticipate it to varying degrees.

Furthermore, plans are now being made and provisions considered for a NLA (new large airliner), with a wingspan and fuselage length both of 85 metres and a passenger capacity of 600–800, raising the issue of two-level loading and unloading, as well as apron facilities: see Section 25.2.

At the other end of the scale there is an increasing demand for 'feeder' aircraft to bring passengers to the departure points of the giant aircraft. British Aerospace, manufacturer of the BAe 146, has estimated that the number of feeder aircraft with 70 seats or less in the world's airline fleets will need to increase by nearly 100 per cent in the next twenty years. This figure compares with an estimated increase in the total fleets over the same period of about 70 per cent, Figure 4.11.

Further reading, Gatwick

Architect's Journal Information Library (1965) Building Illustrated Airport Building at Gatwick. *Architects' Journal*, 3 November.
Bell, G. D. (1988) The development of Gatwick Airport. In *Proceedings of the 8th World Airports Conference, Airports for People (London, 1987).* London: Thomas Telford.
Field, M. (1995) Going into a retail spin. *Architects' Journal*, 30 March.

Further reading, Charles de Gaulle

Andreu, P. (1977) Modular concept for Roissy 2. *Airports International*, August/September.
Beysson, J.-P. (1992) The metamorphosis of Roissy. *Airport Technology International*, 1993.
Momberger, M. (1991) Charles de Gaulle adds futuristic Terminal 3. *Airport Forum*, **6**.
Rieck, J. M. (1982) A 'human' airport terminal. *Airport Forum*, **2**.

Further reading, Heathrow

Hayter, G. (1989) *Heathrow.* London: Pan.

Further reading, Schiphol

Amsterdam Airport Schiphol (1990) *It's all for a better Schiphol.* Amsterdam: Amsterdam Airport Schiphol.
Butterwoth-Hayes, P. (1993) Schiphol targets prime hub position. *Jane's Airport Review*, May.
Schiphol Airport Authority (1976) *The development of Schiphol, 1920–1945–1967*, 8th edition. Amsterdam: Schiphol Airport Authority.
Stungo, N. (1993) Air extensions. *RIBA Journal*, August.
Veltman, T. (1988) Project history of the new C-pier (now E Pier) at Schiphol Airport. *Airport Forum*, **5**.
Wever, R. (1993) Schiphol's building operations in the next five years. *Airport Forum*, **2**.

Further reading, Frankfurt

Gethin, S. (1994) Looking for the long haul. *Airport Support*, October.
Momberger, M. (1992) Frankfurt tops out its new East Terminal. *Airport Forum*, **5**.
Momberger, M. (1994) Opening nears for Frankfurt's showpiece terminal. *Airport Forum*, **5**.
Payne, R. A. (1992) World 'Travel-Port'. *Public Transportation*, Summer.

Further reading, aircraft

Little, D. (1990) Providing for growth – a global necessity. In *Proceedings of Conference Airports into the 21st Century (Hong Kong 1990).* Hong Kong: Hong Kong Institution of Engineers.

5 Airport master planning

This chapter illustrates the context of the terminal within the airport as a whole. It is not a guide to airport master planning as such.

Whether a 'virgin' site or an existing airport site ripe for development, the issues involved in master planning are many. The vast majority of terminal projects are within existing master plans, and involve increasing terminal capacity to match runway capacity. In addition to land allocation and layout for aircraft runways and taxiways, there are:

- environmental factors, and especially noise and pollution control and mitigation measures,
- urban planning aspects for a centre of new activity which will sooner or later be planned to concentrate around the airport,
- ground level transportation planning,
- landscape, and
- technical aspects related to aviation such as fuel supply, air traffic control installations, navigational aids and constraints on obstacles in the vicinity of the airport runways, and many others.

In the terminal area all these factors relate to architectural design, and architects' skills combine with those of civil engineers, urban planners, transportation planners, landscape architects and specialist mechanical, electrical and environmental engineers.

A quick review of the development of the world's airports over the last sixty years reveals the attempts to plan and predict the needs of aviation. Airports with terminal areas created initially with space for flexibility have been able to respond to growth and change best. Notable and surprising examples of failure and success are, at one end of the scale, the original Gatwick Airport (see Chapter 3), and at the other Dallas Fort Worth, Texas (see Section 6.1) and Charles de Gaulle, Paris (see Section 4.1). The land area of Dallas Fort Worth is 7000 hectares and that of Charles de Gaulle a mere 3000 hectares, but they compare well with Heathrow's constricted 1100 hectares.

5.1 Runways and terminals

An early concept for Heathrow Airport in 1947 involved no fewer than nine runways in three triangular formations: the airport was predicted to handle a multiplicity of small aircraft whose take-off and landing direction would be determined by wind direction. At the centre of two intersecting triangles of runways was to be the Central Terminal area. Subsequently only two principal runways have been retained, a pair of parallels separated by 1400 metres (centre to centre)

As for runway length, standards have also developed accordingly. In the 1950s the International Civil Aviation A1 classification gave a runway length at sea level of 2550 m (8500 ft). With the advent of the 141 tonne Boeing 707 in 1959 the standard was immediately increased to 3300 m (11 000 ft). Note that runways need to be longer as altitude above sea level increases.

Even in the 1950s a pattern was emerging of single or twin runways. In other words, as growth has progressed so have the technical aids to support that growth, to the point where now a single runway can allow between 30 and 40 aircraft movements per hour which can offer an annual airport capacity of the order of 25 million passengers.

More specifically, a runway's capacity is determined by its independence from other neighbouring runways, the mix of aircraft and the air traffic control systems operative. Thus, where the single runway is inadequate, the optimum of a pair of parallel, and therefore potentially independent, runways separated by at least 1600–1800 metres has developed. Such a separation allows the location of a complex of terminal buildings between the runways, with the benefit of minimal cross-runway aircraft movements.

In order to keep aircraft handling capacity in balance with passenger handling capacity and demand, planners constantly seek more service from the same facilities. This has led to the mixed mode operation, whereby a judicious combination of arrivals and departures on one runway can permit more hourly movements than permitted by a single mode.

There must be obstacle clearances for both parked aircraft and buildings: a series of surfaces are defined related to runways and their standards of instrumentation. These are specified in Tables 5.1 and 5.2 and Figures 5.1 and 5.2.

For top-category runways, there is a protected horizontal zone of 150 metres measured from the centreline of the runway from which a side slope rises at a gradient of 1 in 7 and through which no stationary obstruction may penetrate.

Noise, not only from runways but also from ground movements and ground power equipment, has been seen as a problem, and caused annoyance to nearby residents. At Heathrow Terminal 4, the design and layout of the building serves as a shield to landside areas, and this has had to be augmented by 7 m high concrete barriers, Figures 5.3 and 5.4.

A newly addressed problem is the one of interference caused by buildings to air traffic control radar, which can be fooled into thinking that there are

Table 5.1 *Obstacles and distance from the runway*

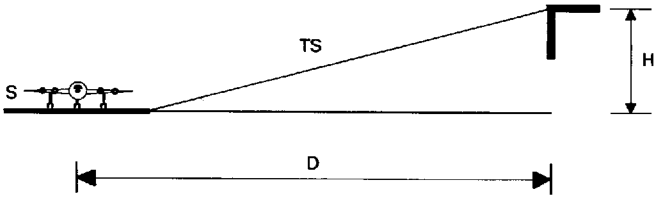
Height of obstacle, H (in m)	*Minimum distance from centreline of top category runway**, D (in m)
5	185
10	220
15	255
20	290
25	325
30	360
35	395
40	430
45	465
Over 45	4000 Maximum at mid-point of runway length

Adapted from ICAO Annex 14.
* Precision instrument approach runway category I, II or III

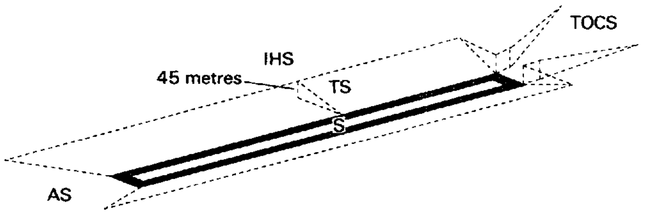
Table 5.2 *Key to obstacle limitations diagram*

Runway length		*Field* <1200 m *and* >800 m	*Field* >1200 m
IHS	Inner horizontal surface		
AS	Approach surface		
	distance from runway end:	60 m	60 m
	inner edge length:	150 m	300 m
	length to IHS:	1800 m	2250 m
	slope:	2.5%	2.0%
	width at IHS:	1050 m	1200 m
TOCS	Take-off climb surface		
	distance from runway end	60 m	60 m
	inner edge length	80 m	180 m
	length to IHS:	1125 m	2250 m
	slope:	4.0%	2.0%
	width at IHS:	305 m	742.5 m
S	Strip width:	150 m	300 m
TS	Transitional surface slope:	14.3% (1 in 7)	14.3%

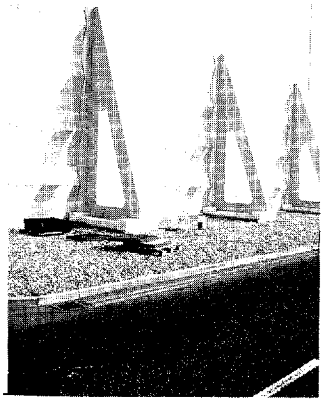
Relevant dimensions given for precision instrument (category I, II or III) approach. Adapted from ICAO Annex 14



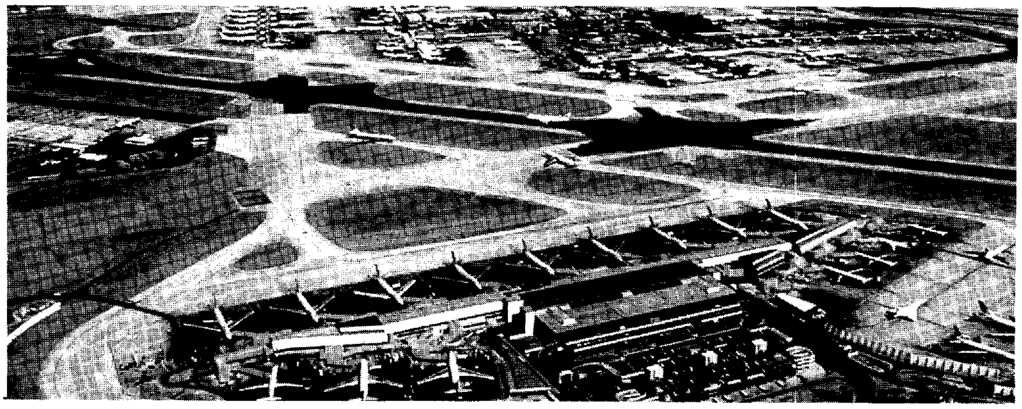
5.1 Side slope clearance showing relative position of permissible fixed or parked obstacle to runway.



5.2 Obstacle limitations.



5.3 Heathrow Terminal 4 noise barrier. Architects: Scott Brownrigg & Turner, Guildford. Engineers: Scott Wilson Kirkpatrick & Co. Ltd.



5.4 Heathrow Terminal 4 aerial view from landside showing screening effect of buildings. Courtesy of Heathrow Airport Ltd.

more aircraft in the air than there really are. In 1980, first attempts were made in the design of aluminium cladding profiles at Heathrow Terminal 4 to mitigate the effect of reflected radar beams. Stealth technology, the science of creating objects transparent to radar, has an increasing role to play in buildings close to airport runways.

5.2 STOLports

London City (1987)

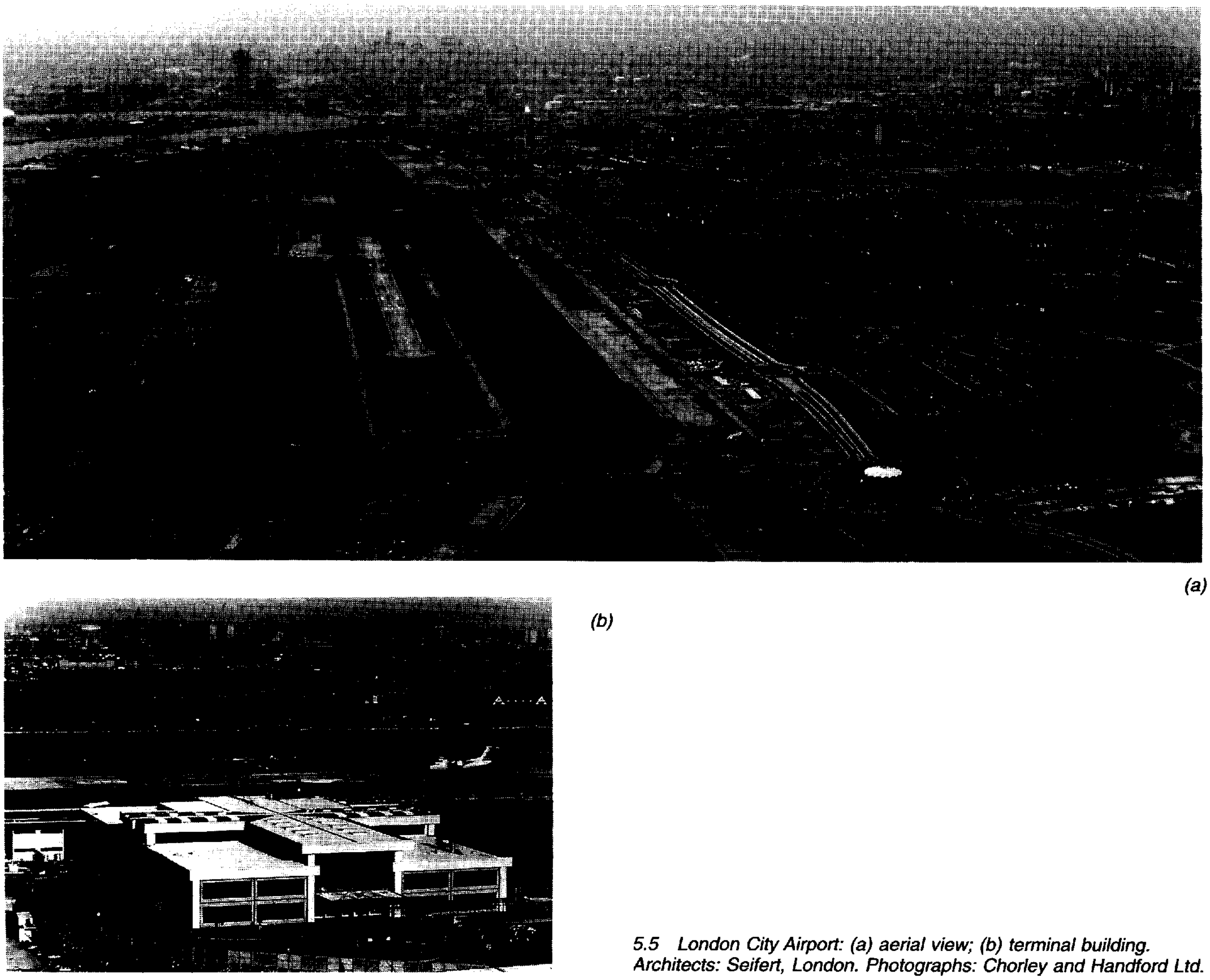
Type: privately owned.
Form: basic with remote aircraft.
Architect: Seifert Architects, London.

Design standards:
Passengers per year: 1.2 million capacity
Aircraft stands: up to 10 Dash 7 or BAe 146 type.

Description: by definition, this airport is suitable only for small and medium capacity aircraft which can use the short-take-off-and-landing runway. The terminal is sized appropriately and is of the simplest design with a short pier to provide weather protection for passengers walking to the open apron stands, Figure 5.5.

5.3 Heliports

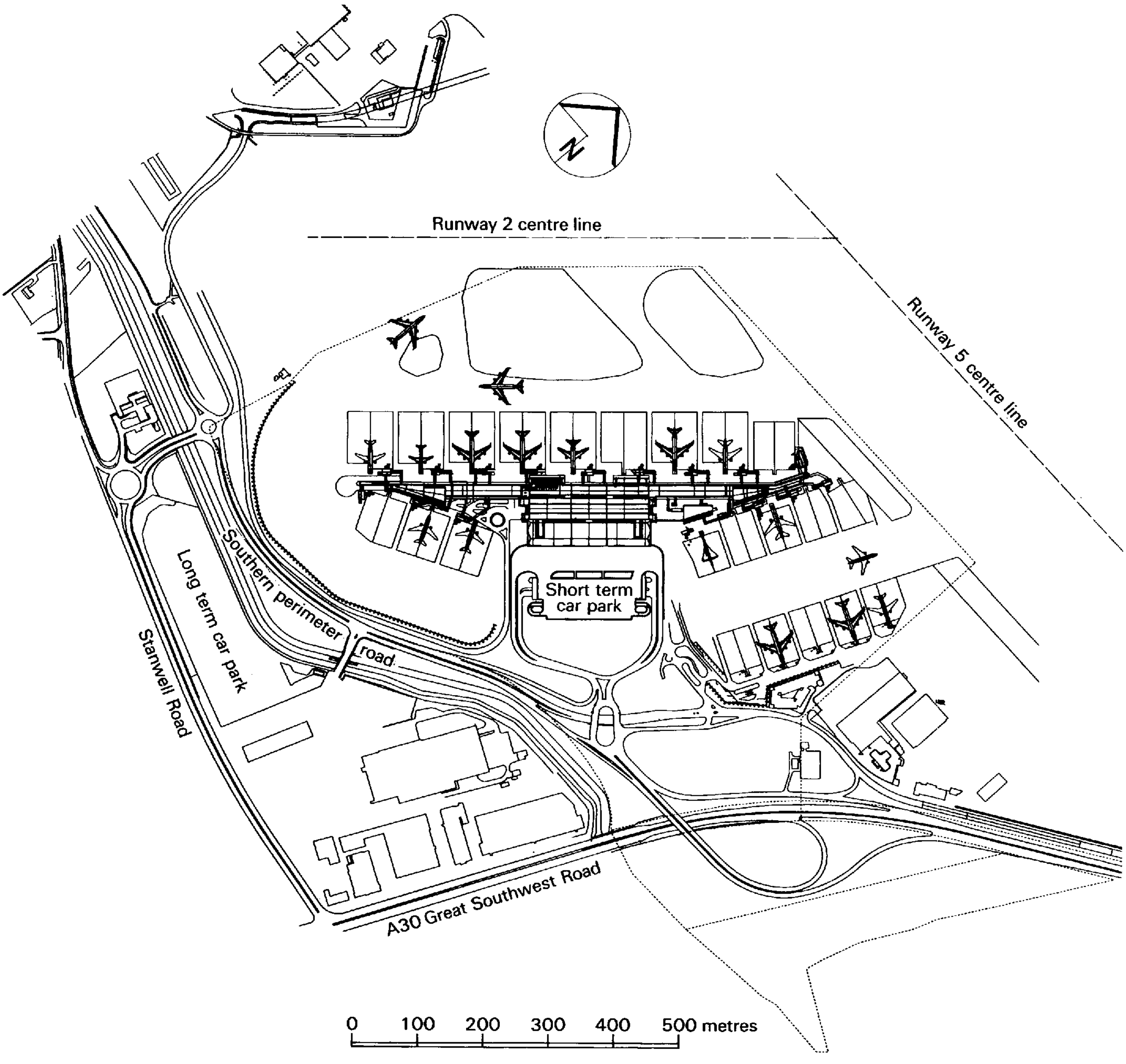
Theoretically attractive though the helicopter is, as both a personal airborne transport and as a mass airborne transport, the development of the craft has stagnated. As a result, there is not a coherent hierarchy of conventional airports, stolports and heliports serving national, regional and local needs. Apart from the prospect at the end of the century of a range of tiltrotor, vertical take-off high speed aircraft, there is little view beyond the continued sporadic use of the helicopter as an emergency transport, as



(a)

(b)

5.5 London City Airport: (a) aerial view; (b) terminal building. Architects: Seifert, London. Photographs: Chorley and Handford Ltd.



5.6 Heathrow Airport Terminal 4 roads/car parks plan. Architects: Scott Brownrigg & Turner, Guildford. Client: Heathrow Airport Ltd.

high-cost personal transport and to serve places where no other transport can reach.The one exception is the prospect of a national network of heliports in Japan, where the helicopter is regarded optimistically as the fourth generation transport, following the sequence of railway, motor car and jet aircraft.

5.4 Landside access

The factors of roads, car parks and public transport are covered in Chapters 22 and 23. The schemes for Heathrow Terminal 4 and Manchester Terminal 2 illustrate the classic dilemma: what should the balance be in terms of land use allocation to aircraft facilities, terminal buildings and roads and car parks? By definition, a terminal and landside access area between two parallel runways will not offer unlimited space around the terminal for car parking. Master plans such as that at Orlando, Florida, with a site area of 4000 hectares and twin runway separation of 2400 metres (see Chapter 16), allow a high degree of flexibility for future provision of parking in all its forms, Figure 5.6.

References

Civil Aviation Authority (1990) *CAP 168 Licensing of Aerodromes* (4th edition). London: Civil Aviation Authority.

International Air Transport Association (1995) *Airport Development Reference Manual* (8th edition). Montreal: IATA.

International Civil Aviation Organization (1987) *Aerodrome Planning Manual, Master Planning,* document 9184 pt 1 (2nd edition). Montreal: ICAO.

International Civil Aviation Organization (1990) *Aerodromes, Volume 1: Aerodrome design and Operations: International standards and recommended practices,* Annex 14 to the Convention on International Civil Aviation (1st edition). Montreal: ICAO.

Further reading

Blyth, A. (1995) Hiding from radar. *Architects' Journal*, 30 March.

British Midland (1990) *How do we meet the demand? – the case for expanding Heathrow.* Derby: British Midland.

Bunch, R. (1989) World issues in heliport development. In *Airport Technology International 1989/90*, edited by M. G. Hudson.

Sainsbury, R. N. (1988) London City Airport – a new approach to city centre travel. In *Proceedings of the 8th World Airports Conference, Airports for People, 1987.* London: Thomas Telford.

Shaw, J. F. B., Toplis A. F. and Williamson, R. K. (1988) STOL: airport access made easy. In *Proceedings of the 8th World Airports Conference, Airports for People, 1987.* London: Thomas Telford.

Turner, D. W. (1984) New concepts in airport planning and design. In *Proceedings of the 7th World Airports Conference, Economics of Air Transportation, 1983.* London: Thomas Telford.

Wilson, J. R. (1990) High growth in heliports forecast. *Jane's Airport Review*, March.

Woolley, D. (1987) London STOLport: amid the politics operations begin. *Airport Forum*, **5**.

6 Functional types of airport terminal

Irrespective of the form of aircraft parking adopted (linear, pier(s), satellite(s) or remote or any combination of these) the terminal will be either single-purpose or multi-purpose, either airline-owned or airport-owned, either for domestic and/or international traffic, either centralized or decentralized.

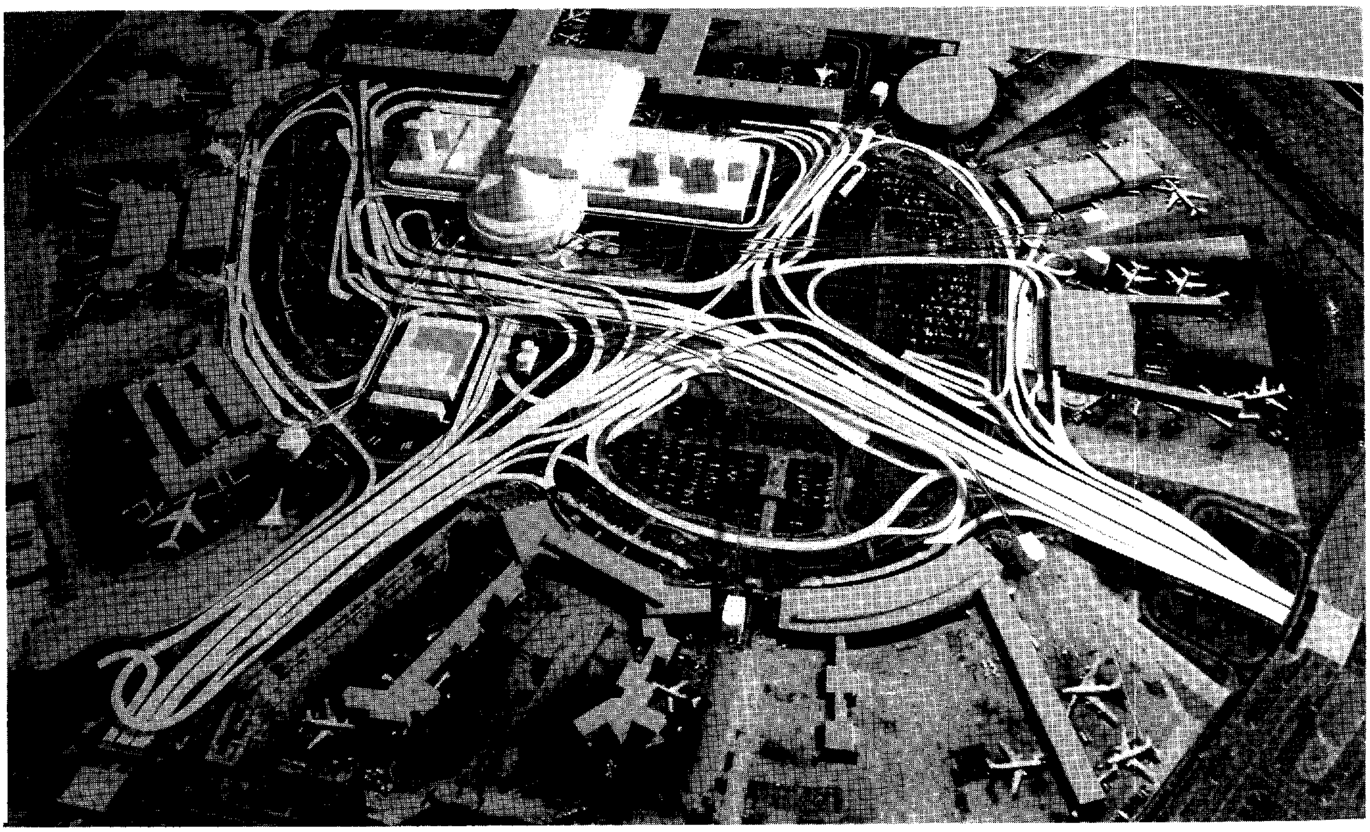
6.1 Who owns it? Airport, airline or developer

If a terminal is built and owned by the airport, the objective is usually to ensure that the terminal is non-specific and therefore likely to be more robust in the face of changing demands. If, however, the terminal is built by and for the airline, the airline's specific requirements (probably short and middle-term) are likely to call the tune. Most of the terminals illustrated in the next section are general purpose terminals.

Examples of airline-owned or airline specific terminals follow:

New York J. F. Kennedy International

Here terminals have been built by individual airlines. A notable example is the British Airways terminal (centre left in Figure 6.1) which features in Chapter 27 as the



6.1 New York J. F. Kennedy conceptual model. Courtesy of Port Authority of New York and New Jersey, New York.

subject of major redevelopment to meet changing airline needs. The access system to the whole complex of nine terminals could be developed in future, as shown by Figure 6.1, to meet the needs of its 30 million annual passengers requiring transfer between terminals. However, transfers are running at only 25 per cent, and therefore the current priority in the mid 1990s is the first new terminal for 25 years built on the site of the former Eastern Airlines terminal (centre right) for a group of international airlines.

Newark New Jersey (1973)

The latest terminal here breaks the pattern of standard multiple terminals and has been built for an airline funded by a loan from the airport.

Type: airport-owned but new terminal for People Express, subsequently Continental Airlines.
Form: multiple satellites, vertically stacked main terminal.
Architect: Port Authority of New York and New Jersey.

Design standards:
Passengers per year: 26 million (1993).
Aircraft stands: 27 (each of A and B) plus 60 (C).

Description: in 1986 Newark overtook JFK to become the largest airport serving New York and may ultimately handle 50 million passengers per annum. The new terminal complex was conceived as three terminals and nine circular satellites; two terminals and six satellites opened in 1973, replacing earlier terminal buildings which in the 1930s had been the busiest in the world. The terminals have two-level forecourts and single-level satellites.

The third terminal (C), while following the general style of Terminals A and B, is twice the size and has piers rather than satellites, Figure 6.2. Continental Airlines, having taken over People Express and its designated part of the new Terminal C, became the largest user of facilities at Newark with 15 million passengers per year. The teminals are now linked to car parks by a monorail system.

Dallas Fort Worth (1973)

Here a kit-of-parts approach to design has been adopted to enable airline requirements to be met within a consistent design form and aesthetic. This example highlights the importance of individual style to airlines. Subsequently a totally different type of terminal, a long two-sided pier, has been brought about by American Airlines' hub operation.

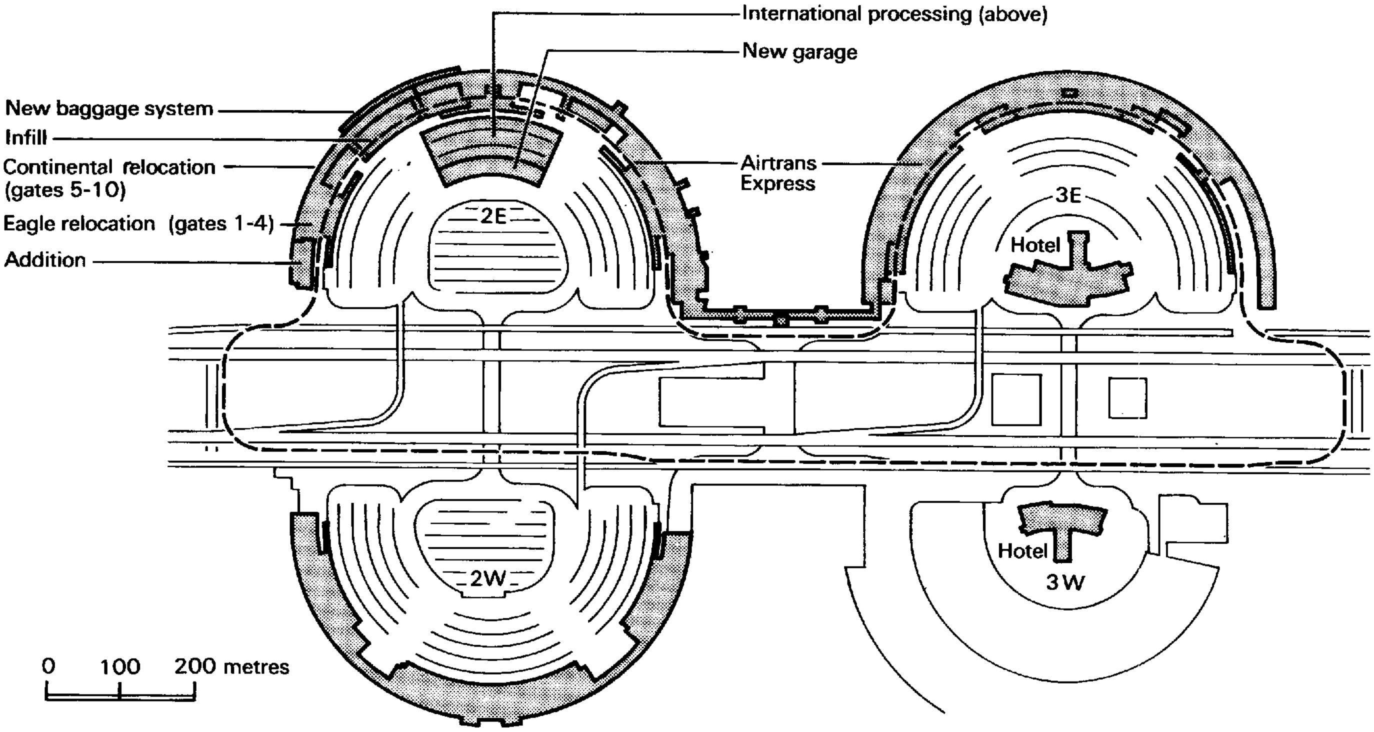
Type: airport-owned with airline modules.
Form: multiple linear units, vertically stacked
Architect: Hellmut Obata Kassabaum (original concept); Corgan Associates Architects (American Airlines Terminal).

Design standards:
Passengers per year: 50 million (1993).
Aircraft stands: approx. 25 to each of 4 semicircular modules.


6.2 Newark New Jersey, satellite. Courtesy of Port Authority of New York and New Jersey, Newark International Airport, Newark, NJ.


6.3 Dallas Fort Worth Airport, articulation of functional parts. Architects: Hellmuth Obata & Kassabaum, Dallas, Texas.

6.4 *Dallas Fort Worth Airport, airside concourse. Architects: Hellmuth Obata & Kassabaum, Dallas, Texas.*



6.5 *Original concept of American airlines Eastside Terminal Development Plan. Courtesy of Corgan Associates Architects.*

Description: Dallas Fort Worth was the last completely new airport of the 1970s and embodied several innovative features, although major changes have been necessary to maintain the responsiveness to the constantly developing US domestic market. The concept involves giant semicircular modules constructed to the requirements of individual airlines and Airtrans electric vehicles link the first four terminals built.

American Airlines has reorganized its large operation in such a way that it occupies two whole modular terminals, linked by a redesigned Airtrans serving four stations on the secure side of the terminal and thereby offering fast transfer between flights, Figures 6.3–6.5.

Birmingham International, Euro-hub Terminal

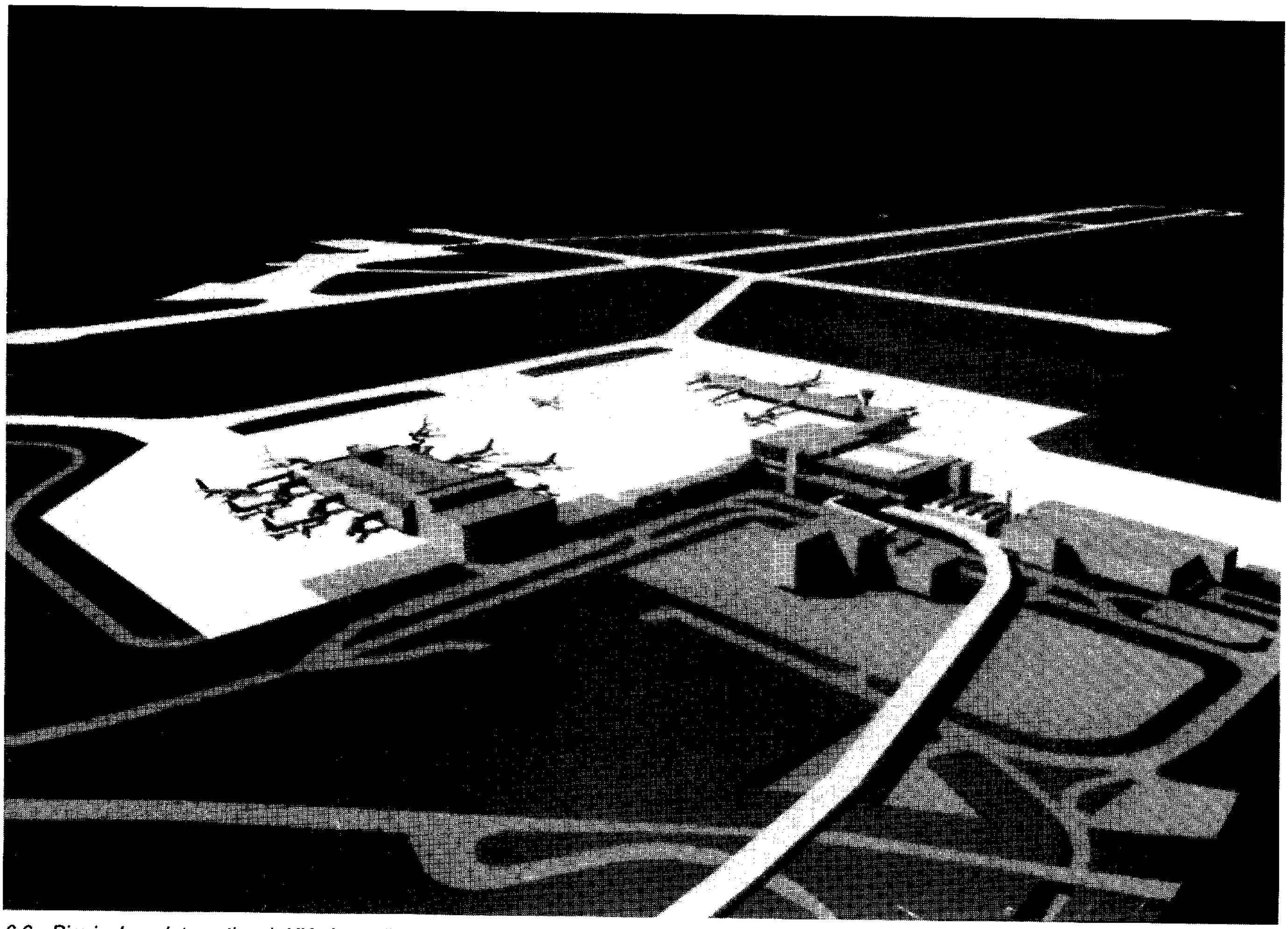
This proposal, approved in 1988 and operational in 1991, provides a compact hub for British Airways (Figure 6.6).

Type: privately owned (airline, airport and others).
Form: linear compact, vertically segregated.
Architect: Scott Brownrigg & Turner (feasibility concept); Sir William Halcrow & Partners (implementation).

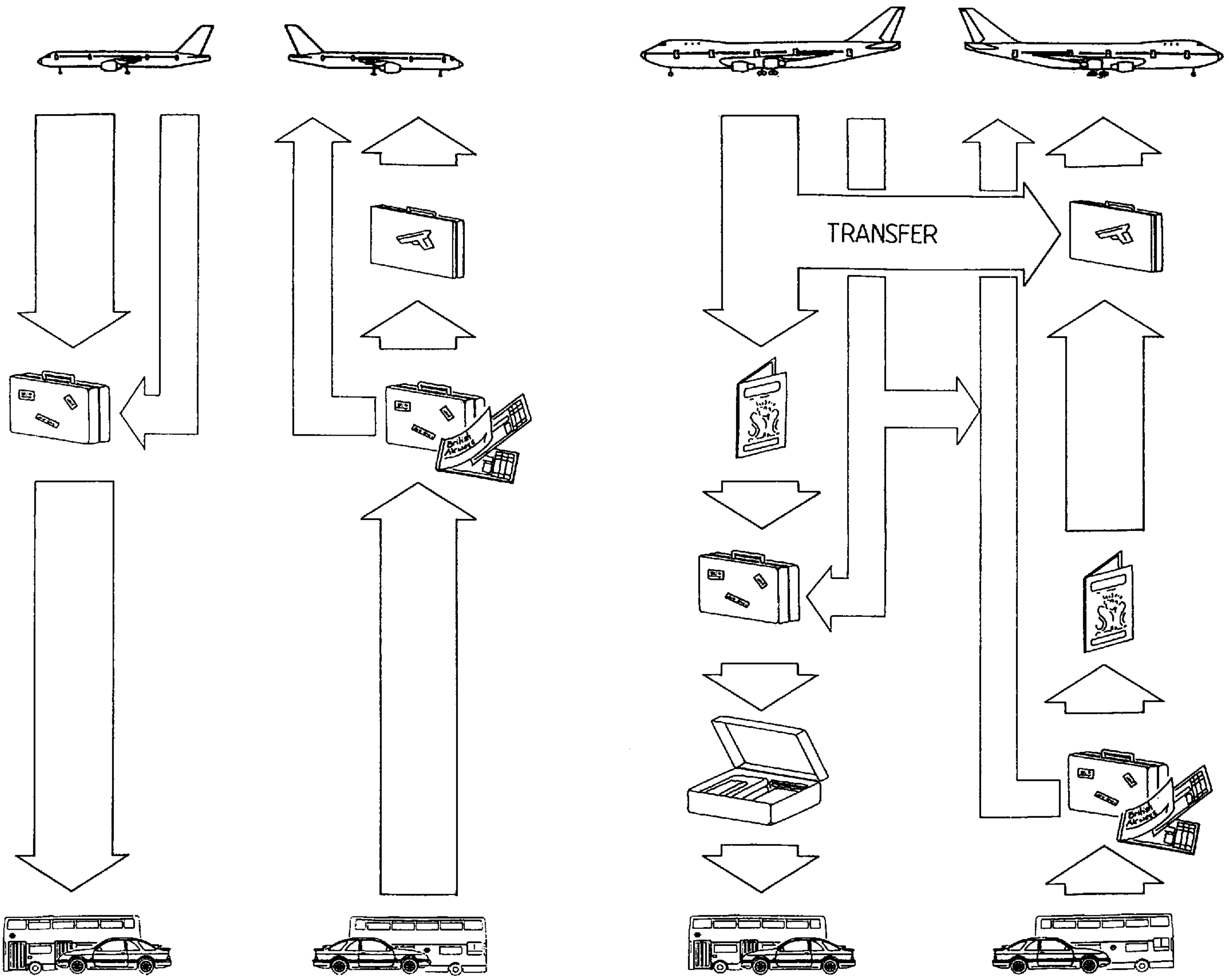
Design standards:
Passengers per hour: 800 one way (Phase 1).
Passengers per year: Phase 1: 3.0 million capacity.
Aircraft stands: Phase 1: 10 stands (9 Boeing 737s and 1 Boeing 767)

The hub application is described in more detail in Section 6.5.

Description: Birmingham International Airport was developed seriously with the opening of a new all-purpose terminal in 1984. The combination of geographical position and marketing strategies created the opportunity for Britain's first airline-driven terminal only four years later. This bold move necessitated replacement of relatively new facilities to open up a new landside approach to a self-contained terminal,



6.6 Birmingham International, UK, three-dimensional computer model: a June 1988 feasibility study. Architects: Scott Brownrigg & Turner, Guildford, with Scott Wilson Kirkpatrick & Co. Ltd.



6.7 Domestic and international passenger flow diagrams illustrating control procedures.

which is explained in the hub context in Section 6.5. The project paved the way for private sector investment in UK terminals, and is owned by a combination of local authorities, airline, hotel group, car park company and construction company.

6.2 Domestic and international terminals

International terminals involve customs and immigration procedures; domestic terminals do not. Domestic terminals can therefore be simpler buildings. However, the advent of passenger and baggage security procedures has caused the grouping of facilities and channelling of passengers, and has reduced the distinction between the two types (Figure 6.7).

6.3 Single-level and multi-level terminals

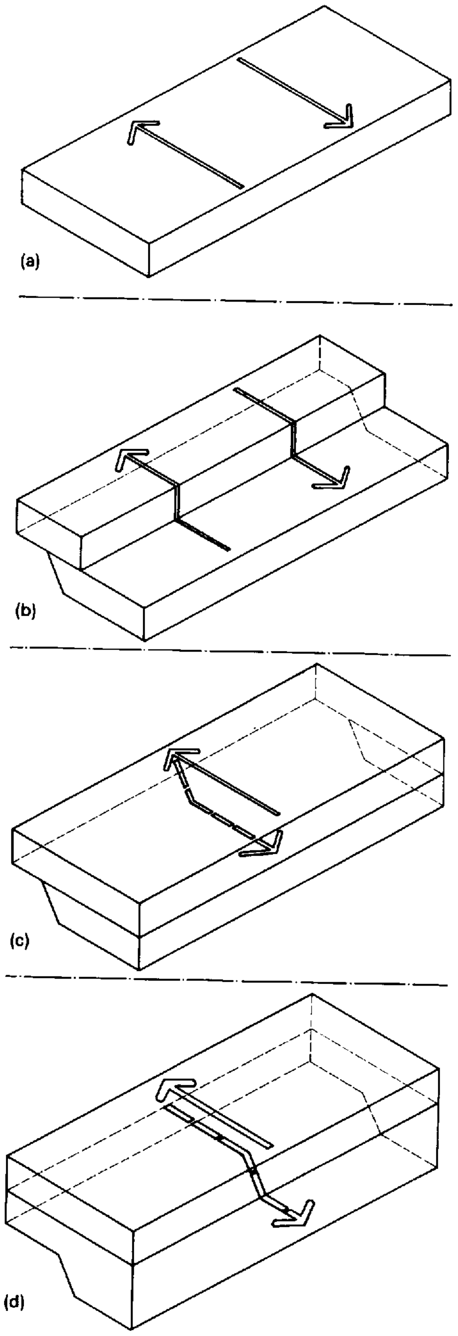
There are four principal types:

1 Side-by-side arrivals and departures on a single main level

Suitable for the smaller scale operations where first-floor movement of passengers from terminal to aircraft via telescopic loading bridges is not justified, Figure 6.8a.

2 Side-by-side arrivals and departures with two-level terminal

This design obviates the need for elevated roads because all kerbside activity can take place at ground level. Escalators and lifts have to be provided to take



6.8 *Four different arrivals and departures configurations.*

departing passengers up to the boarding level, Figure 6.8b.

Note that Heathrow Terminal 3 is a particular example of this type of terminal. The development of Heathrow, including the conversion of the original Oceanic terminal to form the Terminal 3 Departures Building, is featured in an earlier chapter, and the latest redevelopment of Terminal 3 to cater for new commercial needs is featured in Chapter 27.

3 Vertical stacking of arrivals and departures

The majority of large scale terminals now adopt this configuration. Departures facilities are invariably at the high level, usually accompanied by an elevated forecourt, with baggage handling and arrivals facilities below. It is essentially economic and convenient for passenger and baggage movement: departing passengers arrive at an elevated forecourt and move either on the level or down a short distance by ramp to the aircraft loading point. Arriving passengers also, after leaving the aircraft, move downwards to baggage reclaim and landside facilities, Figures 6.8c and 6.9.

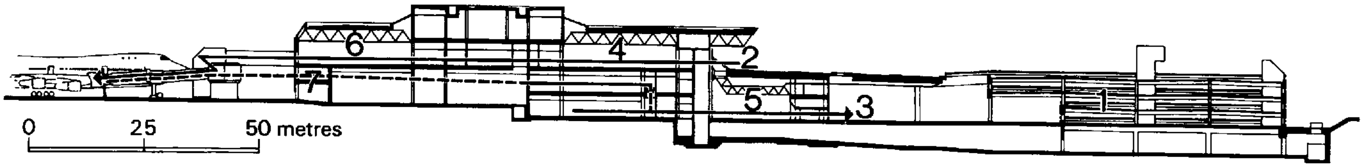
4 Vertical segregation

High volumes of passengers, particularly with wide-bodied aircraft on long-haul routes, are best served by uni-directional circulation routes. Segregation can theoretically be either vertical or horizontal, but in practice the only feasible way to achieve it is by departing passenger routes at high level with downwards circulation to the aircraft and arriving passenger routes below, Figures 6.8d and 6.9.

Note that Bahrain International Airport, featured in Chapter 27, starts as a side-by-side two-level terminal and ends as a stacked terminal with vertical segregation.

6.4 Decentralized terminals

Most airport terminals are centralized groups of functions, commercial, passenger and baggage processing, airline operations, etc. Centralization has



Key

1 Multi-storey car park
2 Departures forecourt
3 Arrivals forecourt
4 Departures concourse
5 Arrivals concourse
6 Airside departures concourse
7 Arrivals corridor

6.9 *Heathrow Terminal 4 section. Architects: Scott Brownrigg & Turner, Guildford.*

the advantage of economy of management if not of passenger convenience. However, where absence of the need for control authorities in the case of domestic terminals, or prime concern for passenger convenience at the expense of centralized control has made it possible, then decentralization has proved beneficial.

Separate units for specific types of traffic

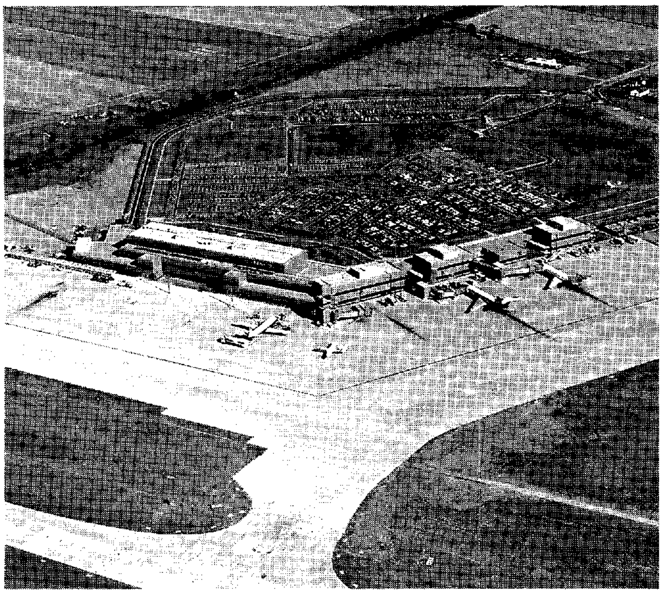
This has proven appropriate in selected cases such as Edinburgh, where the international facility is separate from the domestic 'shuttle' terminal, to the advantage of walk-on shuttle passengers in terms of kerbside convenience and travel distance.

Edinburgh (1977)

Type: owned, with six other airports, by public company.
Form: linear, one stepped main level.
Architect: Robert Matthew Johnson-Marshall Ltd, Edinburgh.

Design standards:
Passengers per year: 2.7 million (1993).
Aircraft stands: 9 (3 with loading bridges).

Description: this new terminal complex is designed for a very specific traffic mix: small turboprop aircraft serving Scottish airports, regular shuttle services to London (operated with Boeing 757 aircraft), and scheduled and non-scheduled international traffic. Each type of traffic is separately catered for. The shuttle gates are positioned in such a way as to allow drive-to-the-gate for maximum passenger convenience and speed, essential for a successful shuttle operation. The separate international section is on two levels with loading bridges, Figure 6.10.



6.10 Edinburgh. Architects: Robert Matthew Johnson-Marshall Ltd, Edinburgh. Client: Scottish Airports Ltd.

Linear units, alternating arrivals and departures

The more common type of decentralization arises in the case of multiple-repeating unit terminals as advocated by the German airline Lufthansa. The unit terminal concept more readily offers the possibility of passengers checking-in immediately adjacent to the aircraft boarding position as well as offering one single airline contact with the passenger, simple baggage handling and the opportunity for self-service. However, this principle does depend upon the flexibility of operation of statutory controls and the preparedness of customs and immigration staff to man a multiplicity of locations within the terminal.

Examples in Chapter 12 are Hanover and Munich.

6.5 Hub terminals

By definition, a hub terminal is designed to support an airline hub operation which in turn is a system of scheduled flights converging on an airport within a short space of time in order to catch another series of onward flights also within a short space of time. Such a system, where the flights are the spokes and the intersection the hub, can take place several times a day at any one airport. Principally the operation is an airline one, with the schedules designed by the airline to both serve its passengers' requirements and to generate traffic. It may also be a device to relieve congestion at another airport where the proportion of transfer passengers is high and impairing the standard of service for originating passengers.

Many hubs have developed at US airports where airline traffic is very dense. In certain cases where geography dictates, two airlines have hubs at the same airport and vie for take-off and landing slots. Certain American hubs operate on a very large scale: United Airlines at Chicago for example have up to 50 inward and 50 outward flights serving 5000 passengers in a peak hub hour.

At such hubs the percentage of passengers transferring, or making a connection between planes, may exceed 70 per cent, in which case the conventional kerbsides, check-in areas, etc. are sized for only 30 per cent of the airport terminal throughput.

The distinction needs to be drawn between transfer passengers who change planes and transit passengers who stop at the airport but do not change planes. Most international hub terminal experience is based on domestic traffic where the movement of passengers is not governed by frontiers, immigration and fiscal control procedures. When and where airlines operate a mixture of international and domestic routes in a hub situation, passengers change from being international to domestic and vice versa.

Alternatively the domestic leg may be classed as international if no passengers are permitted to board at the hub.

Hub terminal trends and facilities

As well as the full normal range of facilities for originating passengers, hub terminals need facilities associated with the immediate areas of disembarkation from aircraft and boarding of aircraft for transfer passengers. In normal, non-delayed, situations transfer passengers move quickly from one flight to another. Most will have no hold baggage, being business travellers using frequent services on heavily trafficked routes between business centres. Those with hold baggage may need to reclaim it before catching their outward flights for customs control reasons. Especially in these circumstances, distances must be short and walking distances and queueing times kept to a minimum.

As a rule transfer passengers will not eat and drink as they transfer but will want to buy books and newspapers.

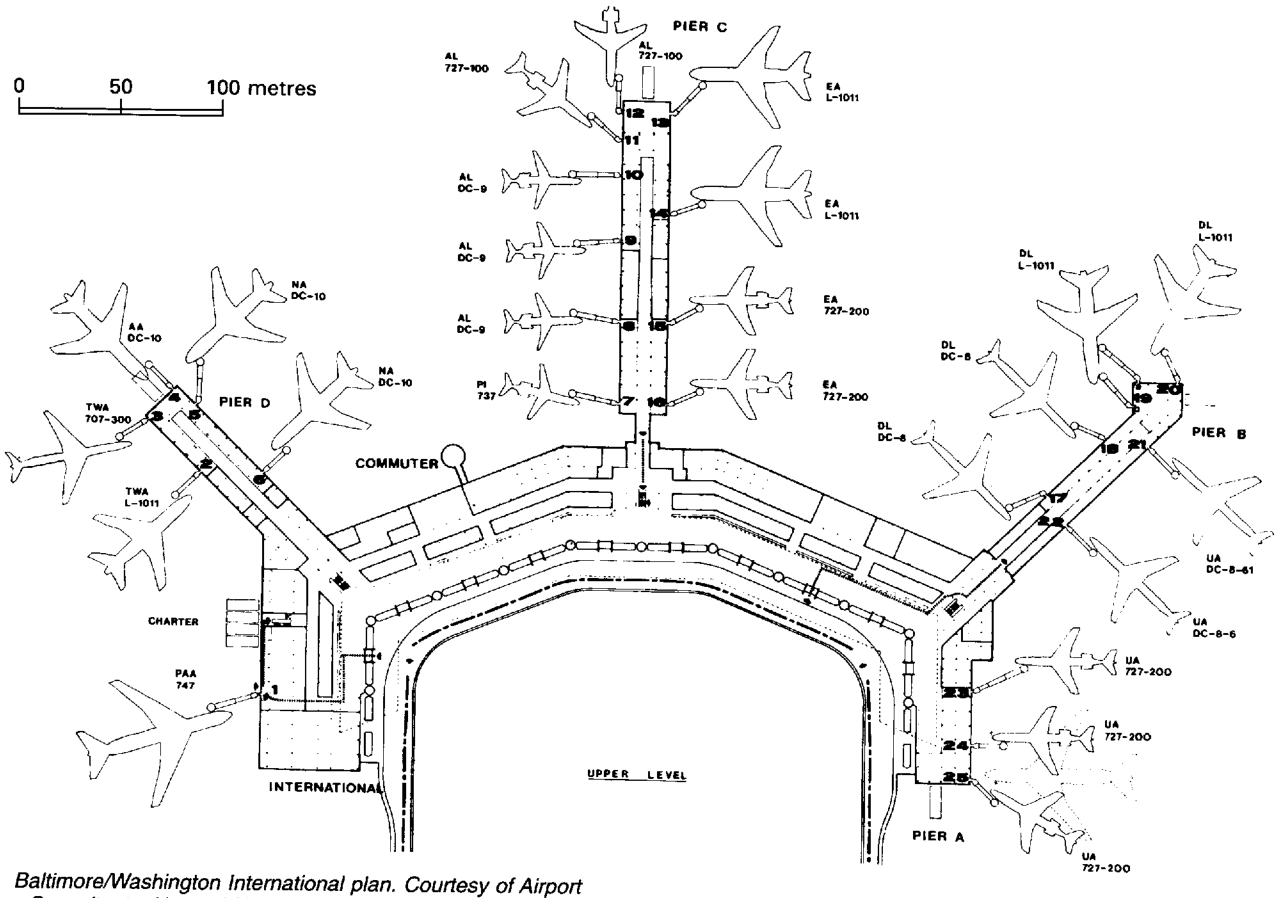
On the aprons and taxiways, layouts must support the fast turnaround of aircraft, with dual taxiways to avoid bottlenecks caused by push-back manoeuvres and with generous and frequent apron equipment parking areas. Certain stands or aircraft parking positions may be pre-allocated to certain flights, both for the benefit of regular passengers, apron staff and baggage handling procedures.

It has often been said that successful terminals depend upon baggage systems and hub terminals are no exception. Speed is even more of the essence in the case of a hub operation, bearing in mind that the transfer passenger is only there because the airline cannot for some reason carry him directly from A to B. Transferring baggage from one aircraft to many others in a short space of time is a very different operation from conventional manual or automatic sorting and make-up post-check-in.

In considering the relation between a hub operation and the other passenger terminal traffic, because rarely will the whole operation be hub-based, there are two fundamentally different principles. Either the hub terminal is part of a larger terminal, sharing kerbside, check-in, etc. with other airlines, or it is a unit terminal exclusive to the hub airline. US examples are:

Baltimore Washington International (1979)

Type: airport-owned.
Form: triple pier, vertically stacked.
Architect: Peterson and Brickbauer.



6.11 Baltimore/Washington International plan. Courtesy of Airport Forum. Consultants: Howard Needles Tammen & Bergendorf.

Design standards:
Passengers per year: 12 million (1994).
Aircraft stands: 27 terminal-served.

Description: here the hub takes place on a radial pier system. This terminal is virtually a new terminal built around an original building dating from 1950. The result is a two-level forecourt and a very simple plan with three piers having a mobile lounge station at the root of the third one for international traffic. The structural form is a bold space frame, providing a canopy to the upper forecourt. In fact it is the archetype of a multi-pier terminal, Figure 6.11.

Atlanta, Georgia

Here the hubs are organized on a series of linear island satellites connected by a sub-apron Westinghouse transit system: see Chapter 13.

Chicago O'Hare, United Airlines

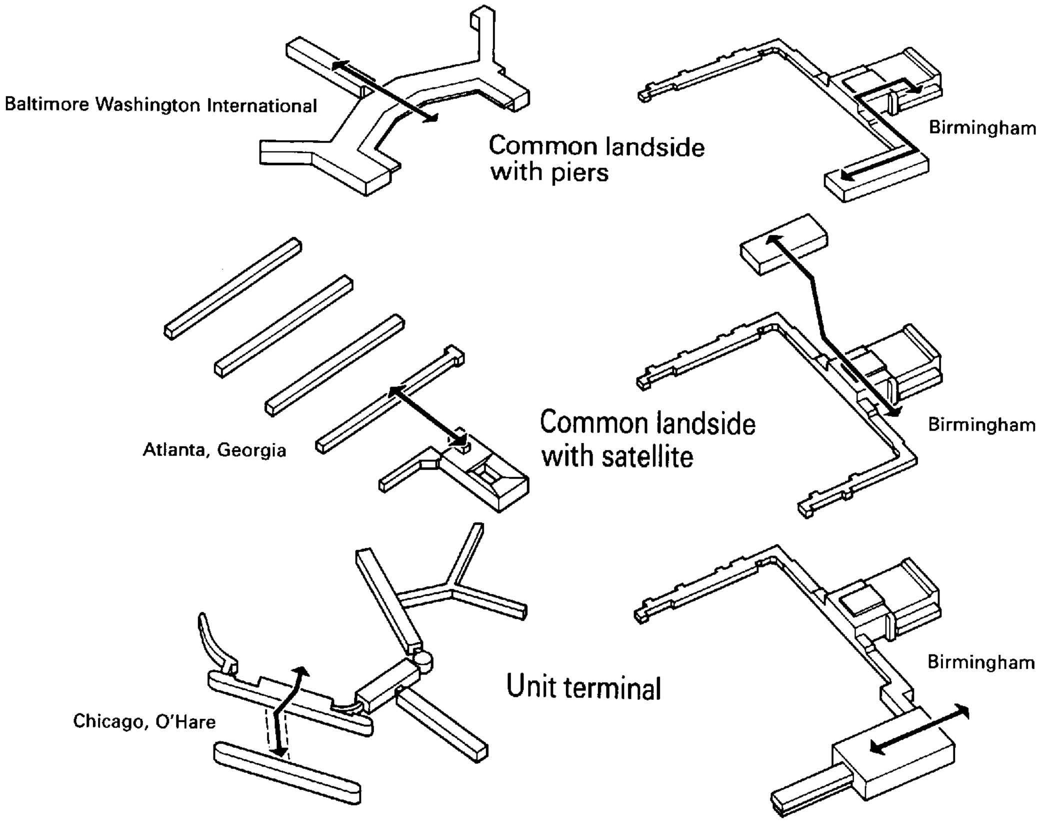
Here the single airline operates a major hub operation from a long landside concourse building with 15 related stands and an island pier/satellite, Figure 6.12, see Chapter 14.

Common features of all these are linear aircraft parking patterns and airline-exclusive gates for mixed ranges of aircraft types.

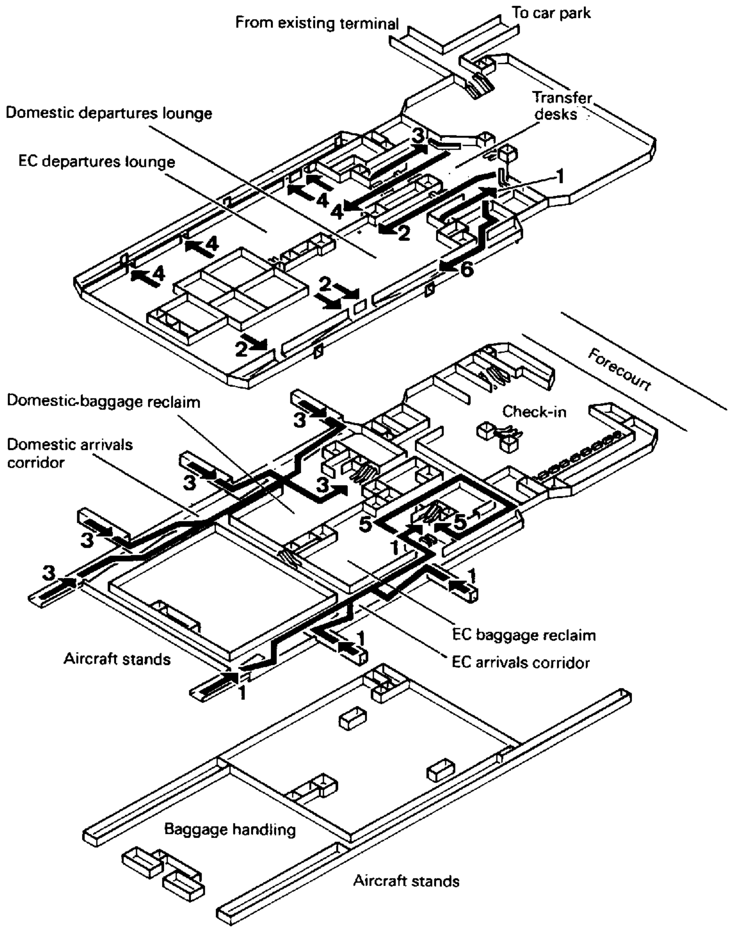
Birmingham International, British Airways Terminal

This new terminal is a notable British example. It is distinctive in the way that the design has responded to the need for passengers and aircraft to transfer from domestic to European Community and international routes and vice versa. The capacity of the building is 3 million passengers per year, and provision has already been made for a second phase increasing capacity to

6.12 Chicago O'Hare, United Airlines Terminal, aerial view. Architects: Murphy & Jahn, New York.



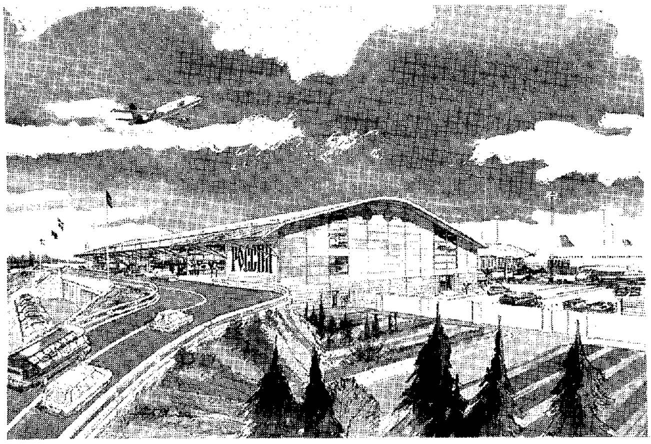
6.13 Birmingham Eurohub terminal: diagrammatic explanation of options compared with USA examples.



Key

1 Passengers arriving as EC, intending to depart as domestic
2 Passengers departing domestic
3 Passengers arriving domestic, intending to depart as EC
4 Passengers departing as EC
5 Additional control for passengers arriving from EC to depart domestic
6 Northern Ireland traffic

6.14 Birmingham International, transfer passenger routes.



6.15 Artist's impression of Moscow Domodedovo Air Russia terminal. Architects: Scott Brownrigg & Turner, Guildford. Artist: John Robinson. Courtesy of British Airways.

4.5 million. Compactness is the key and maximum transfer times of 30 minutes are built into the scheduling of flights by the airline. The proportion of transfer passengers has increased from the 26 per cent previously experienced at Birmingham by British Airways to 35 per cent in the first four years of the life of the new terminal.

The speedy transfer operation is enhanced by information technology with automatic ticketing and boarding pass issue and with a centrally controlled door operation system to control passenger flows. Extreme flexibilty is the order of the day: any gate may serve as a domestic arrival or departure or as an international arrival or departure, Figures 6.13 and 6.14.

Moscow Domodedovo, Air Russia hub terminal project

This project has been designed as a new terminal building grafted on to the existing apron at Moscow's principal domestic airport, Domodedovo, 45 km south east of Moscow and with giant twin runways and road and rail links to Moscow. A new airline, Air Russia, has been planned to use Moscow as a new transit point for Europe–Asia and US–Asia services and to attract passengers by fares competing with long-haul services as well as by the opportunity of a stopover at Moscow. Feeder traffic will be provided from intra-CIS routes already at Domodedovo.

The hub building form has to be compact. The chosen concept comprises a two-level landside terminal with an elevated forecourt and a two-storey airside pier with two-sided aircraft parking and segregation of arriving and departing passengers. Baggage handling facilities are located below the landside building, offering expansion and combining the arrivals and departures areas with an advantage for the high proportion of transfer baggage. In the first phase, terminal-served stands are to be provided for three Boeing 747s and five Boeing 767-300s, with provision to add two more Boeing 767s. Initial hourly design flows for a hub peak hour are to be 1000 passengers per hour, rising to 1400 passengers per hour, and the split is to be 35 per cent origin and destination/65 per cent transfer and transit, Figure 6.15.

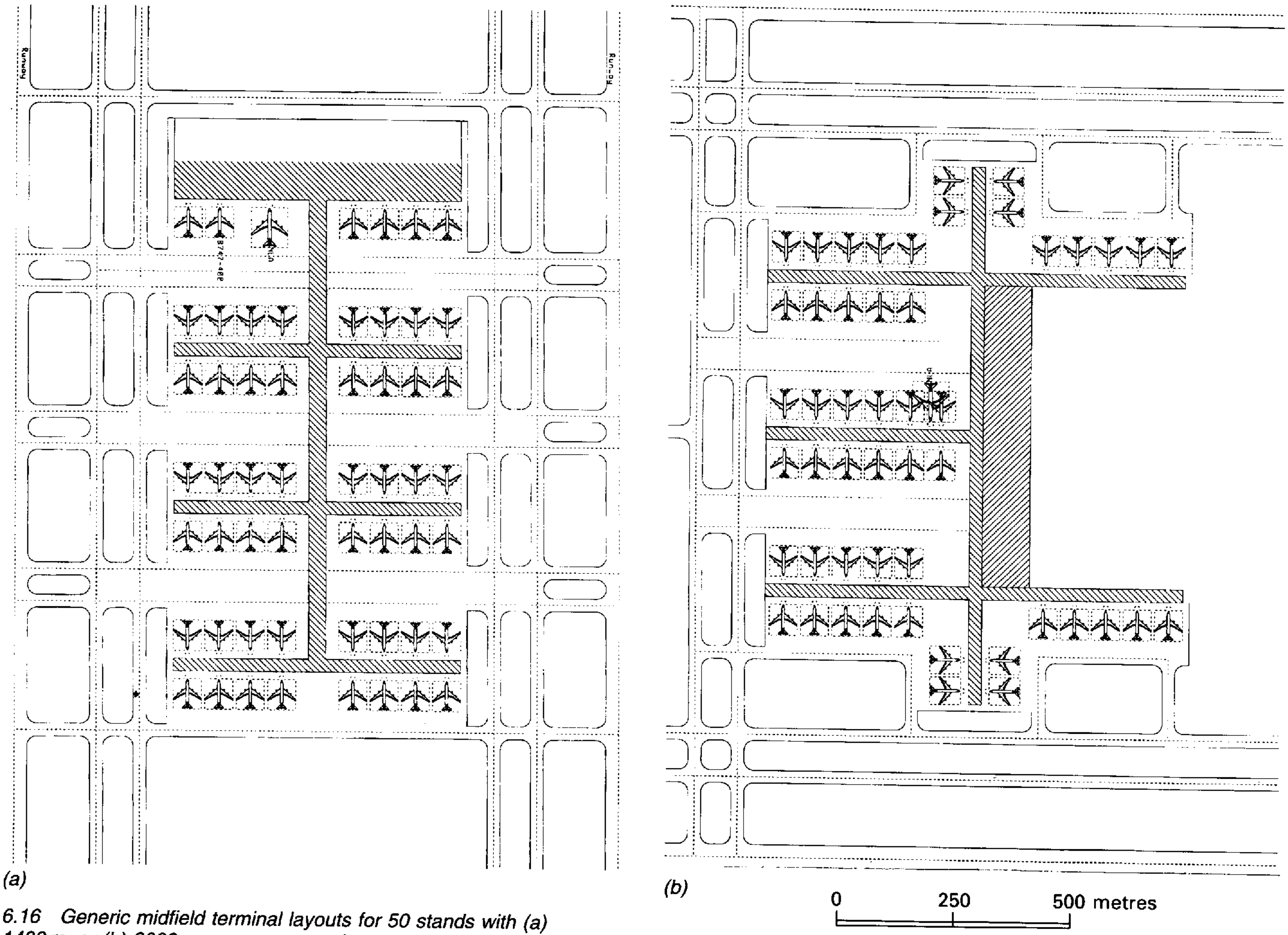
The pure hub

A terminal system designed from day one for maximum transfer convenience for up to 30 million passengers per annum and with contact stands for up to 50 wide-bodied aircraft can have two distinctly different shapes: multiple contiguous piers or multiple island piers. When the scale of the operation grows beyond that, either in initial planning or even in initial construction, other criteria come into play. Experience shows that when the overall apron has to provide more than about 50 72.5-metre stands, the distances involved between the farthest stands are starting to limit the success of a fully flexible hub without a people mover or with a target minimum connecting time of 45 minutes.

Island pier midfield terminals: A 50 million passengers per annum initial phase is demonstrated by Atlanta Hartsfield, illustrated in Section 13.1, as being dependant upon a sub-apron people mover. Denver Colorado illustrated in Section 13.3 has an initial design capacity of 30 million passengers per annum, but adopts the same principle. The new Hong Kong Airport at Chek Lap Kok illustrated in Section 10.3, has a very different form, incorporating a sub-apron people mover in readiness for growth beyond the 35 million passengers per annum threshold. Initial designs for Heathrow's Terminal 5, with a capacity of 30 million passengers per annum and 50 wide-body contact gates, are also based on island piers and a sub-apron people mover. Is early investment in a people mover, particularly an embedded one, strictly necessary?

Compact midfield terminals: Figure 6.16 shows two midfield terminal systems, one for a runway separation of 1400 m and the other for a runway separation of 2000 m. The former has the same constraints as, for example, the Heathrow Terminal 5 site, and the latter as the Second Bangkok International Airport master plan, illustrated in Section 10.4. Setting-out dimensions are based on ICAO Annex 14 (1990). Incidentally, one feature of the short twin-taxilane cul-de-sacs is the possibility they offer for new large aircraft and single centrelines at the roots of the piers.

Either of these solutions suggests an integral passenger transport installation without the expense of a sub-apron system and the need for excessive changes of level. The people mover at Japan's new Kansai Airport illustrated in Section 24.1 is such an example.



6.16 Generic midfield terminal layouts for 50 stands with (a) 1400 m, or (b) 2000 m runway separation.

Wayports

It is a short logical step from the idea of a hub airport, serving a large number of transfer passengers but in the vicinity of a city to which they do not want to go or even overfly, to a wayport exclusively serving transfer passengers and nowhere near to a major centre of population.

Further reading, J. F. Kennedy and Newark

Butterworth-Hayes, P. (1985) Airport interest in People grows. *Airports International*, May.
Papadatos, S. P. (1994) New York architects target the aspirations of the passenger. *Airport Forum*, **6**.
Schwartz, A. C. (1986) Kennedy, LaGuardia and Newark to be improved. *Airport Forum*, **5**.
Schwartz, A. C. (1987) Continental leases Newark's Terminal C. *Airport Forum*, **6**.
Schwartz, A. C. (1989) Newark Airport to build new international terminal. *Airport Forum*, **2**.
Schwartz, A. C. (1993) Billon-dollar investments pave way to New York future. *Airport Forum*, **6**.
Wagner, W. (1974) Newark: where a sophisticated owner mustered talent from all sources. *Architectural Record*, November.

Further reading, Dallas Fort Worth

Hilscher, G. (1982) Construction booming at Dallas-Fort Worth. *Airport Forum*, **6**.
Lopez, R. (1990) Dallas Ft Worth: big and still growing. *Jane's Airport Review*, March.
Pastier, J. (1978) Dallas Fort Worth: Metroplex and MegaAirport. *AIA Journal*, March.

Further reading, Birmingham

Alcock, C. (1989) Balanced design pays. *Airports International*, April.
Innes, Sir Peter (1990) Developments in regional airports in the United Kingdom. In *Proceedings of the Conference Airports into the 21st Century (Hong Kong, 1990)*. Hong Kong: Hong Kong Institution of Engineers.

Keown, R. (1989) Second terminal for Birmingham gets a green light. *Building Design*, September 1.
Woolley, D. (1990) Birmingham's Euro-hub forges ahead. *Airport Forum*, **2**.

Further reading, Edinburgh

Architects' Journal Information Library (1977) Buildings illustrated: New terminal buildings at Edinburgh . . . *Architects' Journal*, 31 August.

Further reading, linear units

Tutty, E. B. (1982) IATA's unit terminal concept. *Airport Forum*, **1**.
Piper, H. P. (1974) Design principles for decentralized terminals. *Airport Forum*, **3**.

Further reading, Baltimore

Godman, W. H. (1980) Baltimore opens $70 m terminal. *Airports International*, January.
Hoyt, C. (1980) Baltimore Washington International Airport. *Architectural Record*, December.
Reiss, S. M. (1983) BWI – ten years later. *Airports Forum*, **1**.

Further reading, wayports

Alcock, C. and Plenderleith, I. (1989) Where there's a will there's a Wayport. *Airports International*, September.
Momberger, M. and others (1989) The Wayport concept – a way out of the capacity dilemma? *Airport Forum*, **4**.
Street, J. (1989) Wayport concept pushed by private developers. *Airport Forum*, **3**.

Part II A taxonomy of airport terminal forms

Airport terminal designs are presented as forms with organizational properties, classified in the same way as bio-forms. These examples are selected from notable projects in the last 15–20 years in Europe, South East Asia and the USA.

7 Basic terminals with remote aircraft
7.1 Malta Luqa new terminal building
7.2 Stuttgart new terminal building
7.3 Southampton new terminal building

8 Basic terminals with mobile lounges
An innovation introduced at Washington Dulles in 1962 in conjunction with the Chrysler-built vehicles which raised and lowered themselves by hydraulic rams to match the height of terminal building floor and aircraft door sill.
8.1 Washington Dulles terminal building
8.2 Montreal Mirabel terminal building

9 Linear terminals
Aircraft dock directly against the building providing short travel distances. Three examples from the United Kingdom, the first two close neighbours in time and location and the third located at the UK's third largest and largest provincial airport, are matched by a stretched Japanese example and a US example of this common type.
9.1 London Heathrow Terminal 4
9.2 London Gatwick North Terminal
9.3 Manchester Terminal 2
9.4 Osaka Kansai Terminal
9.5 Chicago O'Hare International Terminal

10 Piers: single or multiple
With aircraft docked against double-sided extensions suitable for a large-scale operation. Two European examples are matched by two Asian projects on a much larger scale.
10.1 Zürich Kloten Terminal B
10.2 Zürich Kloten Terminal A, new pier
10.3 Hong Kong's new airport at Chek Lap Kok
10.4 Second Bangkok International Airport project

11 Satellites: single or multiple
With aircraft docked against circular or rectangular island buildings, similarly suited to large-scale operations. The characteristics of circular or orthogonal forms are discussed in Chapter 25. Two examples from Florida:
11.1 Tampa
11.2 Orlando

12 Multiple linear units
With several mini-terminals in a line and with aircraft docked against these mini-terminals.
12.1 Hanover Langenhagen
12.2 Munich

13 Multiple island piers
With several linear island buildings against which the aircraft dock, the buildings being linked to the parent terminal by an underground railway or similar.
13.1 Atlanta William B. Hartsfield International
13.2 London Stansted New Terminal
13.3 Denver

14 Hybrids: combinations of forms
14.1 Chicago O'Hare, United Airlines Terminal

7 Basic terminals with remote aircraft

7.1 Malta Luqa new terminal building

Type: state-owned (1986 competition).
Form: basic with remote aircraft, one-stepped main level.
Architect: Scott Brownrigg & Turner, competition design.

Design standards:
International passengers per hour: 750 each way (year 1992–95).
Domestic passengers per hour: nil.
Transit/transfer passengers: only 1%.
Passengers per year: 1.9 million (year 1992–95).
Aircraft stands: 11 (various).

Description: this competition scheme is interesting in that it exploits a change of level of 7 metres between the landside and the apron to give what is effectively a stepped single-level terminal with side-by-side arrivals and departures. The stepping allows all baggage handling and airside vehicle service to be underneath the airside part of the passenger building, Figures 7.1–7.5.

Because the traffic does not justify loading bridges, all airside passenger circulation is at apron level with generous departure lounge frontage for an apron coach service or direct passenger routeing to aircraft positions, with the largest aircraft at the centre of the apron opposite the terminal.

7.2 Stuttgart new terminal building

Type: airport-owned (1991).
Form: basic with remote aircraft.
Architect: Von Gerkan, Marg & Partner.

Design standards:
International passengers per hour: 3200 (combined arrivals and departures).
Domestic passengers per hour: 3200 (combined arrivals and departures).
Passengers per year: 5 million (1993) 60% international.
Aircraft stands: 28.

Description: this new small and elegant terminal offers passengers a simple route from roadway to airside bus. All departing passengers, including those coming up two banks of escalators from the urban railway, arrive at first floor level to check in and pass through international and domestic control channels. They assemble in holding lounges, international on one side and domestic on the other, before descending to bus-boarding points. Arriving passengers enter the building at ground level from apron buses at two points, one for international and one for domestic. The whole building is enclosed by a great inclined roof, balanced delicately on a tracery of twelve branching structural steel supports, Figures 7.6 and 7.7.

Further reading:

Davey, P (1990) Stuttgart airport opens. *Architectural Review*, May 1991.

7.3 Southampton new terminal building

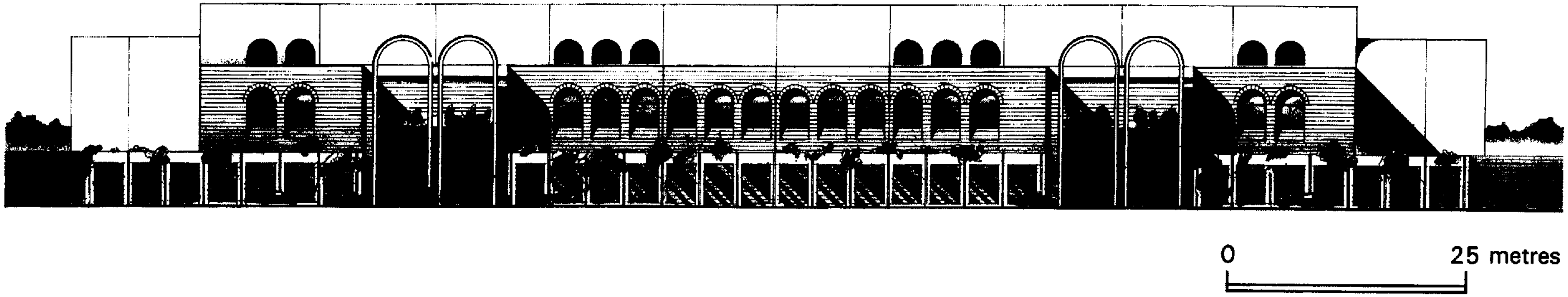
Type: owned, with six other airports, by public company (1995).
Form: basic with remote aircraft.
Architect: Manser Associates.

Design standards:
International passengers per hour: 350 (all channels 1995).
Domestic passengers per hour: included above.
Passengers per year: 500 000 (1994–95), capacity 1.5 million.
Aircraft stands: 14 (various).

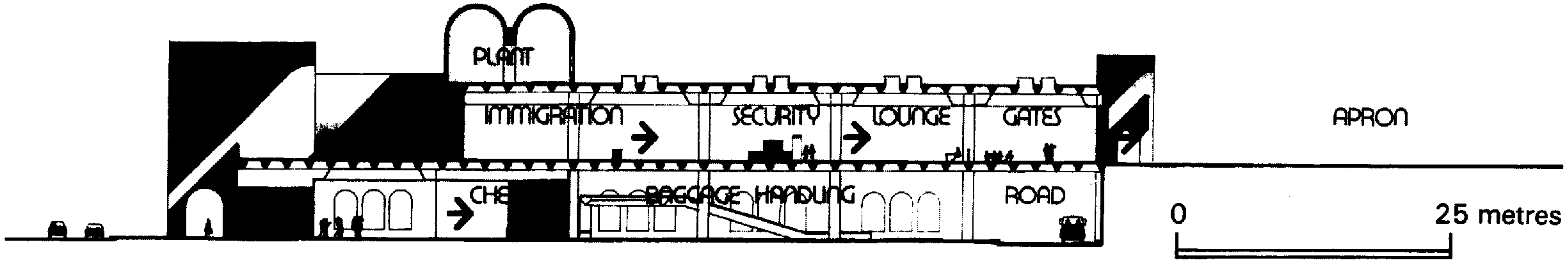
Description: apart from the fact that Southampton (Eastleigh), now Southampton International Airport, is the smallest BAA airport, it has three special features, all of which have influenced the design of the new single-level terminal, Figures 7.8–7.10.

Firstly, its location as a natural bridgehead to the Channel Islands: this has acted as the mainstay of the

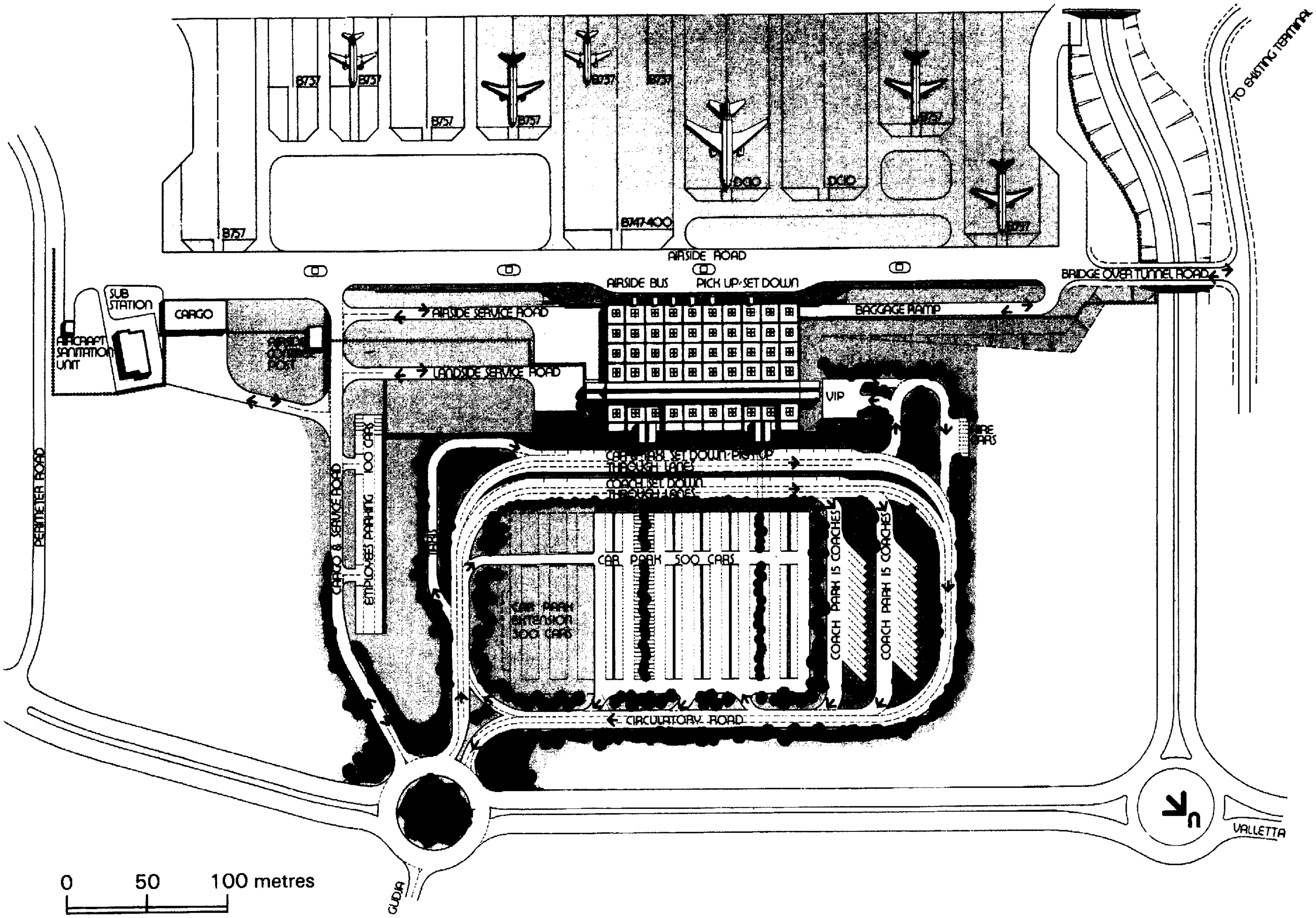
(continued on page 56)



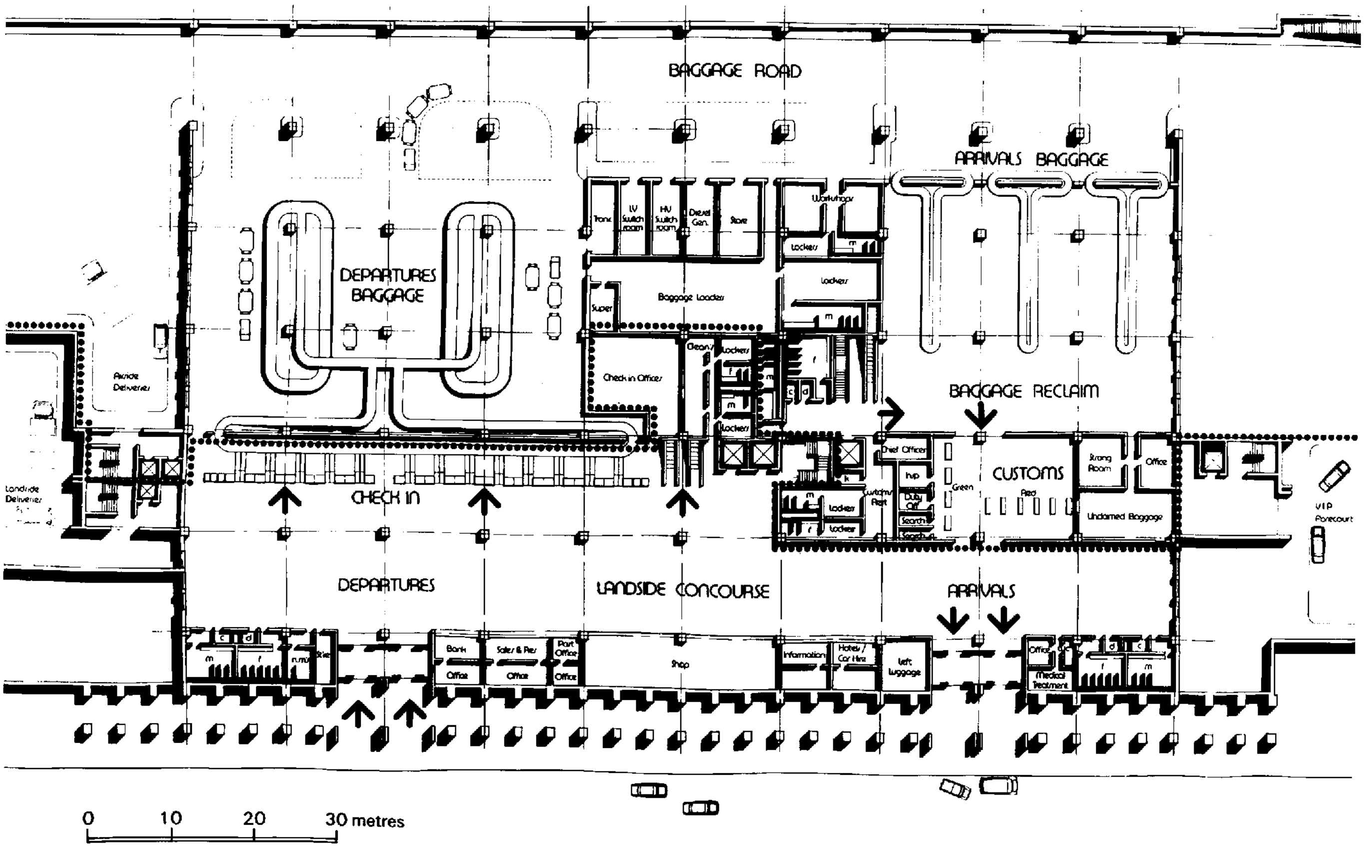
7.1 *Malta Luqa, landside elevation.*



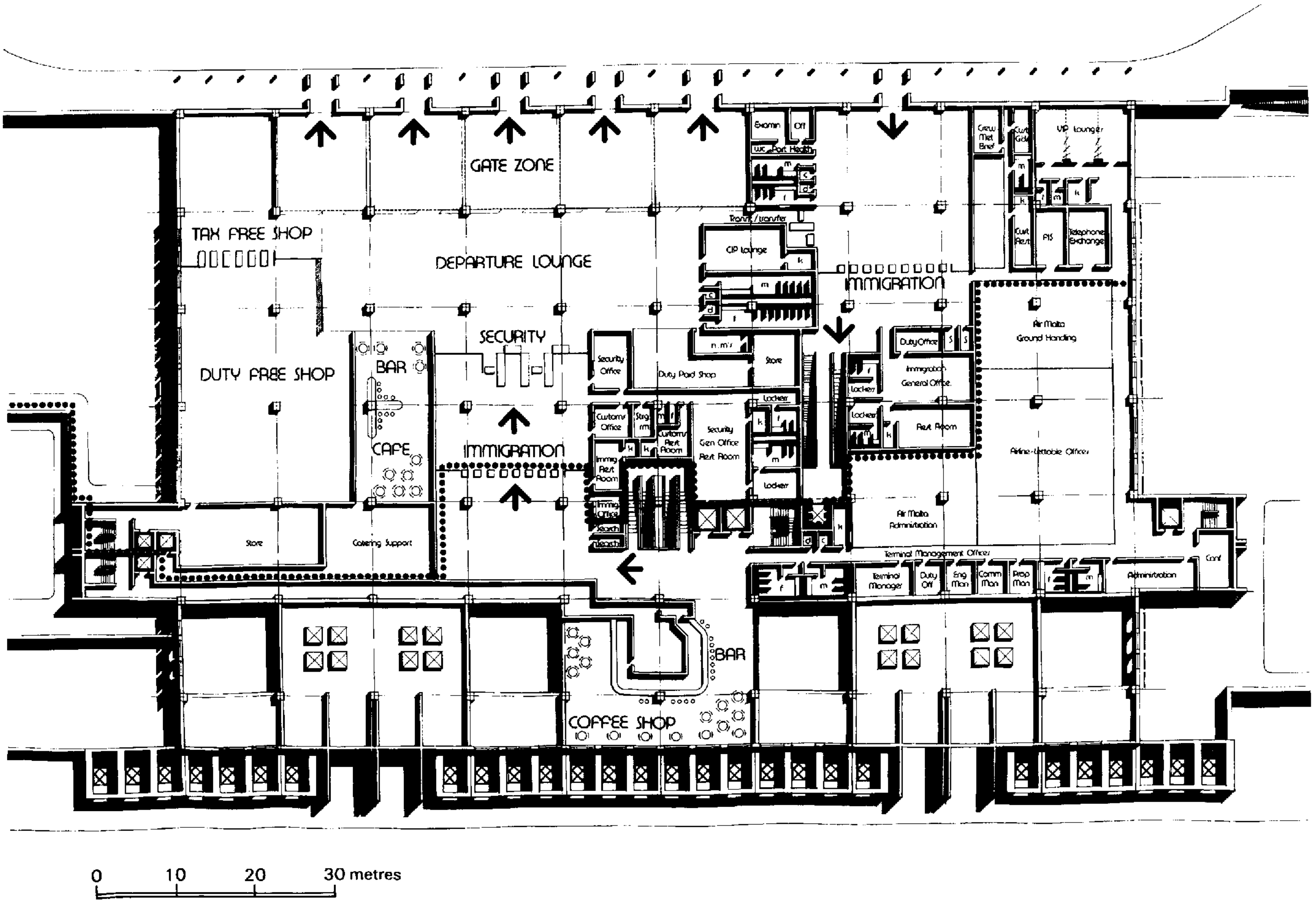
7.2 *Departures section.*



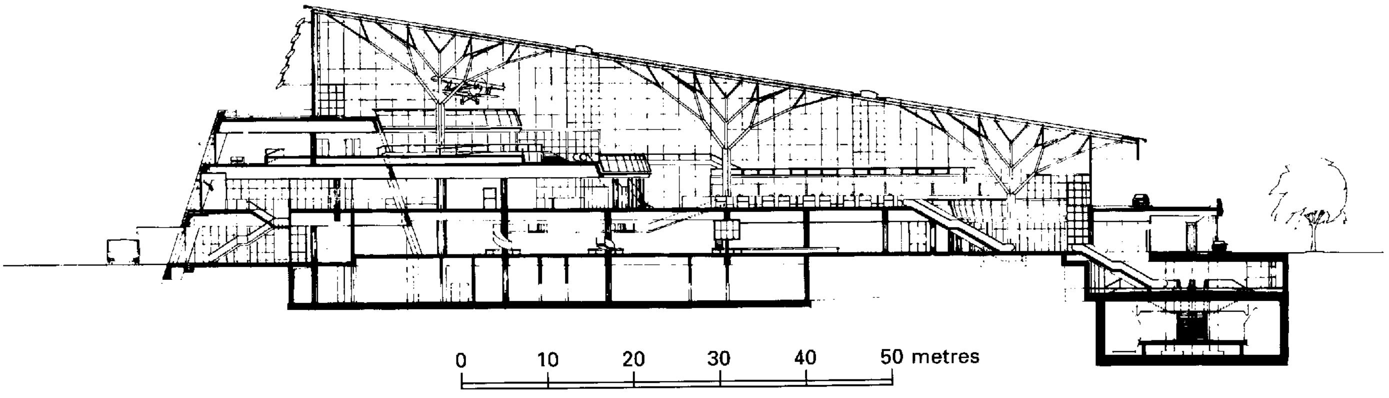
7.3 Malta Luqa site plan



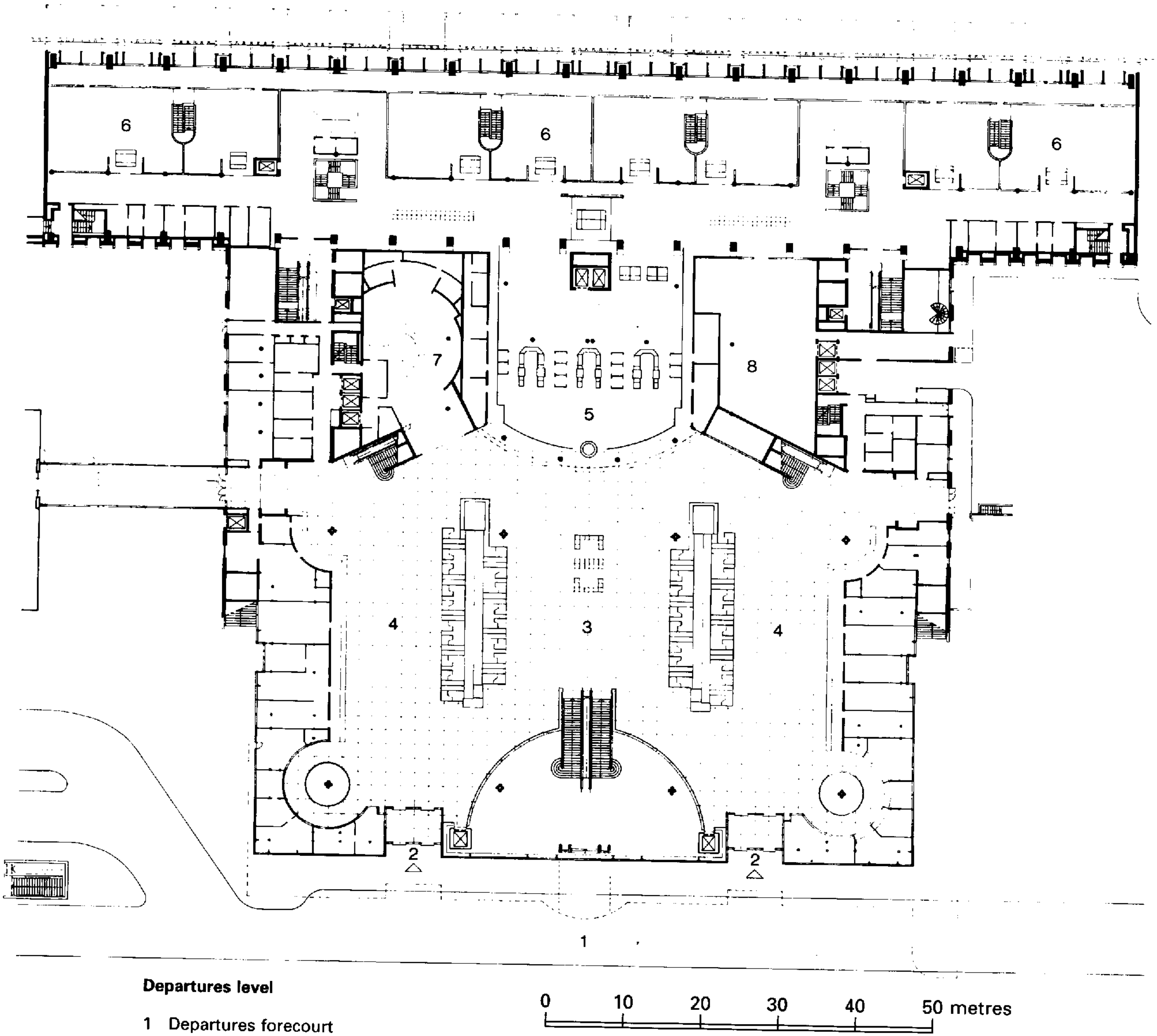
7.4 Malta Luqa plan, level at 0 m.



7.5 *Malta Luqa plan, level +7 m. Figures 7.1–7.5 from Scott Brownrigg & Turner report.*



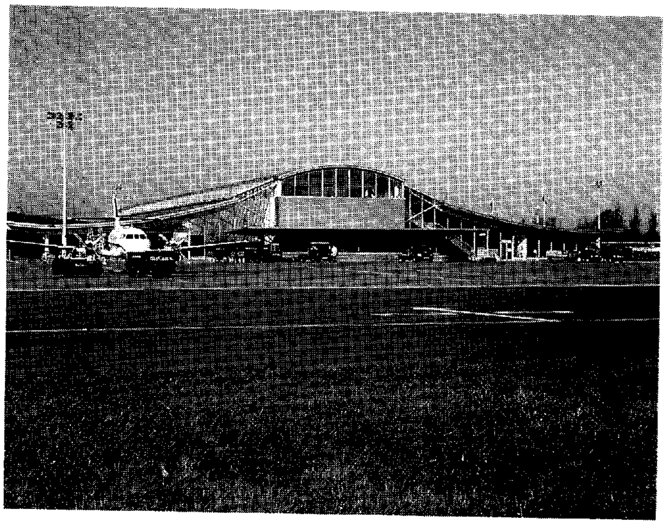
7.6 *Stuttgart cross-section. Courtesy of architects: Von Gerkan, Marg & Partner.*



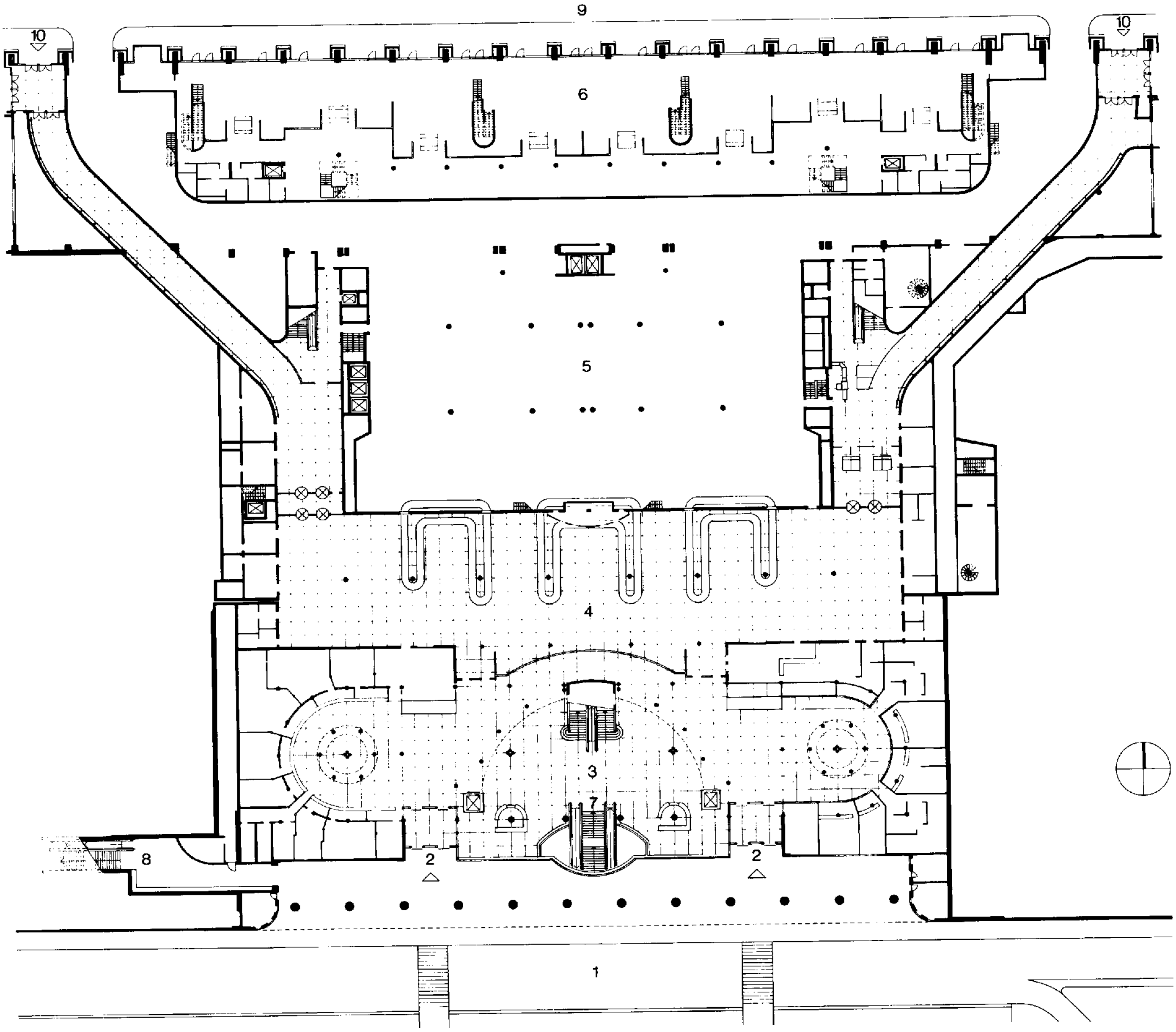
Departures level

1 Departures forecourt
2 Entrances
3 Departures concourse
4 Check-in
5 Controls
6 Holding lounges
7 Kiosk and coffee shop
8 Duty-free shop

7.7 Stuttgart, plan of two main levels: (a) departures.



7.8 Exterior view of Southampton Airport. Photograph: Morley von Sternberg.

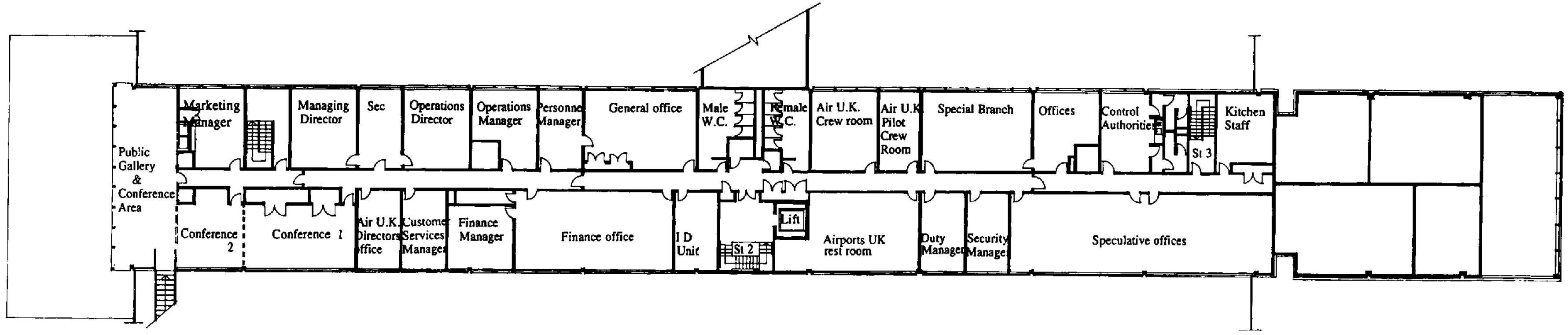


Arrivals level

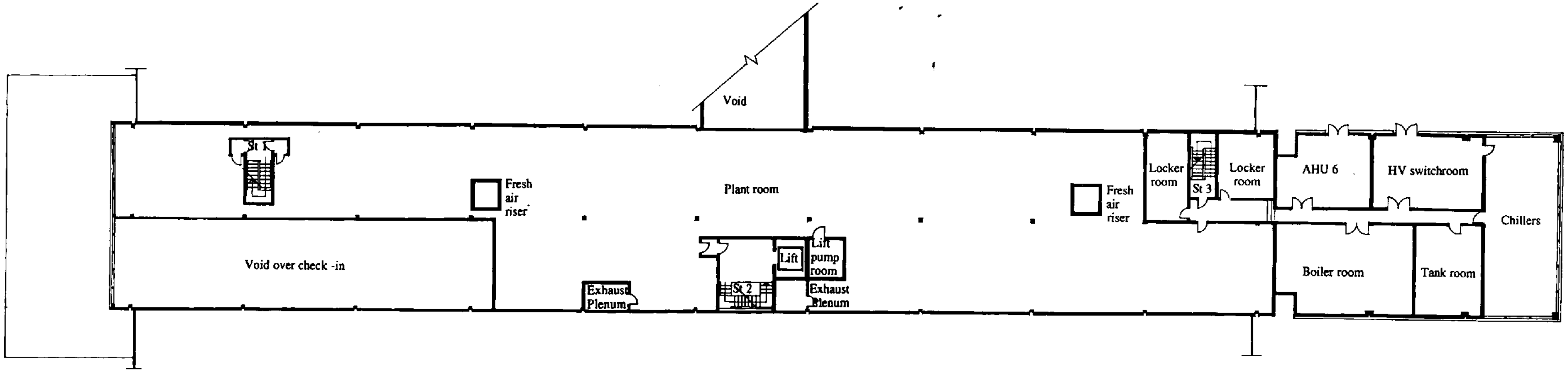
1 Arrivals forecourt
2 Entrances
3 Arrivals concourse
4 Baggage reclaim
5 Baggage handling
6 Holding lounges
7 Stairs to railway station
8 Stairs to bus station
9 Airside
10 Entrances for arrivals

7.7 Stuttgart, plan of two main levels: (b) arrivals.

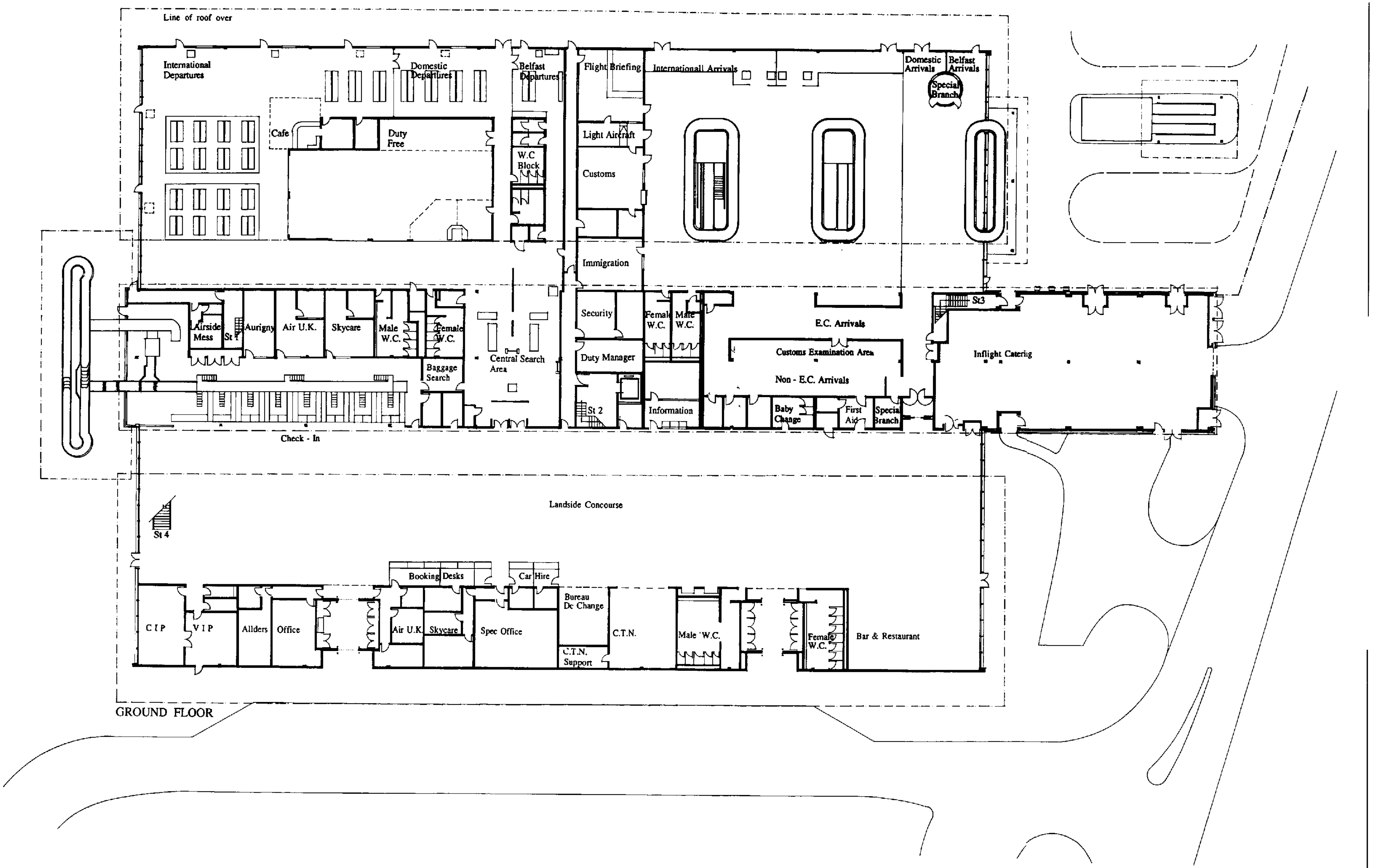
7.9 Interior view of Southampton Airport. Photograph: Dennis Gilbert.



FIRST FLOOR



MEZZANINE



7.10 *Southampton Airport, ground and first floor plans. Courtesy of architects: Manser Associates.*

airport and generates 50 per cent of the traffic, hence the high demand for duty-free shopping.

Secondly, its location as a regional airport for the southern part of Hampshire and a catchment area of nearly 2 million people, offering in 1995 seven mainland destinations and eight Irish or other European destinations as well as the Channel Islands. This range of traffic demands five different sets of border control procedures in one simple building. These are: domestic, Belfast (with special branch surveillance), Common travel area (Channel Islands, Isle of Man and Ireland with duty-free), EC and European/International non-EC.

Thirdly, and not least, its location adjacent to Southampton Parkway station, served by fast trains to London Waterloo. Although only 11 per cent of passengers use the rail link at present, this is expected to be a growth area.

It is interesting to think that Gatwick's beehive (Chapter 3) and rail-air link was a model for the 1930s, as Southampton could be for the 1990s.

Further reading

McGuire, P. (1995) Southerly approach. *Architectural Review*, February.

Spring, M. (1994) Air wave. *Building*, 9 December.

Various contributors (1995). A pilot airport for the 1990s, *Architects' Journal*, 30 March.

8 Basic terminals with mobile lounges

Mobile lounges were an innovation first introduced at Washington Dulles in 1962 in conjunction with the Chrysler-built vehicles which raised and lowered themselves by hydraulic rams to match the height of the terminal building floor and the aircraft door sill.

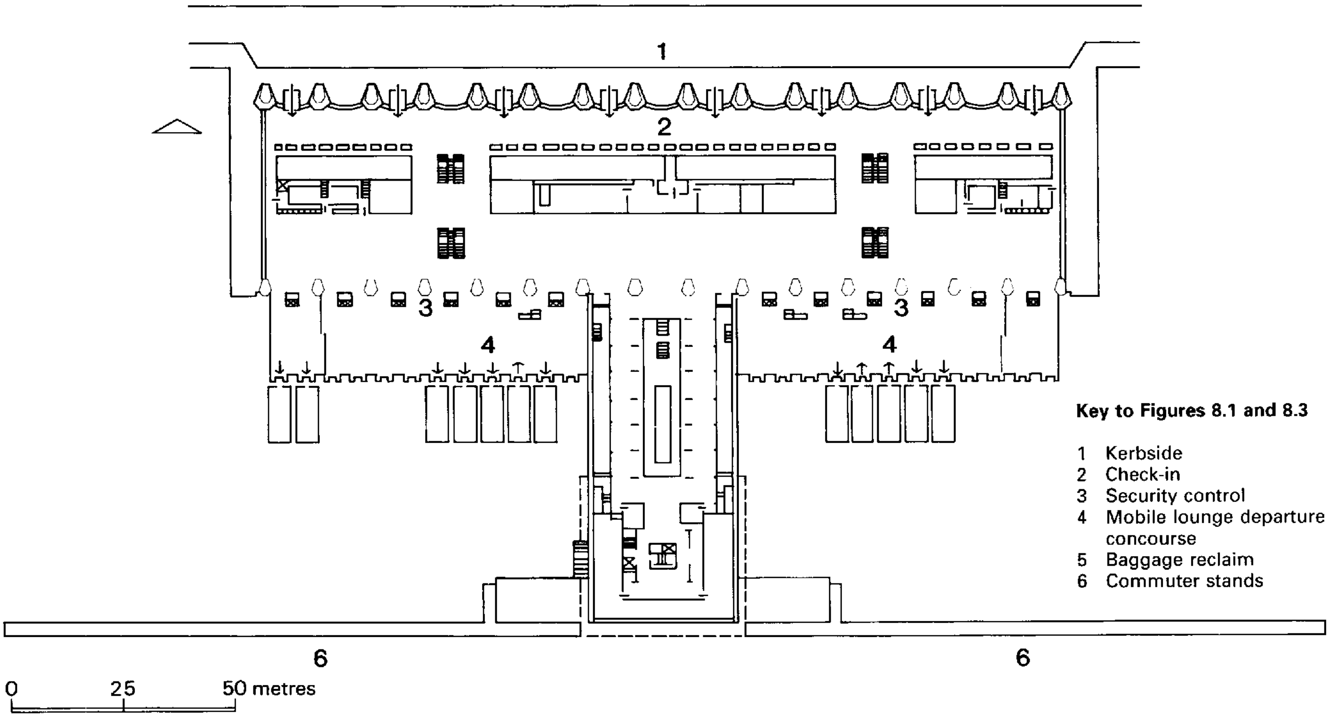
8.1 Washington Dulles terminal building

Type: airport-owned (1962 + several extensions).
Form: basic terminal vertically stacked, with mobile lounges.
Architect: Eero Saarinen.

Design standards:
International passengers per hour: 2400 (capacity 1993).
Domestic passengers per hour: no figures available.
Passengers per year: 10.9 million in 1993 (80% domestic).
Aircraft stands: 30 wide-body remote from terminal.

Description: mobile lounges serve all but commuter aircraft stands. It is included here because it was the first mobile lounge airport; it was specifically designed as a giant pavilion with the kerbside on one side and the mobile lounge loading points on the other. The main passenger level is elevated with baggage handling and service areas below. The airside face was rebuilt in 1980 to provide better airside assembly areas, Figures 8.1–8.3.

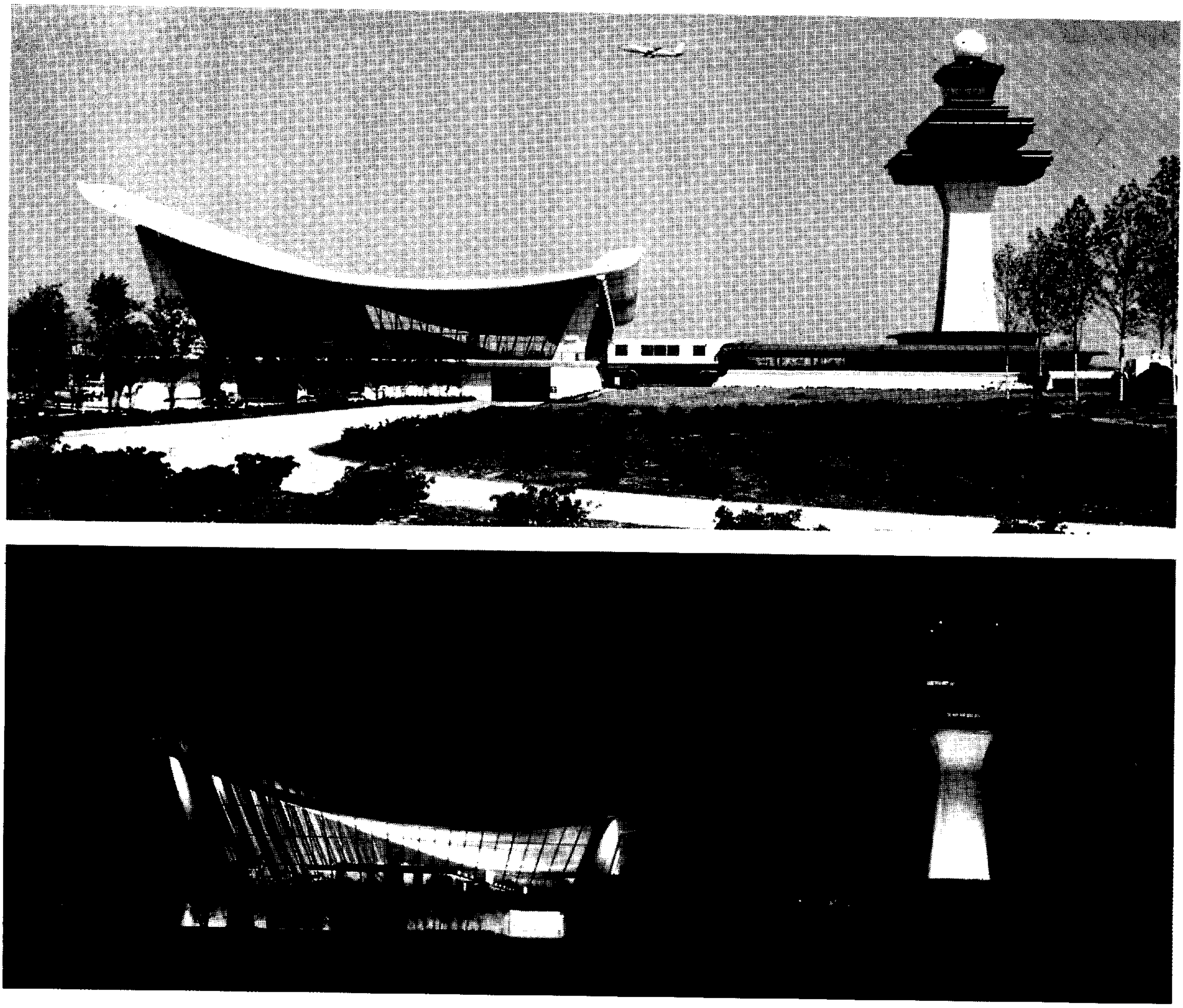
Subsequently, new airside piers have been added to increase the capacity of the terminal, an international passenger facility added, and further midfield terminal



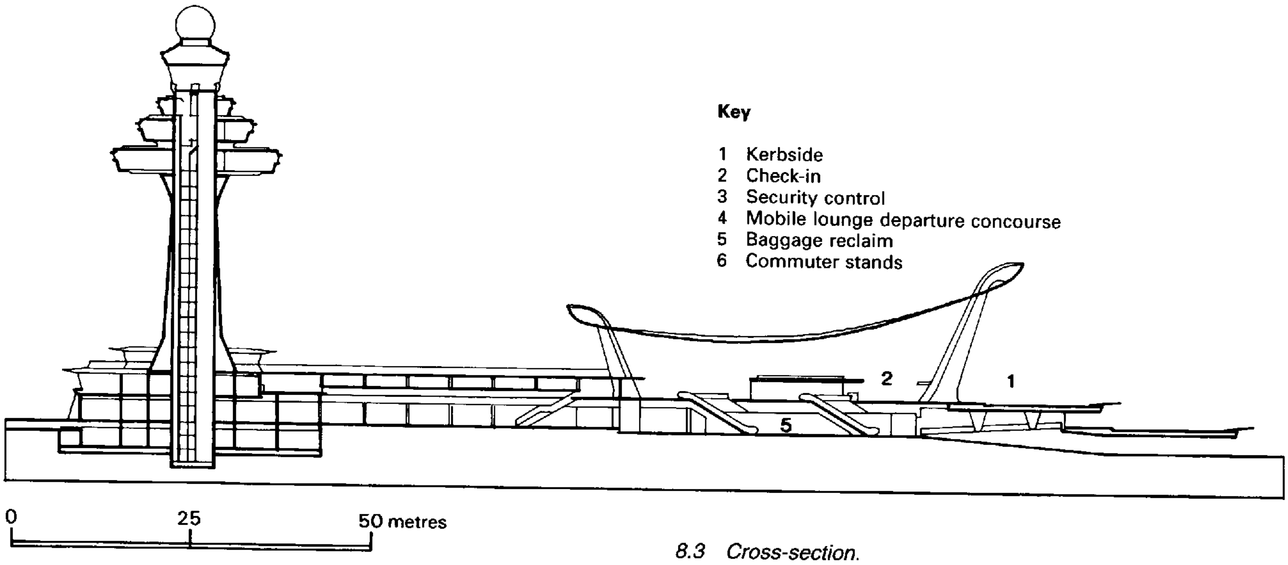
Key to Figures 8.1 and 8.3

1 Kerbside
2 Check-in
3 Security control
4 Mobile lounge departure concourse
5 Baggage reclaim
6 Commuter stands

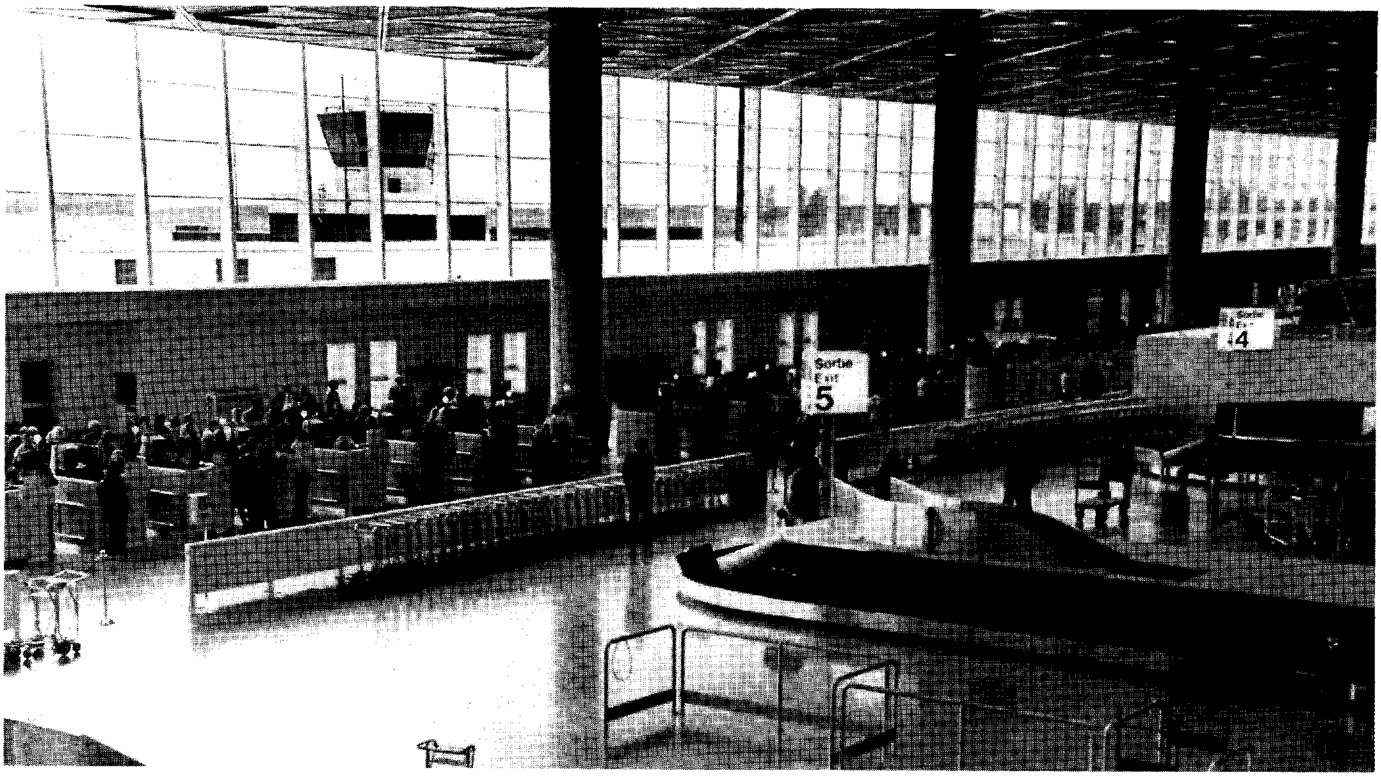
8.1 Washington Dulles, plan at main passenger level.



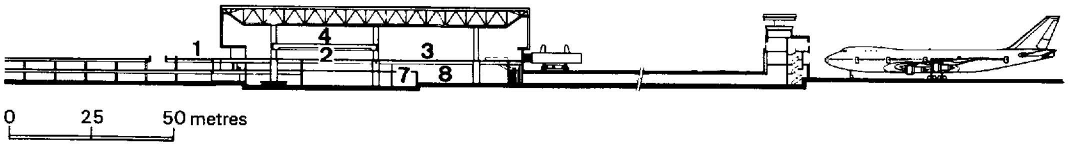
8.2 *Washington Dulles by day and by night. Courtesy of US Department of Transportation.*



8.3 *Cross-section.*



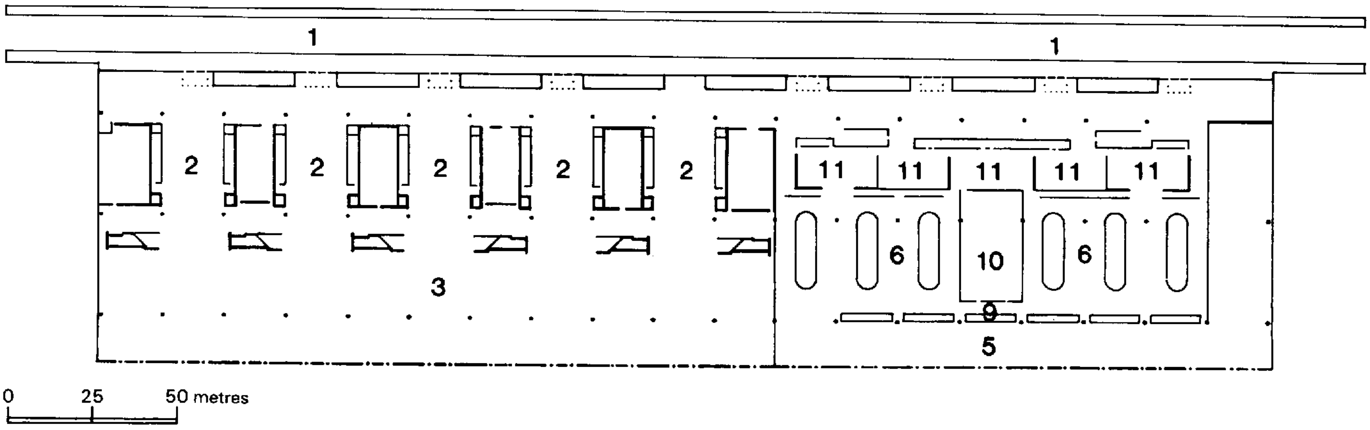
8.4 Montreal Mirabel, interior.



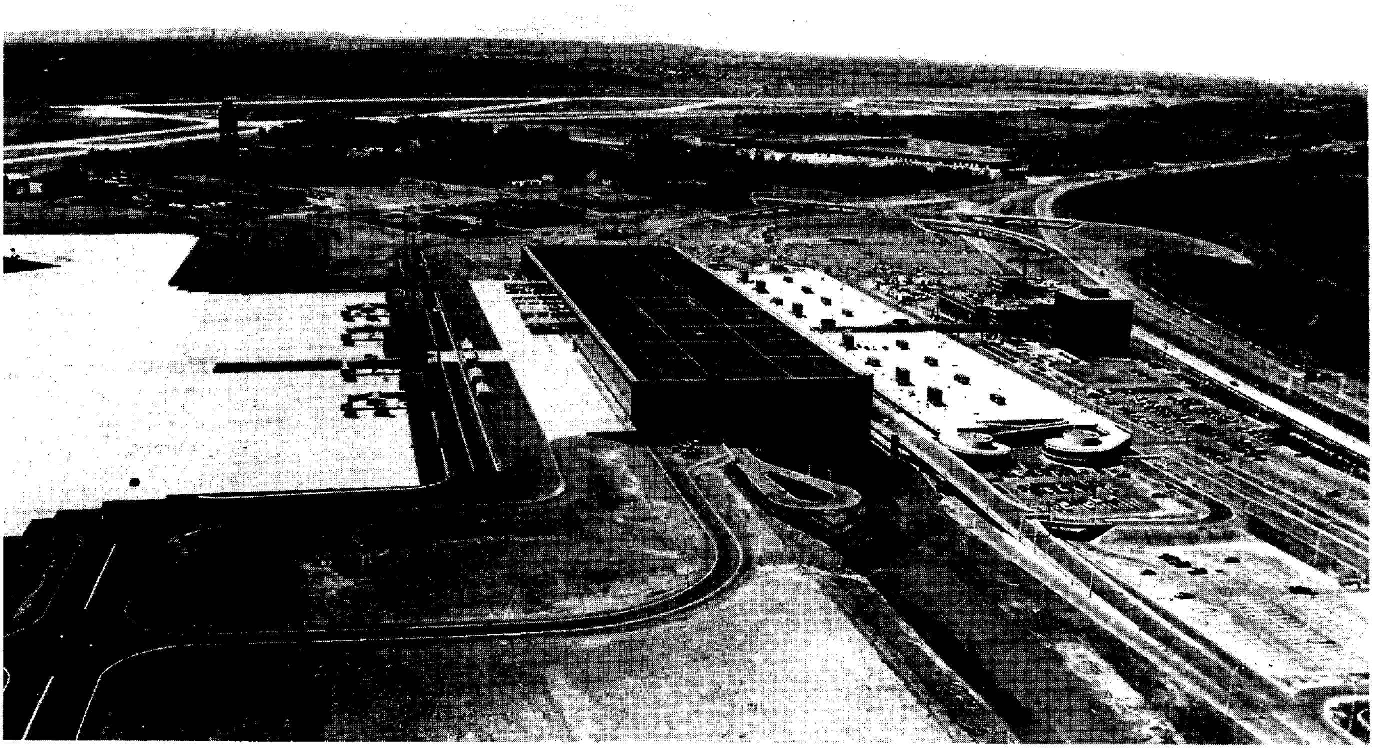
8.5 Section.

Key to Figures 8.5 and 8.6

1 Kerbside
2 Check-in
3 Mobile lounge departure concourse
4 Shopping and catering
5 Arrivals
6 Baggage reclaim
7 Service road
8 Baggage handling area
9 Primary inbound immigration and customs control
10 Secondary immigration control
11 Secondary customs control



8.6 Plan of passenger processing level.



8.7 Montreal Mirabel aerial view.

structures are planned. The main terminal is to be extended at both ends on foundations originally placed in 1962.

Further reading

Greer, N. R. (1988) Eero Saarinen's Dulles Airport wins AIA 25-year award. *Architecture (AIA Journal)*, May.

Schwartz, A. (1993) Washington Dulles expanding terminal according to original master plan. *Airport Forum*, **3**.

8.2 Montreal Mirabel terminal building

Type: airport-owned (1985).
Form: basic terminal with mobile lounges, side-by-side arrivals and departures.
Architect: Bland LeMoyne Shine and Victor Prus.

Design standards:
International passengers per hour: capacity of 4000.
Transit/transfer passengers: no figures available.
Passengers per year: 6–10 million capacity (2.2 million actual in 1993).
Aircraft stands: 24 remote.

Description: this is the first new mobile-lounge terminal built since Dulles (Washington) in 1962, and is essentially a grand pavilion with the kerbside on one side and the mobile lounge assembly areas on the other. The structure is a long span space deck. Baggage handling and service areas are located below the passenger processing level, Figures 8.4–8.7.

Due to changes in the legislation of air transport in Canada, Mirabel has not built up traffic yet to much more than 10 per cent of the terminal capacity or even 2 per cent of the ultimate site and runway capacity. However, the mobile lounge or PTV (passenger transfer vehicle) service has proven satisfactory and adaptable. For example, hub transfers are possible by taking passengers directly from aircraft to aircraft as in the case of the Tel Aviv to Miami, Boston and Chicago services.

Further reading

Blacklock, M. (1990) Montreal must exit traffic cul de sac. *Airports International*, July/August.

Shine, A. and Haley, P. (1976) Mirabel – Scope for development until 2020. *Airport Forum*, **2**.

Woolley, D. (1977) Mirabel – how goes it? *Airports International*, August/September.

9 Linear terminals

In linear terminals, aircraft dock directly against the buildings, which gives potentially short travel distances.

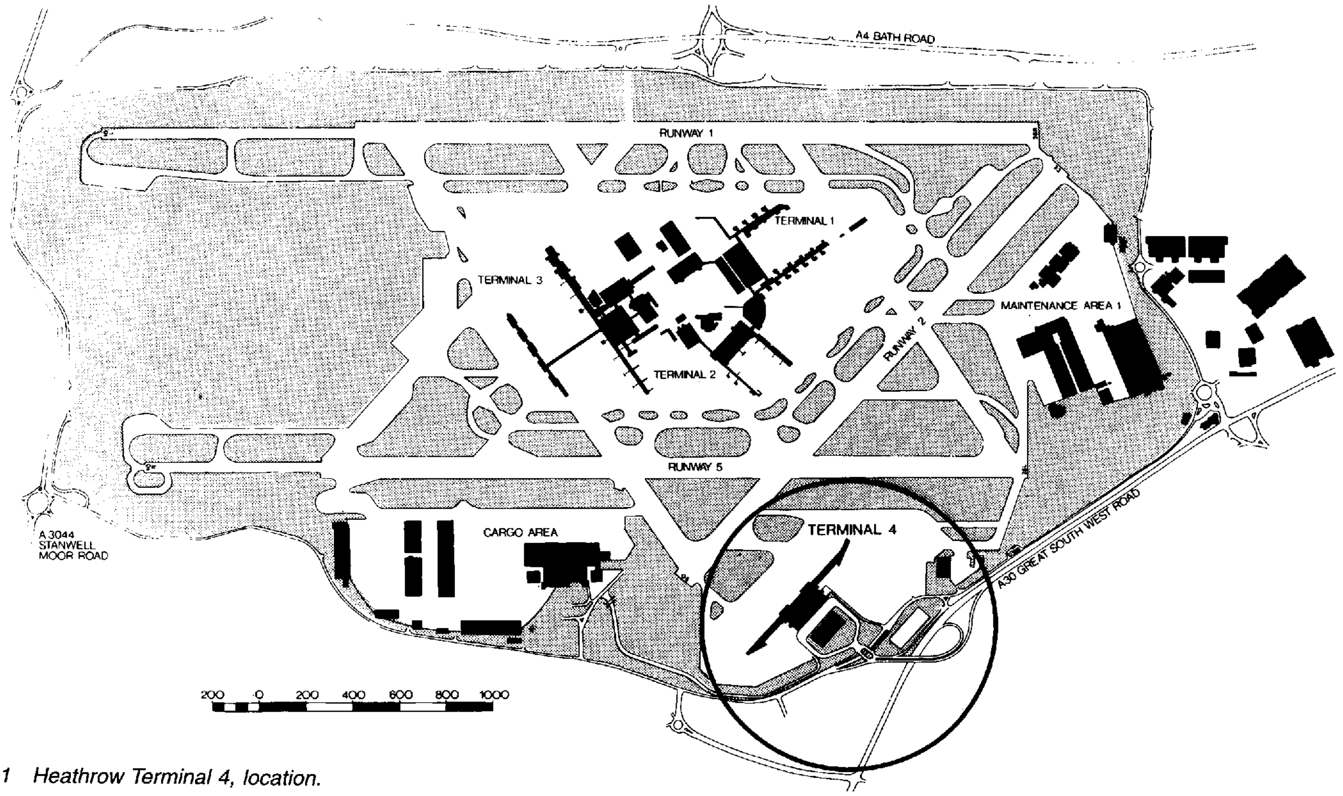
9.1 London Heathrow Terminal 4

Type: owned, with six other airports, by public company (1986).
Form: linear, vertically stacked and segregated.
Architect: Scott Brownrigg & Turner, Guildford.

Design standards:
International passengers per hour: 2000.
Domestic passengers per hour: nil.
Transit/transfer passengers: 15% (1986), 30%+ (1995).
Passengers per year: 6–8 million design capacity.

Aircraft stands:
17 terminal served (including 8 NLAs) plus 5 remote (1986).
22 terminal served (including 8 NLAs) plus 4 remote (1995).

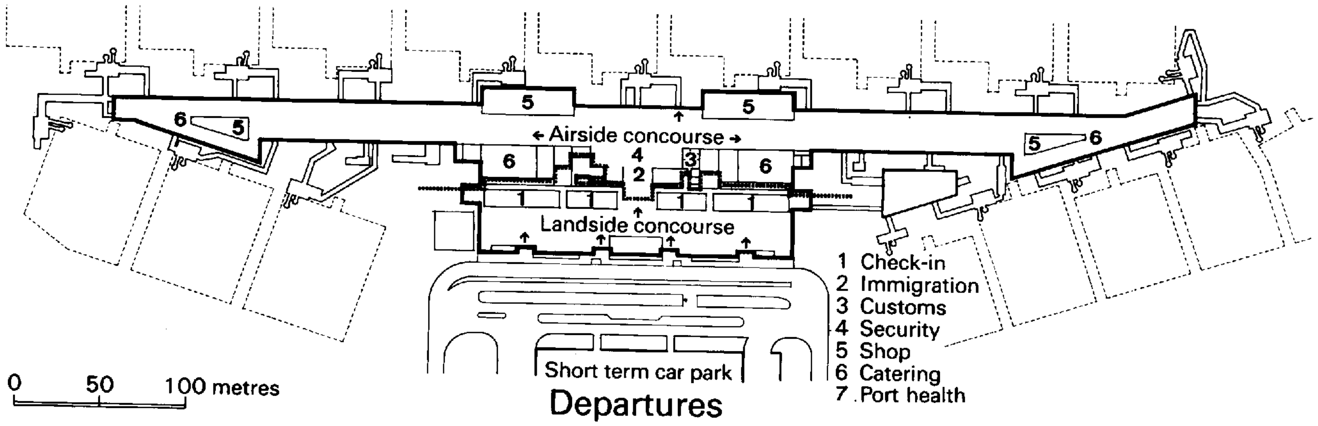
Description: the central terminal area of Heathrow Airport, constrained by the runway pattern surrounding it, had developed steadily between 1950 and 1977. Then the decision was made to build a fourth terminal outside the central area, using land on an area originallly designated as an aircraft maintenance area. The site was in fact the last remaining one on the perimeter of the airport until the future release of major areas of land by the relocation of a sewage disposal plant. Even so, the available site was



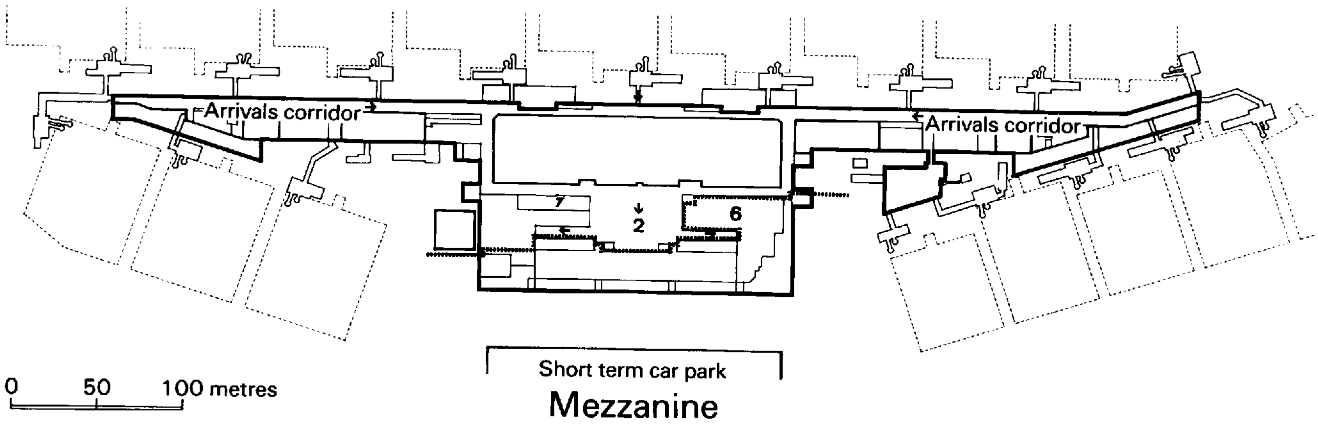
9.1 Heathrow Terminal 4, location.

severely constrained by the perimeter road and the retained crosswind runway, Figures 9.1–9.7.

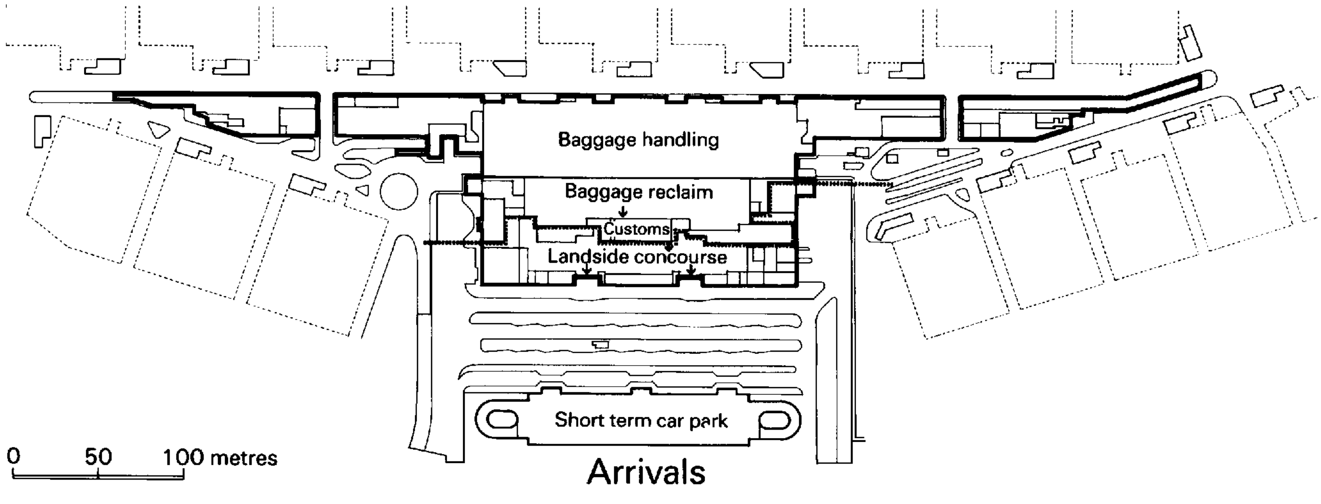
The new terminal was always planned as a predominantly long-haul one, in order to relieve pressure on the long-haul Terminal 3. The desired objective of parking the maximum number of wide-bodied aircraft directly at the terminal was achieved; in 1986 Terminal 4 had 80 per cent of its stands terminal served, in contrast to the 60 per cent of Terminals 1, 2 and 3 stands which were terminal



9.2 *Departure level plan.*

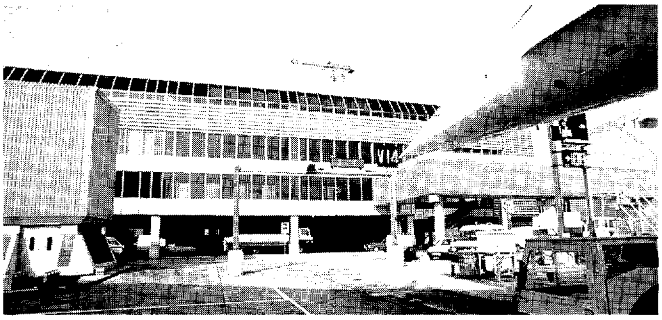


9.3 *Mezzanine level plan.*

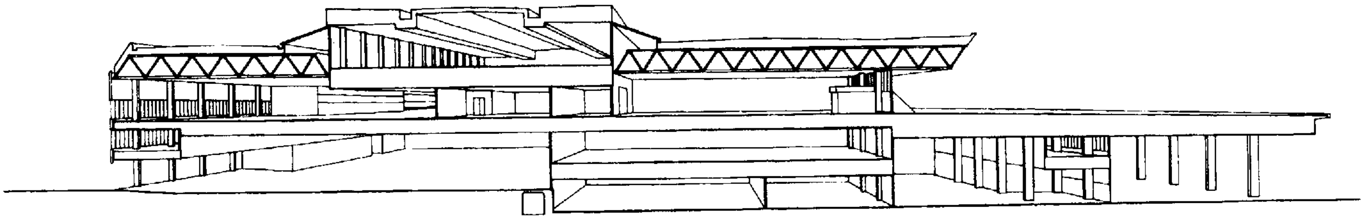


9.4 *Arrivals level plan.*

9.5 Aerial view of Heathrow, April 1986. Photograph: Chorley & Handford.



9.6 Exterior photograph. Architects: Scott Brownrigg & Turner, Guildford. Client: Heathrow Airport Ltd.



9.7 Cross-section through Heathrow Terminal 4.

served. Since 1990 both pier and apron construction has raised capacity and improved passenger service standards. Furthermore the apron layout at Terminal 4 safeguards for the advent of aircraft with maximum wingspan of 70 metres, length of 86 metres and tail height (under the constraining runway side-slope) of 21 metres. Innovative features of the terminal design are the vertical segregation of arrivals and departures, centralized security clearance and a wide airside concourse without gate assembly enclosures. A London Underground Piccadilly Line station is located under the multi-storey car park which adjoins the two-level forecourts, and this is to be supplemented by the terminus of the Heathrow Express direct rail link to London Paddington.

Further reading:

Allen, R. (1986) Capacity expansion for Heathrow. Airport Forum, **2**.

Hawker, T. J. (1985) T4: ready for take off. *Building Services*, December.

Pettipher, M. (1993) Pier ahead. *New Builder*, 26 February.

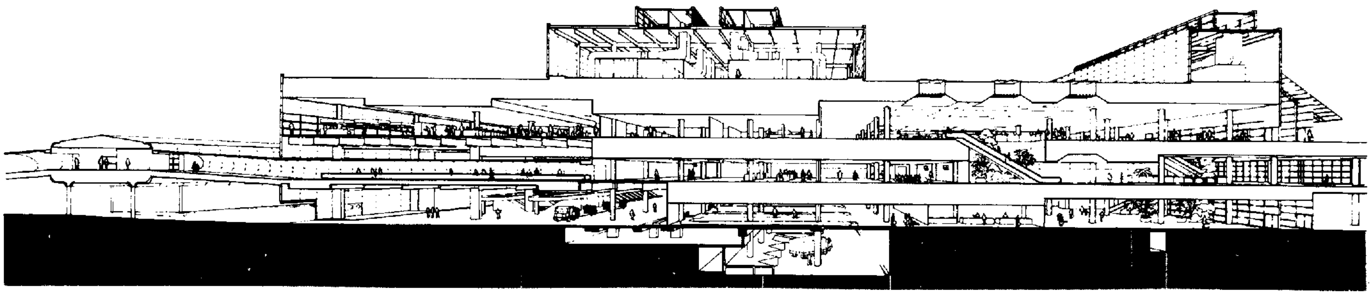
Williams, A. (1986) Terminal 4 Heathrow Airport. *Building*, August 8.

Woolley, D. (1987) T4 revisited. *Airport Forum*, **3**.

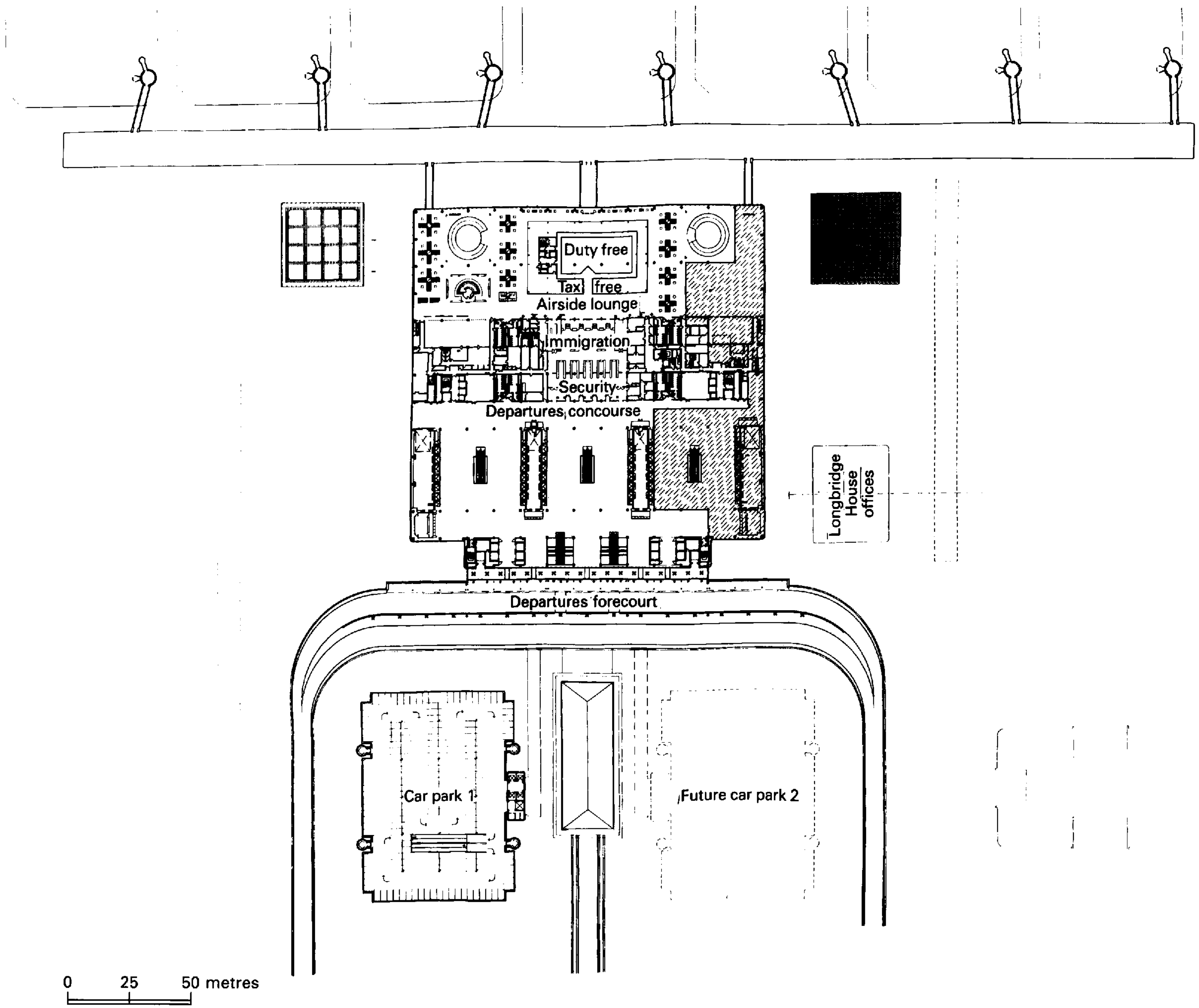
9.2 London Gatwick North Terminal

Type: owned, with six other airports, by public company (1988).
Form: linear, vertically stacked.
Architect: YRM Architects and Planners, London.

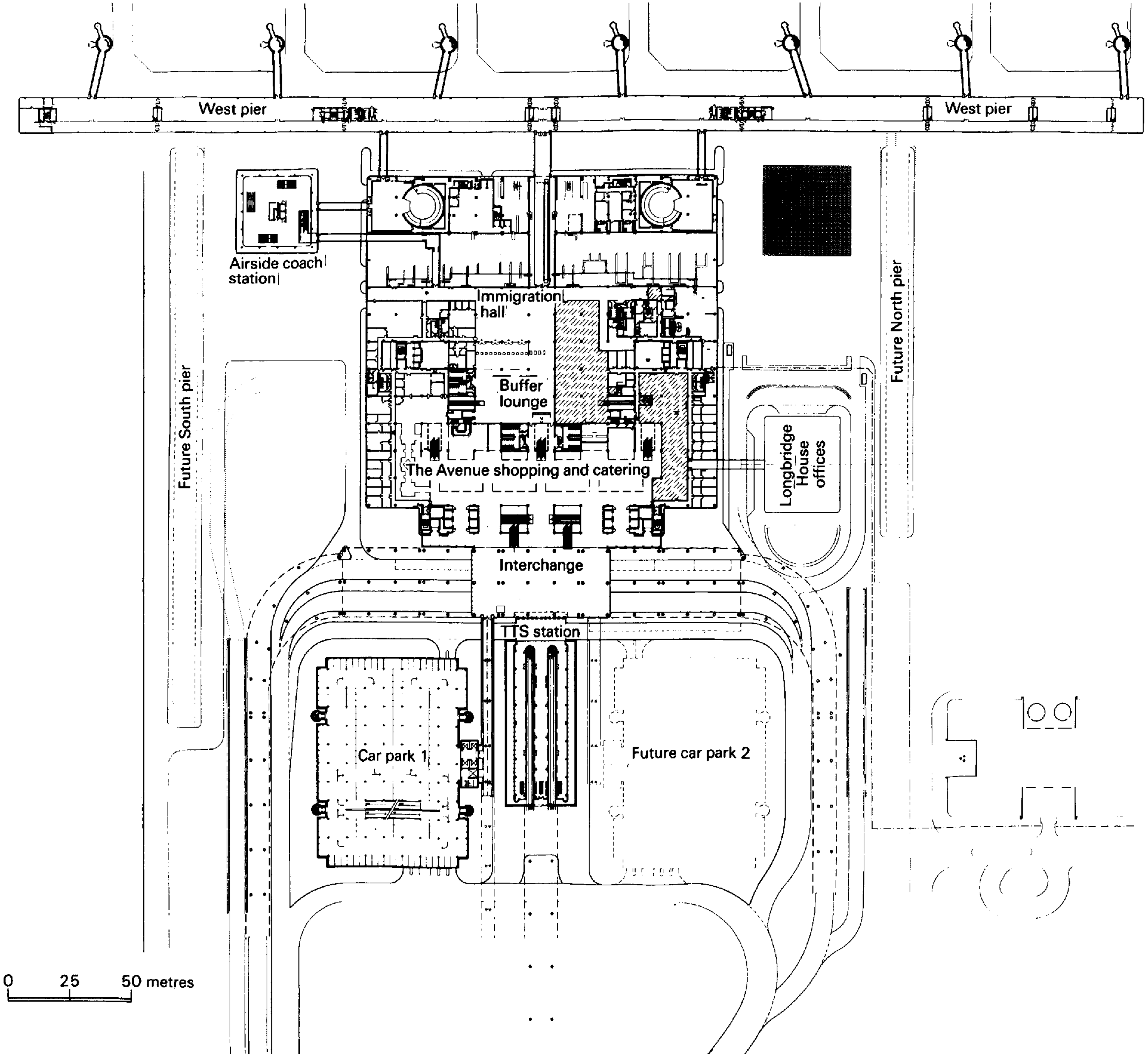
Design standards:
International passengers per hour: 2500 ultimate.
Domestic passengers per hour: nil.
Passengers per year: 9 million ultimate.
Aircraft stands: 7 Boeing 747 in Phase 1 (1988), 15 (1991).



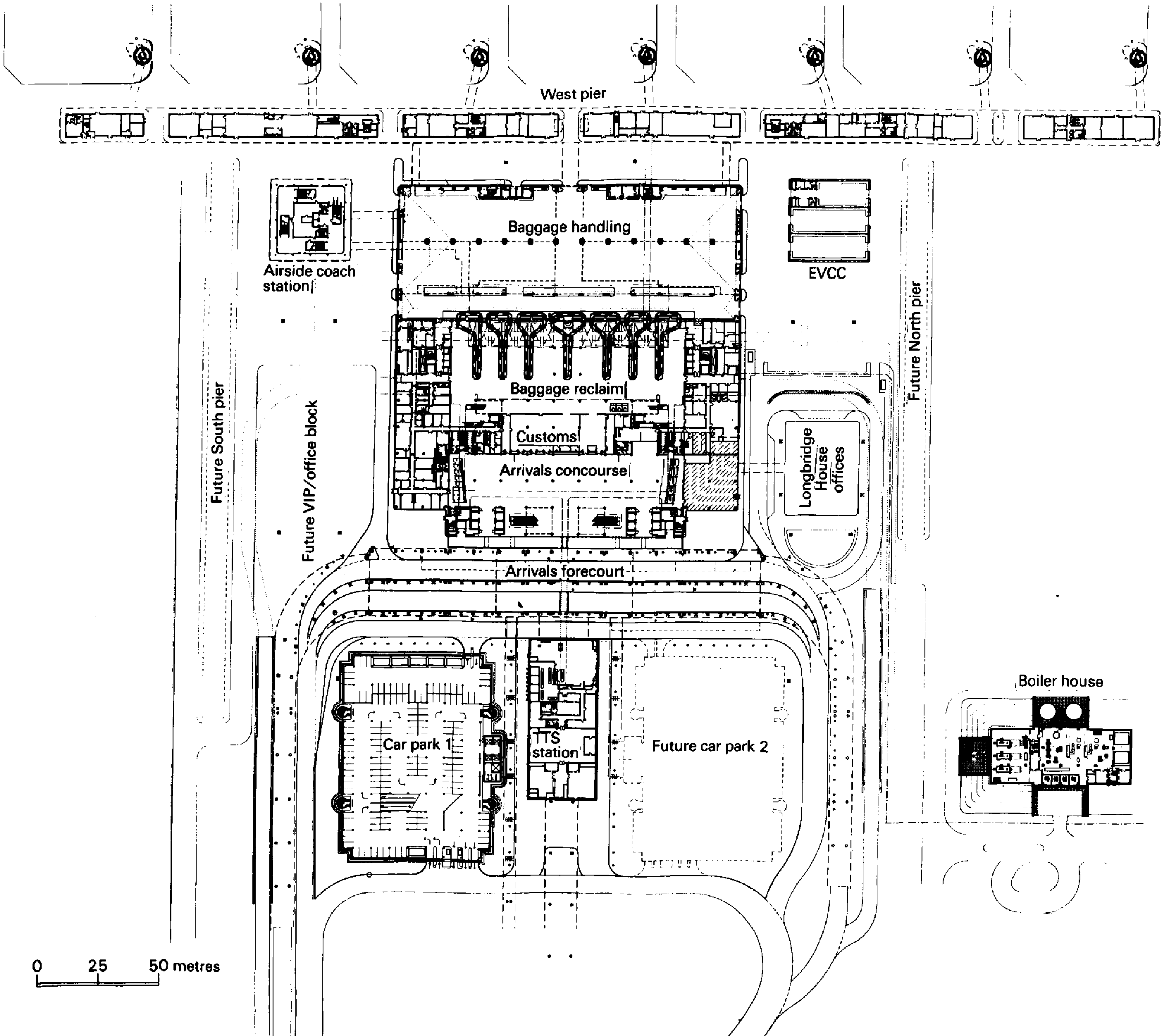
9.8 Gatwick North Terminal section.



9.9 Second floor plan, 1988.



9.10 First floor plan, 1988.



9.11 *Ground floor plan, 1988.*

Description: this second international terminal supplements the original and expanded South Terminal and raises the planned capacity of the airport from 16 million passengers per annum to 25 million pasengers per annum. The central terminal building has been built for the full 9 million passenger capacity, but only two-thirds of it has been fitted out. The three-storey structure has a departures forecourt, check-in hall and departures lounge on the upper level. The middle level has the rapid transit station and a large shopping area on the landside and the inbound immigration facility on the airside. At apron level there are the baggage handling facilities and customs and arrivals landside concourse and forecourt, Figures 9.8–9.11.

With a single-level 1988 airside concourse, reached by two spiral ramps from the departures lounge above, the now required segregation of arrivals and departures creates a problem. Screens and manned check-points ensure that arriving and departing streams do not mingle. A new pier added in 1991 has vertically-segregated passenger levels.

Although the North Terminal is self-contained, there is a rapid transit link to the South Terminal and the British Rail station.

Further reading:

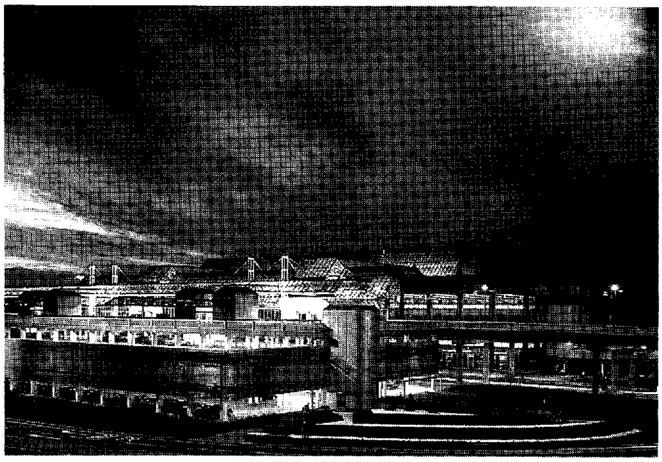
Ashley, S. (1985) Gatwick: the North Terminal. *Building Services*, December.
Butterworth-Hayes, P. (ed.) (1987) Unhappy separations. *Airports International*, September.
Doyle, N. (1991) Happy landing. *New Builder*, 22–29 August.
Manser, J. (1988) Fly and buy. *Building*, March 18.
Woolley, D. (1987) New Gatwick terminal nearing completion. *Airport Forum*, **4**.

9.3 Manchester Terminal 2

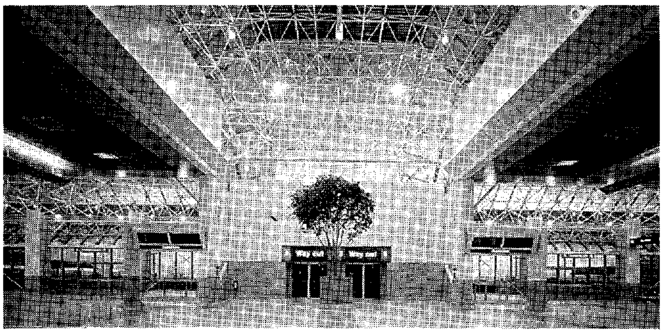
Type: airport-owned (1993).
Form: linear, vertically stacked and segregated.
Architect: Scott Brownrigg & Turner, Guildford.

Design standards:
International passengers per hour: 1850 each way (at 6 million passengers per year) and 2700 each way (at 12 million passengers per year).
Domestic passengers per hour: nil.
Transit/transfer passengers: 15%.
Passengers per year: 6 million (Phase 1) plus 6 million (Phase 2).
Aircraft stands: 8 Boeing 747-400 (or Boeing 757/Boeing 757 or Boeing 767/Boeing 737 on each) at Phase 1, and 14 Boeing 747-400 plus 5 MD 11, including the remote pier, at Phase 2.

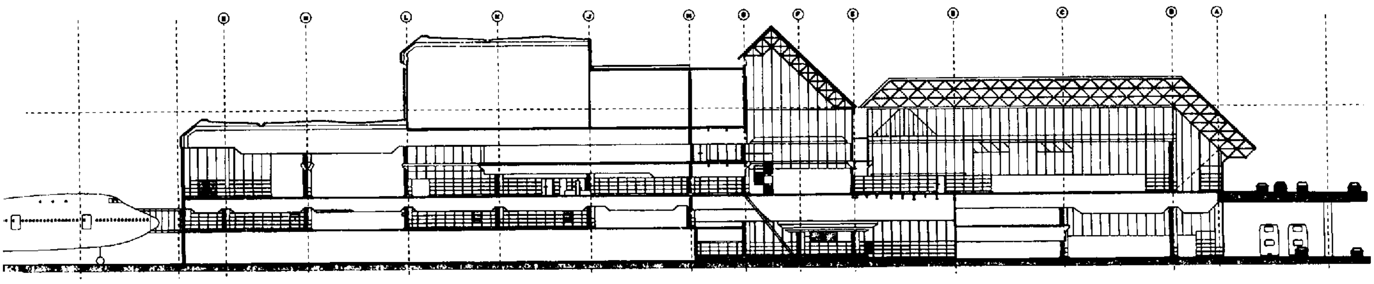
Description: Manchester Airport's first terminal, together with the domestic pier known as Terminal A and opened in May 1989 (see Chapter 27), has a capacity of 12 million passengers per year. The new second terminal, the first phase of which opened in



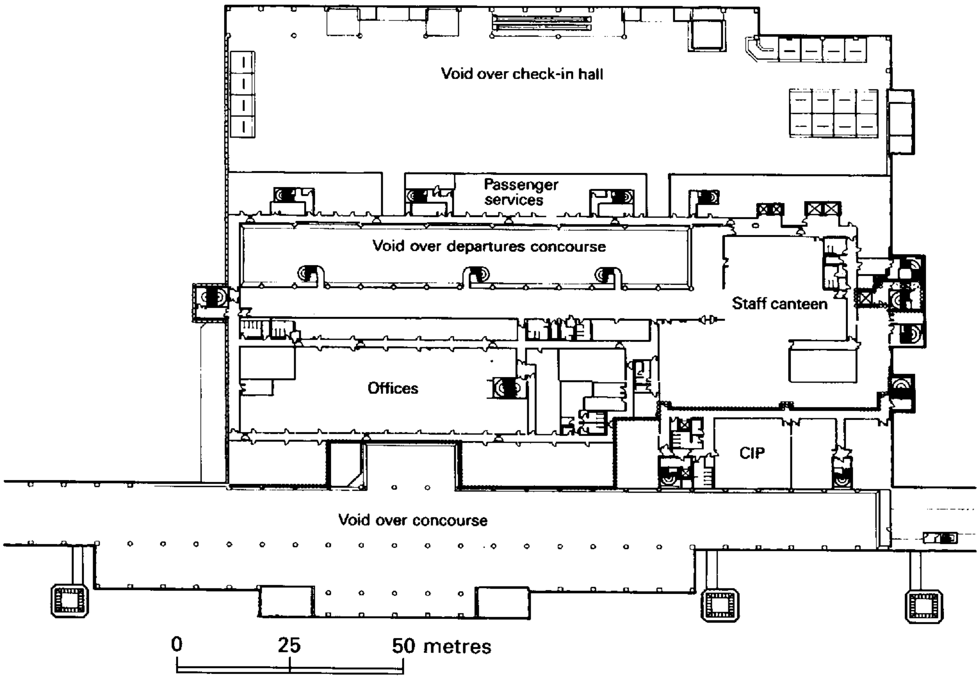
9.12 Manchester Terminal 2, landside exterior view. Architects: Scott Brownrigg & Turner, Guildford. Client: Manchester Airport plc.



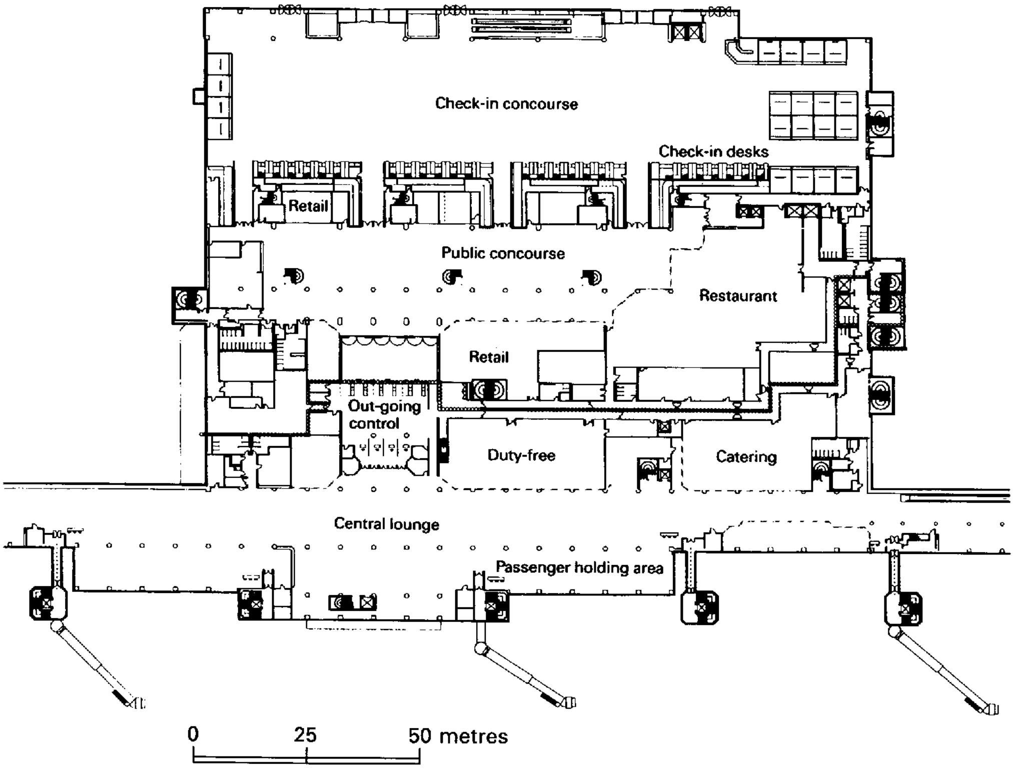
9.13 Landside interior view.



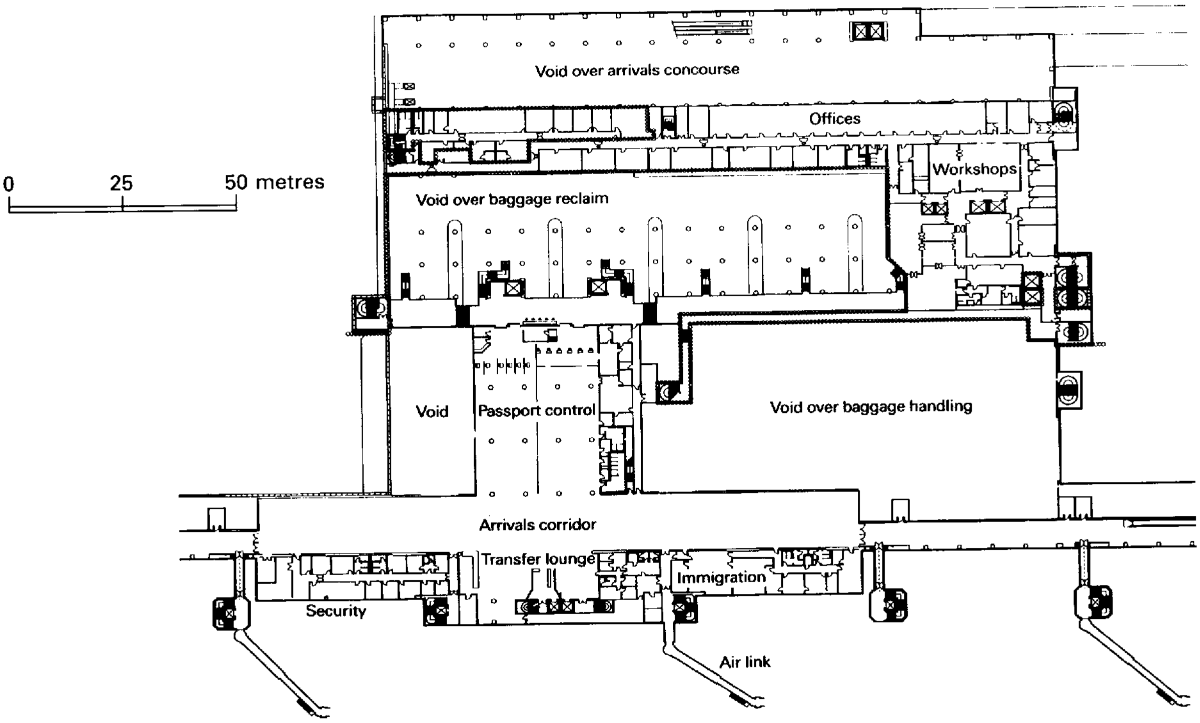
9.14 Section.



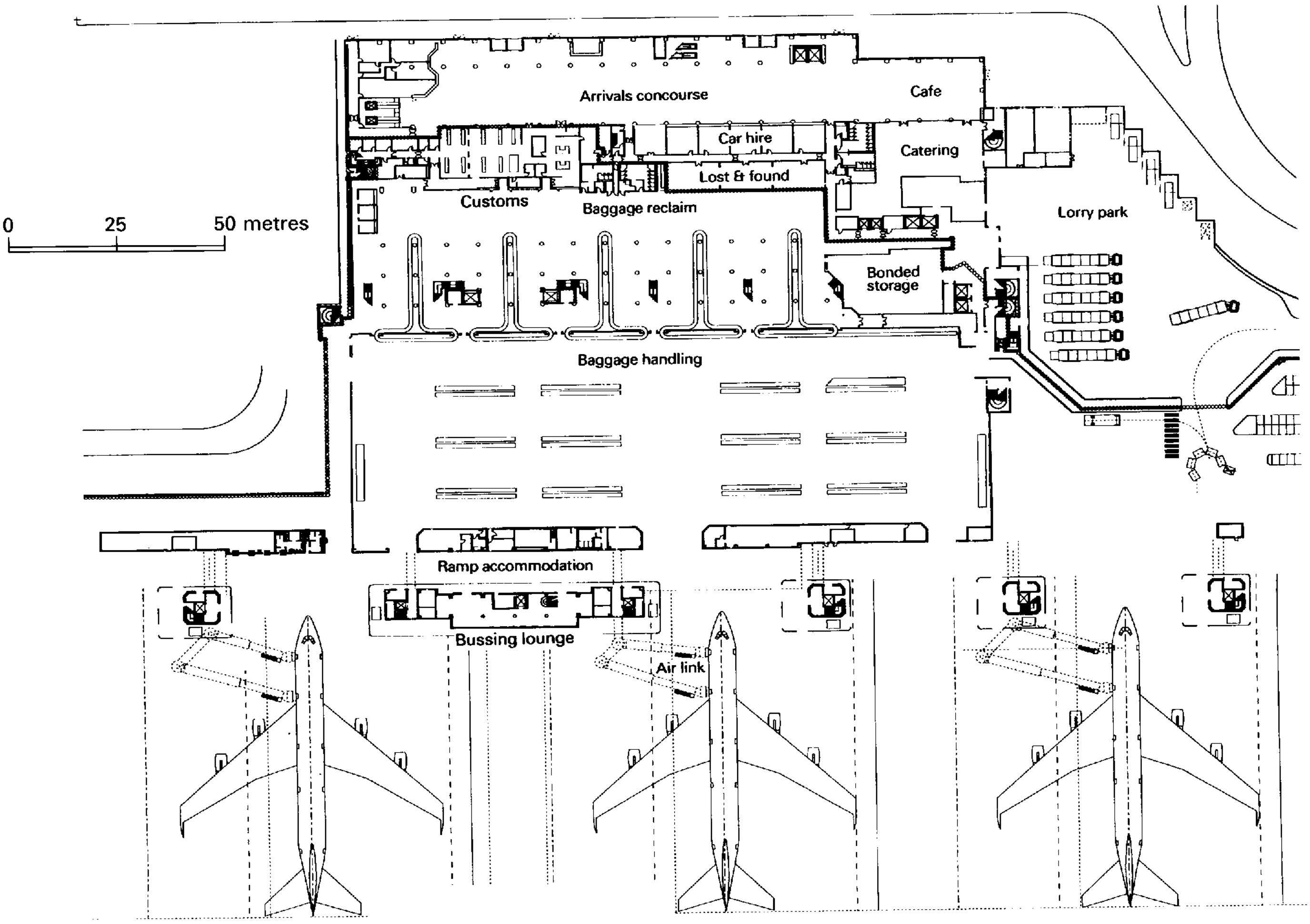
9.15 Departures mezzanine level plan.



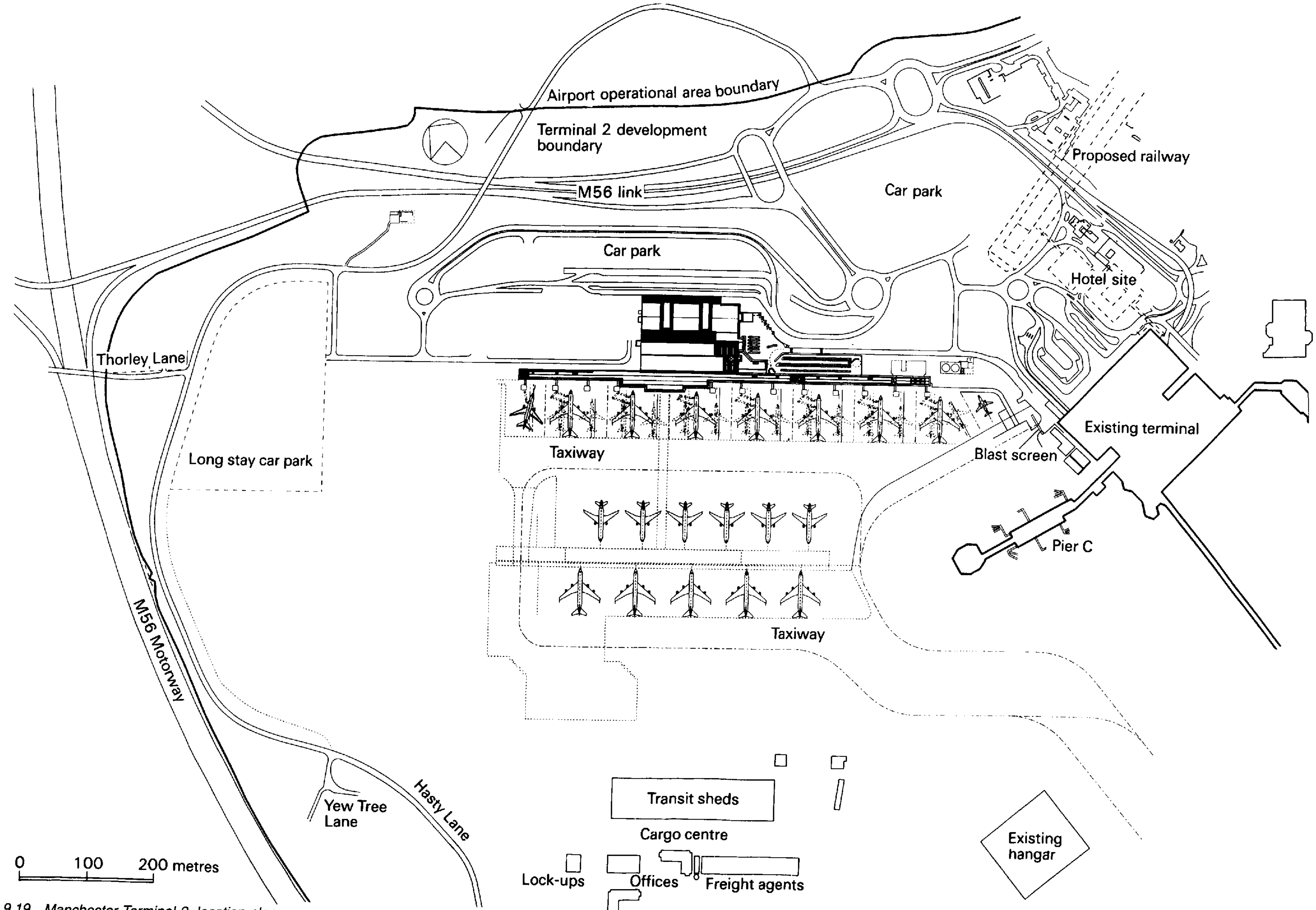
9.16 Departures level plan.



9.17 Arrivals mezzanine level plan.



9.18 Arrivals level plan.



9.19 Manchester Terminal 2, location plan.

1993, is Manchester's answer to a growth strategy of additional long-haul routes, traffic which otherwise might be routed via one of the overcrowded airports of the south east of England. The capacity of the second terminal is to grow to 12 million passengers per year in two phases. The site constraints have determined that the first phase shall comprise most of a central terminal and a long single-sided pier; the second phase plus a remote island two-sided pier will comprise the remainder, Figures 9.12–9.19.

The building offers segregation of arriving and departing passengers: From the elevated departures forecourt to check-in, outbound controls and then the airside concourse, passengers have a level route. A series of stand access towers on the airside face provide stairs and lifts down to the loading bridges. Arriving passengers have a level route into an arrivals corridor which leads to the inbound central immigration control and thence down to baggage reclaim, customs and the landside concourse.

When Phase 2 is constructed a series of escalators and lifts will link the passenger levels of the central building with a tunnel to the remote pier.

Further reading:

Congdon, L. and Taylor, A. (1989) New user-friendly terminal for Manchester. *Airport Forum*, **5**.

Pilling, M. (1993) Manchester sets northern challenge. *Airports International*, April.

Various authors (1993) New terminal makes light of flying. *Architects' Journal*, 19 May.

Woolley, D. (1993) New terminal paves way to Manchester's future. *Airport Forum*, **3**.

Yates, C. (1993) Manchester International Airport. *Supplement to Jane's Airport Review*, March.

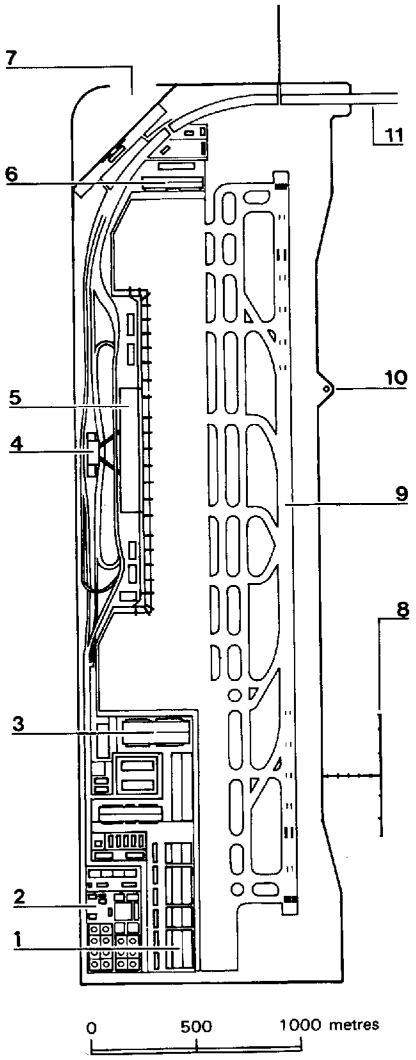
9.4 Osaka Kansai Terminal

Type: airport-owned (1994).
Form: stretched linear, vertically stacked and segregated domestic and international.
Architect: Renzo Piano Building Workshop/Nikken Sekkei.

Design standards:
International passengers per hour: variable for different facilities.
Domestic passengers per hour: variable for different facilities.
Transit/transfer passengers: variable for different facilities.
Passengers per year: capacity 25 million (12 million international and 13 million domestic).
Aircraft stands: 41 wide-body, all contact.

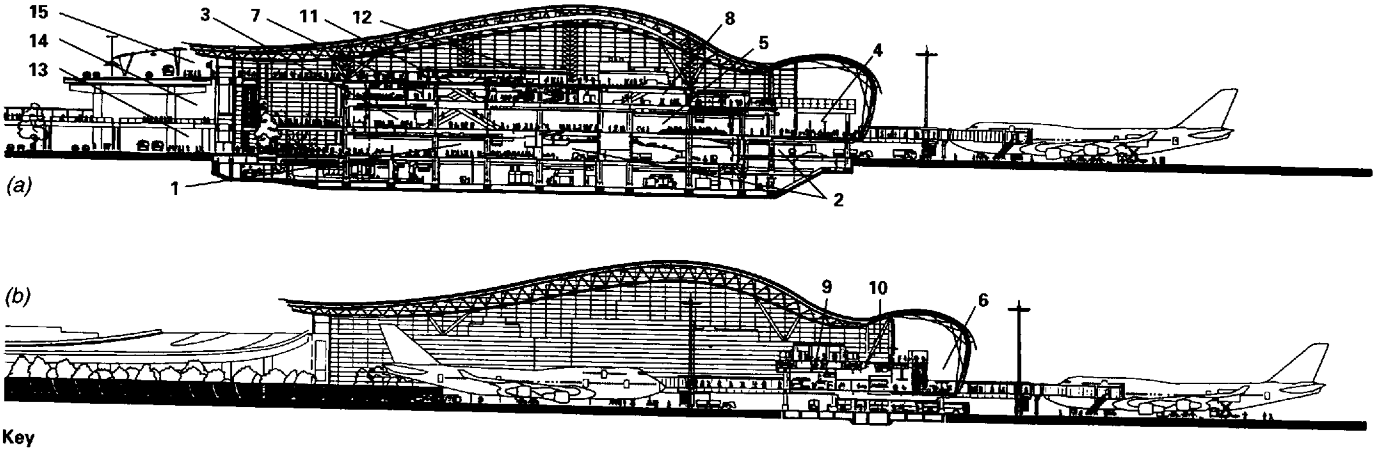
Description: the terminal building is a striking model for the future. Designed by Renzo Piano, it has a giant snaking curved roof as a grand statement of structure and aviation. To quote Piano, 'I believe that structure, especially of an airport terminal, should be a diagram of people moving through it. And all the atmospheric elements of the space – the light, the sound, the movement of the air – should contribute to the logic of their movement.' The building, including two double-sided piers, is more than a mile long. Inside, a 'green canyon' of mature trees has been created, but the most spectacular feature of the building is the roof. Supported on curved trusses spanning 60 metres, it sweeps and swells like an enormous wave on the point of breaking.

Passenger processing takes place on three levels: domestic traffic is located on the middle level, between departures on top and arrivals below. This reduces travel distances for transfer passengers, bearing in



1 Maintenance area
2 Supply and disposal zone
3 International cargo terminal
4 Railway station
5 Passenger terminal
6 Domestic cargo terminal
7 Access from sea
8 Oil tanker berth
9 Runway (3500 × 60m)
10 Navigation aid
11 Access bridge for rail and road

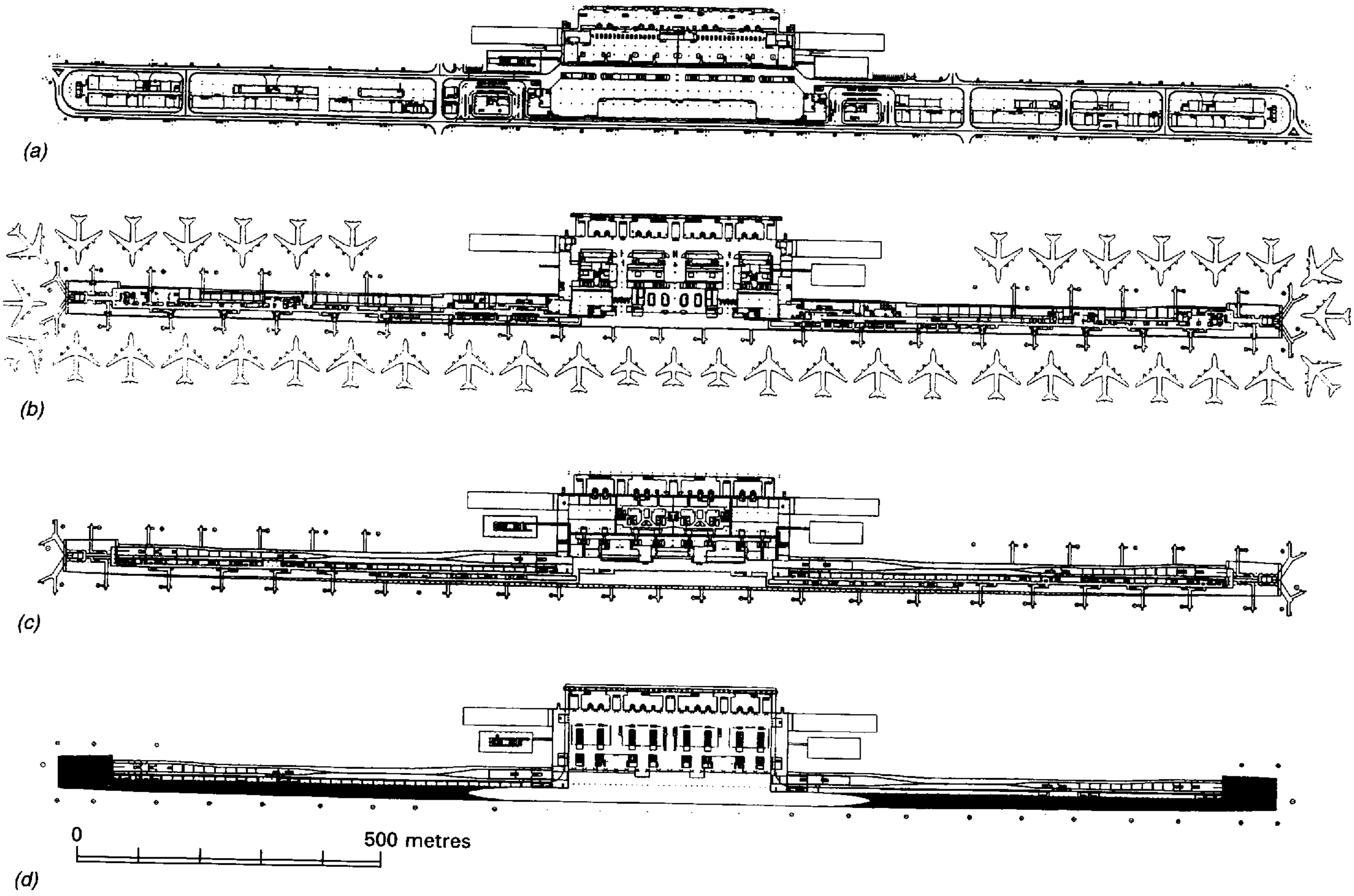
9.20 Osaka Kansai, master plan. Courtesy of Kansai International Airport Ltd.



Key

1 International arrivals, baggage collection and customs
2 Baggage handling
3 Domestic check-in counters
4 Domestic boarding lounge
5 Domestic arrivals baggage collection
6 International boarding lounge
7 Non duty-free shops and cafes
8 Duty-free shops
9 Automatic guided transport (AGT) stations
10 International arrivals walkway
11 International departures hall
12 Check-in counters
13 Arrivals collection
14 Bridge from station
15 Departures drop-off

9.21 Kansai cross-sections: (a) through terminal; (b) through wing.



9.22 Kansai plans; (a) island level, international arrivals and baggage handling; (b) first level, domestic arrivals and all boarding; (c) second level, concessions in terminal, arrivals in wings; (d) third level, international departures hall. Drawings courtesy of Nikkei BP Company.

9.23 *Kansai International Airport, terminal interior. Architects: Renzo Piano Building Workshop and Nikken Sekkei. Courtesy of Japan Airport Consultants.*

mind that the alternative was to have separate domestic and international terminals. Domestic gates are located at the centre of the terminal and some are interchangeable between international and domestic use as traffic demands, Figures 9.20–9.23.

Two people movers take international passengers down the length of each pier (see Section 23.1).

Further reading:

Buchanan, P. (1994) Kansai. *Architectural Review*, November.

Momberger, M. (1991) The Kansai International Airport passenger terminal building. *Airport Forum*, **6**.

Paylor, A. (1994) Turbulent take-off for Kansai. *Airports International*, September.

Welsh, J. (1994) On a wing and a layer. RIBA Journal, July.

9.5 Chicago O'Hare International Terminal

Type: airport-owned (1993).
Form: linear, vertically segregated.
Architect: Perkins & Will, Chicago.

Design standards:
International passengers per hour: capacity 2500 (departures) and 4000 (arrivals).
Domestic passengers per hour: nil.
Passengers per year: 6 million (1993), 8 million (predicted 1995).
Aircraft stands: 21 wide-body gates.

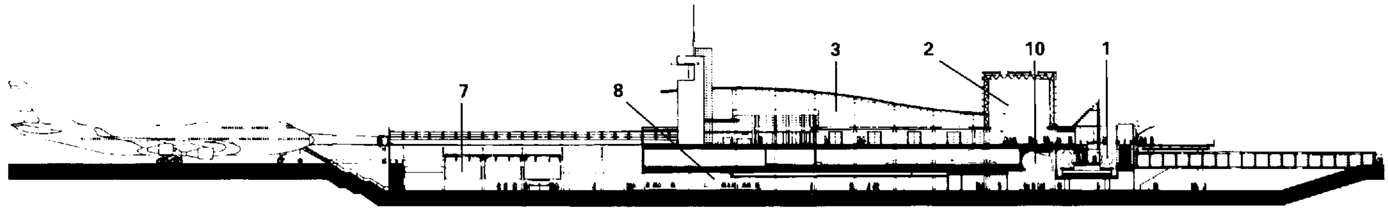
Description: the layout of this terminal, Chicago O'Hare's Terminal 4, is determined by the available land and road access. The new requirements of the Federal Inspection Service for an international terminal dictated total centralization and segregation of passenger movement. The terminal is designed to handle all international arrivals but only departures by foreign airlines: this is demonstrated by the design capacities for arrivals and departures respectively. Dominant features of the building are the great arching roof over the 250 m long ticketing pavilion, the Galleria link to the airside and the single-side three-level piers with a total length of 500 m, Figures 9.24 and 9.25. An automated transit system links this terminal to the other terminals and remote car parks.

Further reading

Branch, M. A. (1993) Now arriving. *Progressive Architecture*, June.

Linn, C. (1994) Form follows flight. *Architectural Record*, June.

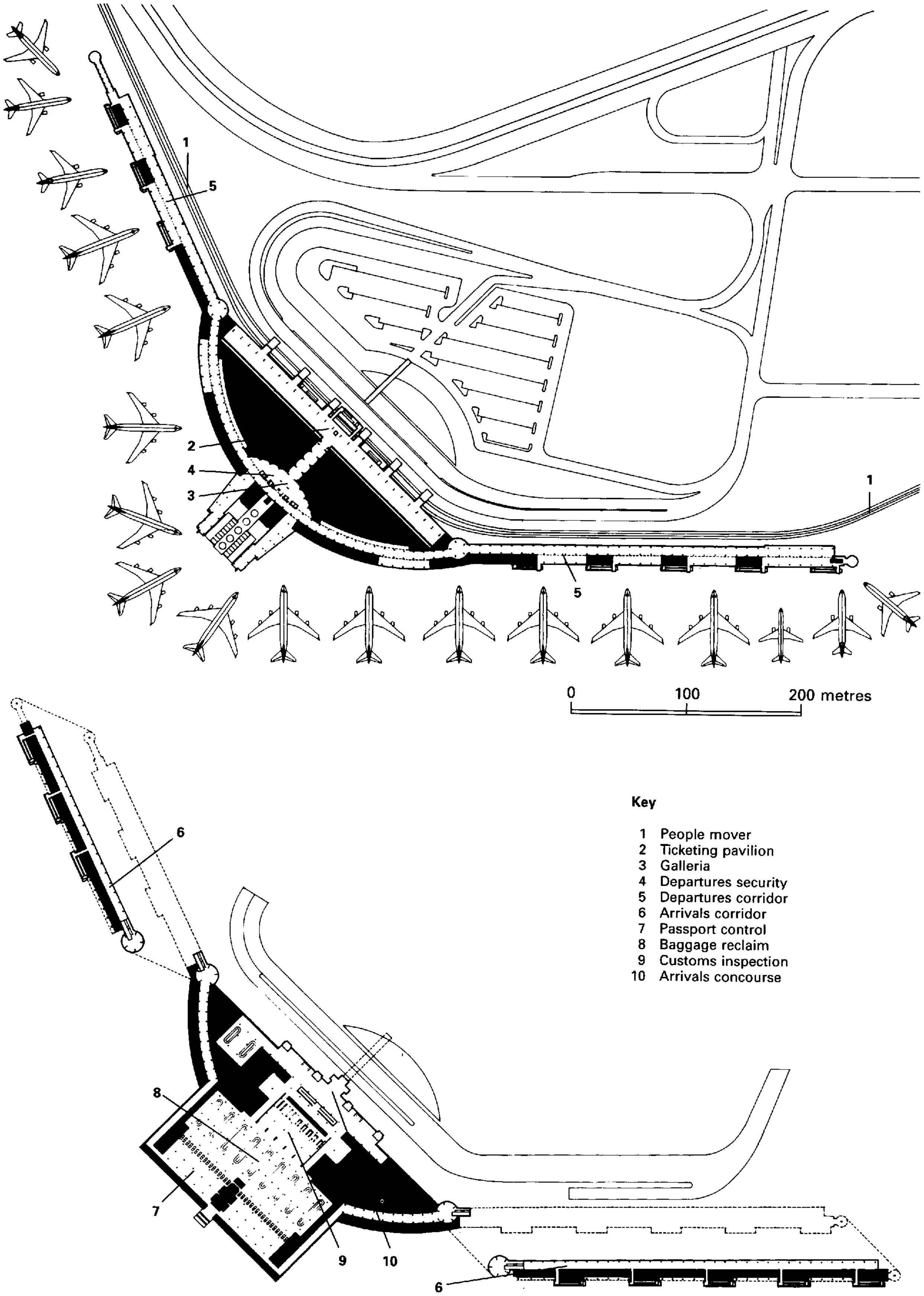
Schwartz, A. (1993) O'Hare opens largest international terminal in US. *Airport Forum*, **4**.



Key

1	People mover	7	Passport control
2	Ticketing pavilion	8	Baggage reclaim
3	Galleria	10	Arrivals concourse

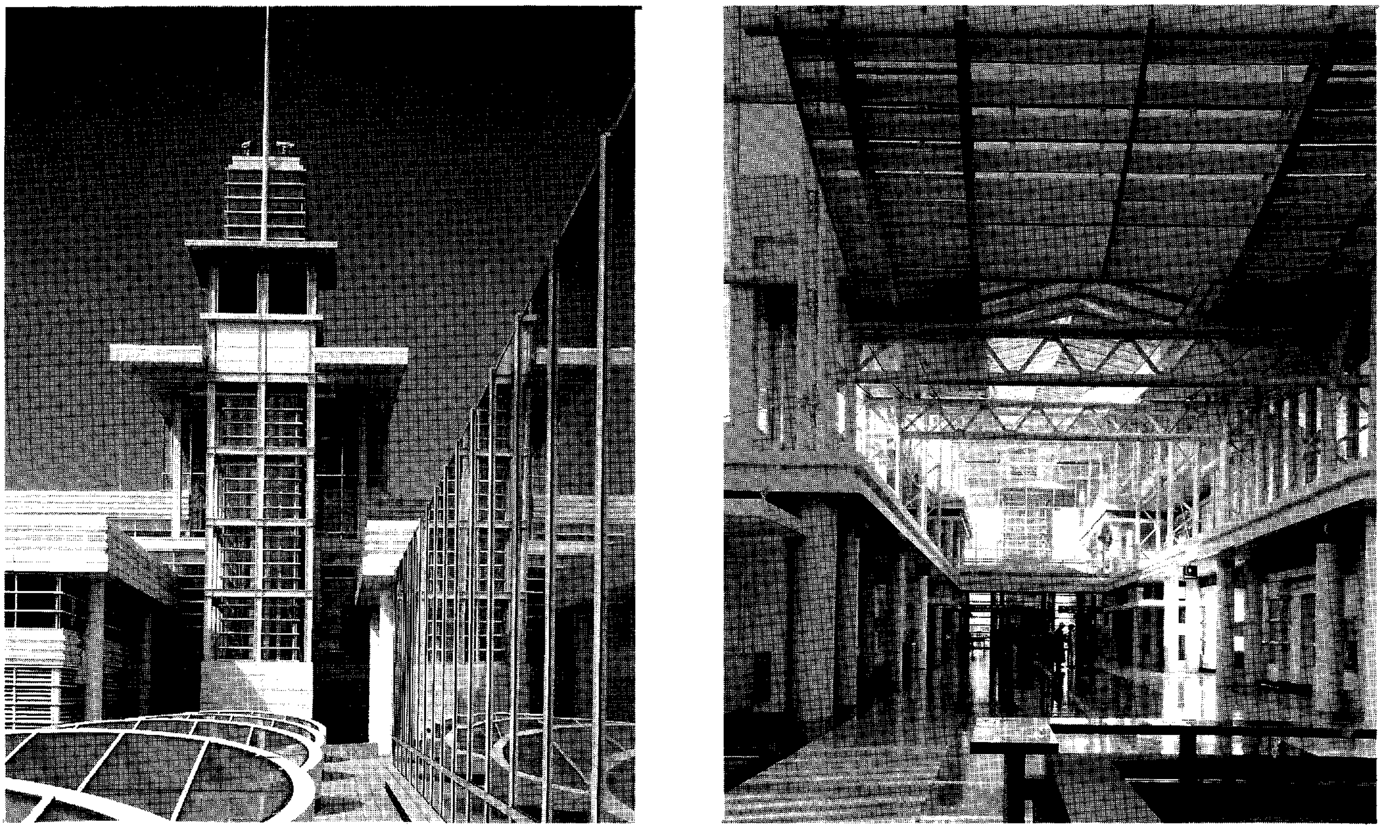
9.24 *Chicago O'Hare, cross-section. Courtesy of architects: Perkins & Will, Chicago.*



Key

1	People mover
2	Ticketing pavilion
3	Galleria
4	Departures security
5	Departures corridor
6	Arrivals corridor
7	Passport control
8	Baggage reclaim
9	Customs inspection
10	Arrivals concourse

9.25 Plans of two main levels.



(a) (b)

9.26 Chicago O'Hare: (a) exterior; (b) interior. Courtesy of architects: Perkins & Will, Chicago. Photographer: Hedrich/Blessing.

10 Piers: single or multiple

With piers, aircraft dock against double-sided extensions. This arrangement is suitable for a large-scale operation.

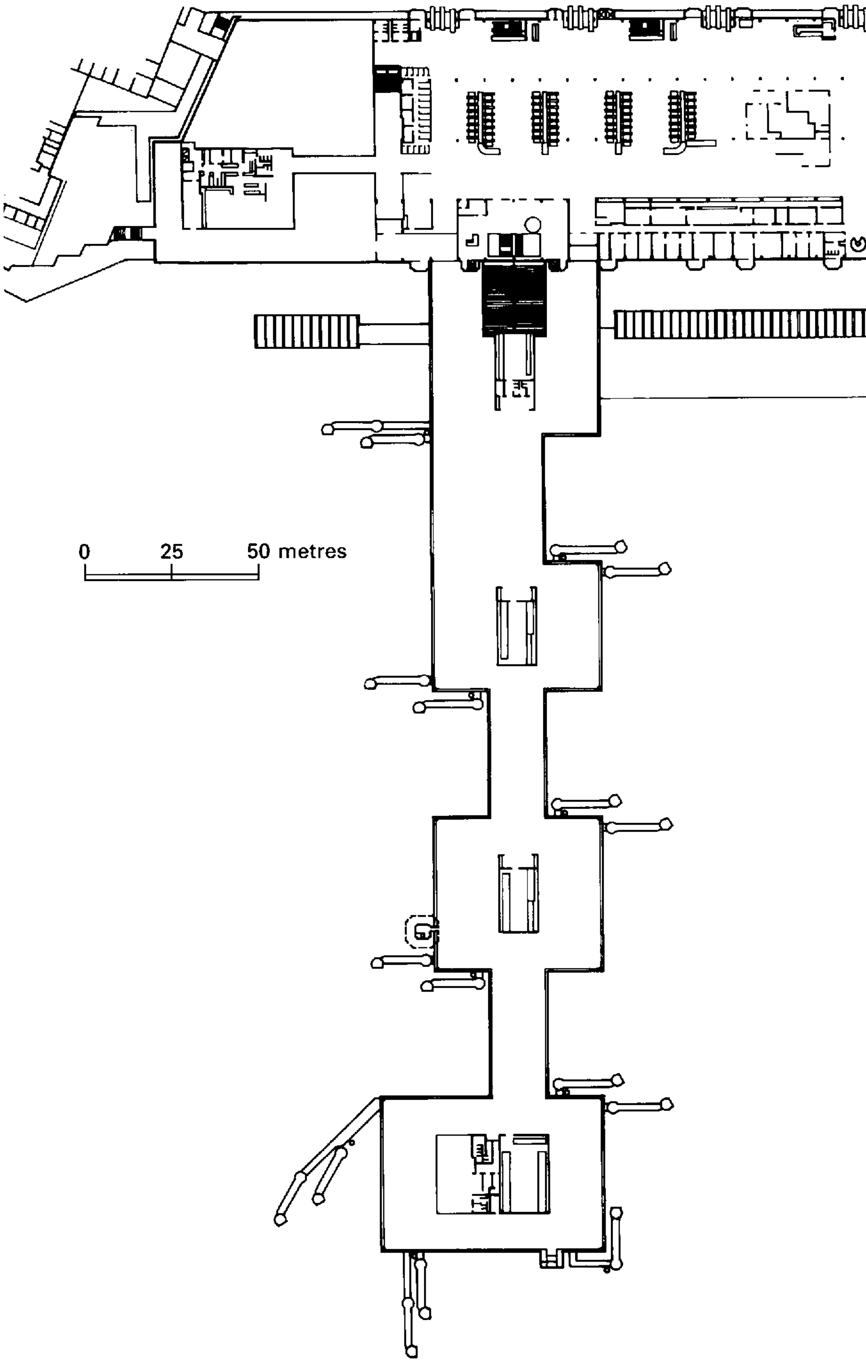
10.1 Zürich Kloten Terminal B

Type: airport-owned (1975).
Form: single pier, main terminal vertically stacked.

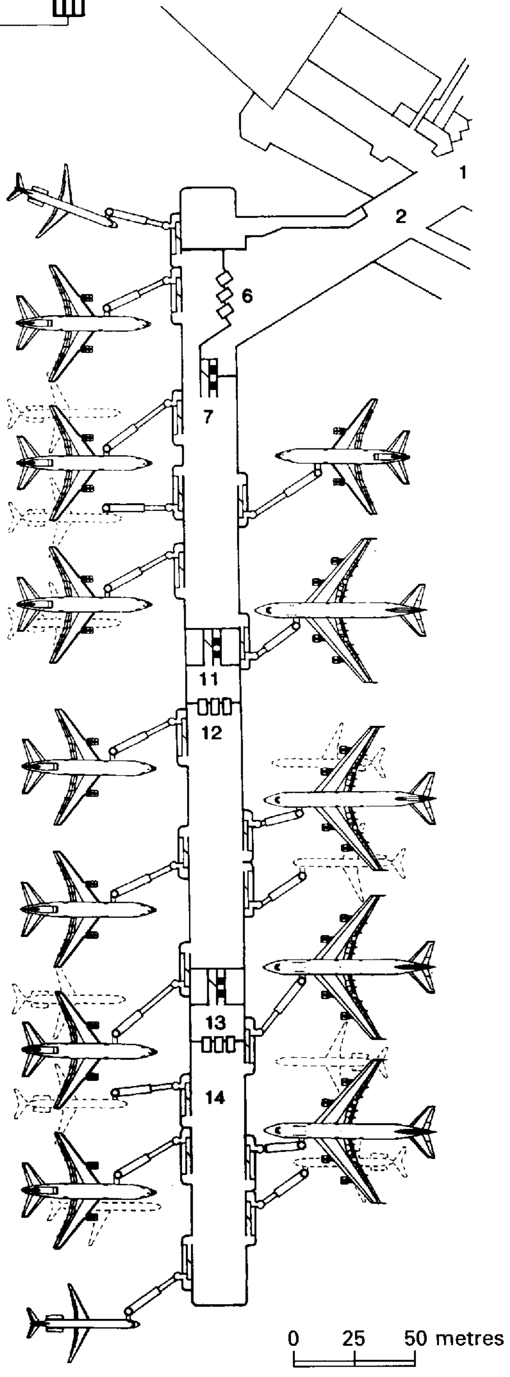
Design standards:
International passengers per hour: 3500.
Domestic passengers per hour: nil.
Passengers per year: 6 million.
Aircraft stands: 9 terminal-served wide-bodied aircraft.

Description: this separate terminal was added to an existing terminal and apron system and built to new forward planning standards. The form of the airside layout is a single wide pier. 50 per cent of terminal served stands provide for 20 per cent-stretched B747s, Figures 10.1–10.7. Direct access is provided from the terminal to the rail network.

10.1 Zürich Kloten Terminal B, aerial view.



10.2 Plan. Courtesy of Zürich Flughafen Informationsdienst.



10.3 Terminal A, main passenger level.

10.4 Zürich Kloten Pier A. Courtesy of Thyssen Henschel.

Further reading

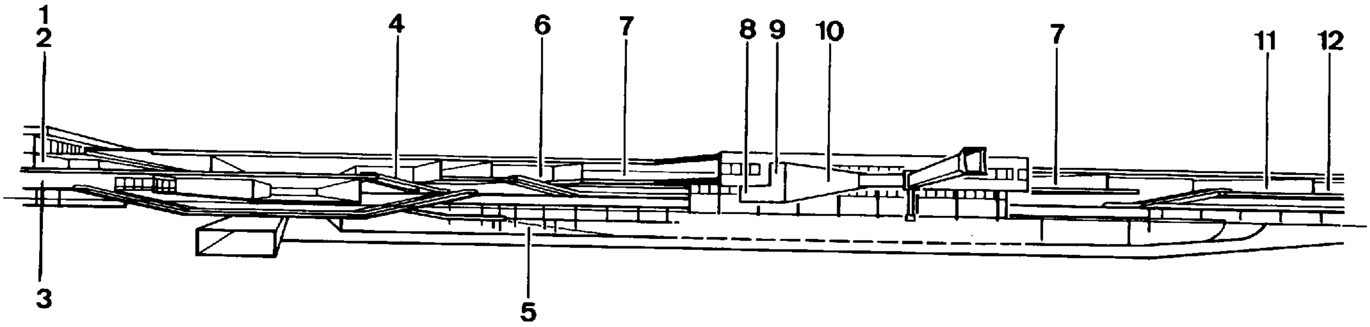
Nanni, H. and Pestalozzi (1976) Terminal B at Zurich. *Airport Forum*, 1.

10.2 Zürich Kloten Terminal A, new pier

Type: airport-owned (1985).
Form: single pier vertically segregated, landside terminal vertically stacked.

Design standards:
Passengers per year: total capacity of whole airport is 12 million.
Aircraft stands: up to 18 terminal-served, in multiple combinations.

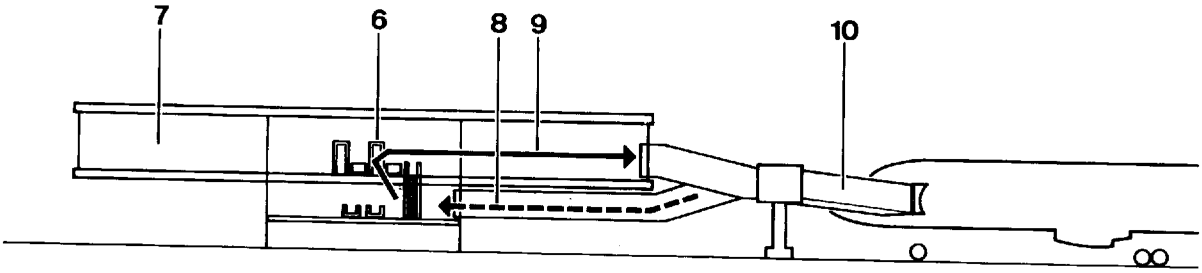
Description: this pier replaces an open apron operation and has the form of three piers or lounges laid end to end. Each unit has its own security control. The outer two lounges are reached from the stem of the pier by moving walkways which 'duck under' into a mezzanine level which also provides a segregated route for arriving passengers, Figures 10.3–10.6.



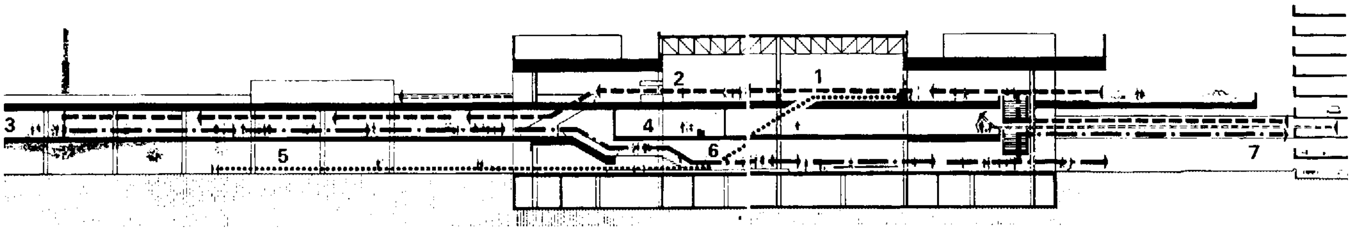
10.5 General section.

Key to Figures 10.5 and 10.6

1 Terminal A
2 Outbound immigration control
3 Inbound immigration control
4 Transit
5 Baggage sorting area
6 Security control, Gate zone 1
7 Gate zone 1
8 Arrivals
9 Departures
10 Loading bridge
11 Security control, Gate zone 2
12 Gate zone 2
13 Security control, Gate zone 3
14 Gate zone 3



10.6 Gate section. Figures 10.5 and 10.6 courtesy of Zürich Flughafen Informationsdienst.



Key

1 Check-in desks
2 Passport control
3 Gate lounge
4 Transit area
5 Service roads
6 Baggage reclaim
7 Bridge to multi-storey car park

10.7 Zürich Kloten Terminal B, section. Courtesy of Airport Forum.

There is direct access to the national rail network by the new railway station under the concourse of Terminal B.

Further reading

Butterworth-Hayes, P. (ed.) (1985) Pier will smooth traffic. *Airports International*, January.
Harder, H. (1988) New-design passenger loading bridges for Pier A. *Airport Forum*, **6**.
Hilscher, G. (1985) Zurich opens boarding pier. *Airport Forum*, **6**.

10.3 Hong Kong's new airport at Chek Lap Kok

Type: airport-owned (due to open 1997).
Form: single y-shaped pier vertically segregated, landside terminal vertically stacked.
Architect: Sir Norman Foster, Foster Hong Kong Ltd.

Design standards:
International passengers per hour: Phase 1 capacity 5500.
Domestic passengers per hour: nil.
Passengers per year: Phase 1 capacity 35 million.
Aircraft stands: Phase 1 38 wide-body contact and 24 remote.

Description: The first phase of this terminal for an airport with an ultimate capacity of 80 million passengers per year is already a record-breaking project. When open it will replace the existing terminal at Kai Tak, already reaching saturation in 1994 with an annual throughput of 24 million passengers served by a single runway. The new airport's first runway in Phase 1 will be followed by the second soon afterwards. The two runways are spaced 1525 metres apart, imposing severe constraints on the midfield terminal system, Figures 10.8–10.10.

The design of the building incorporates a Ground Transportation Centre with platforms for a dedicated high-speed rail link from the airport to urban Hong Kong on the landside, and a sub-ground people mover which will ultimately link to a giant satellite on the airside.

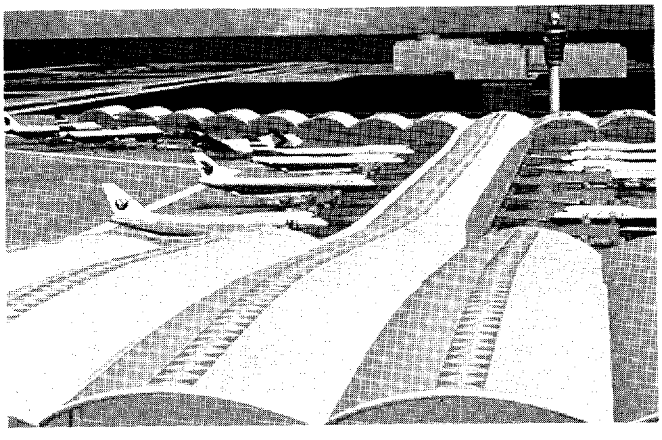
Further reading

Mangan, D. (1994) Down to earth approach for Chek Lap Kok. *Airport Technology International*, 1994/95.
Momberger, M.(1993) CLK work starts in earnest. *Airport Forum*, **3**.

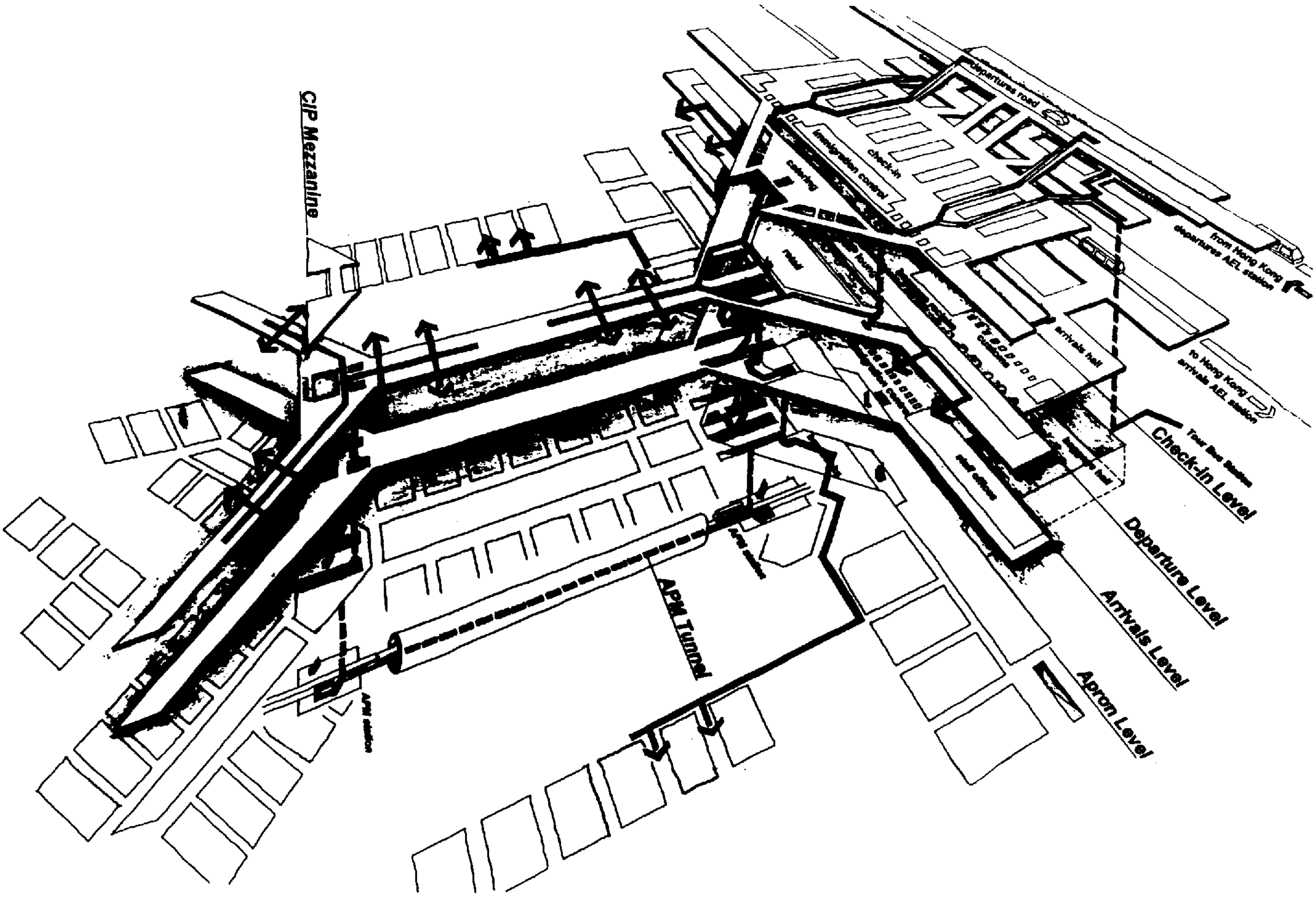
10.4 Second Bangkok International Airport project

Type: government project (1994).
Form: multiple piers, main terminal vertically stacked.
Architect: competition entry by Scott Brownrigg & Turner in association with Mott MacDonald.

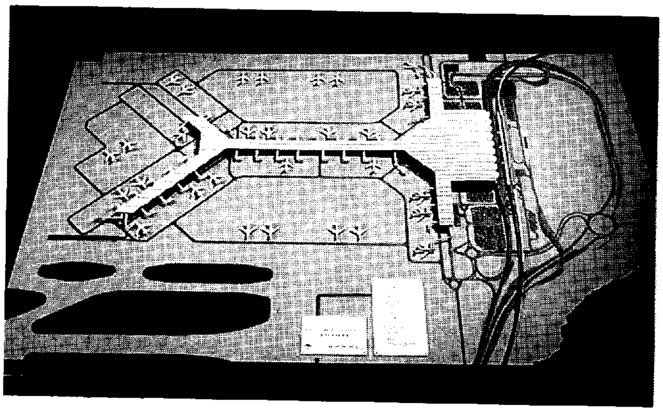
Design standards:
International passengers per hour: one-way airside 4600–5200.
Domestic passengers per hour: one-way airside 1600–2500.
Transit/transfer passengers: up to 45% of traffic under one possible scenario.
Passengers per year: Phase 1 capacity 30 million.



10.8 Impression of Kong Kong's new airport in the year 1998. Courtesy of Provisional Airport Authority, Hong Kong. Architect: Sir Norman Foster & Partners.



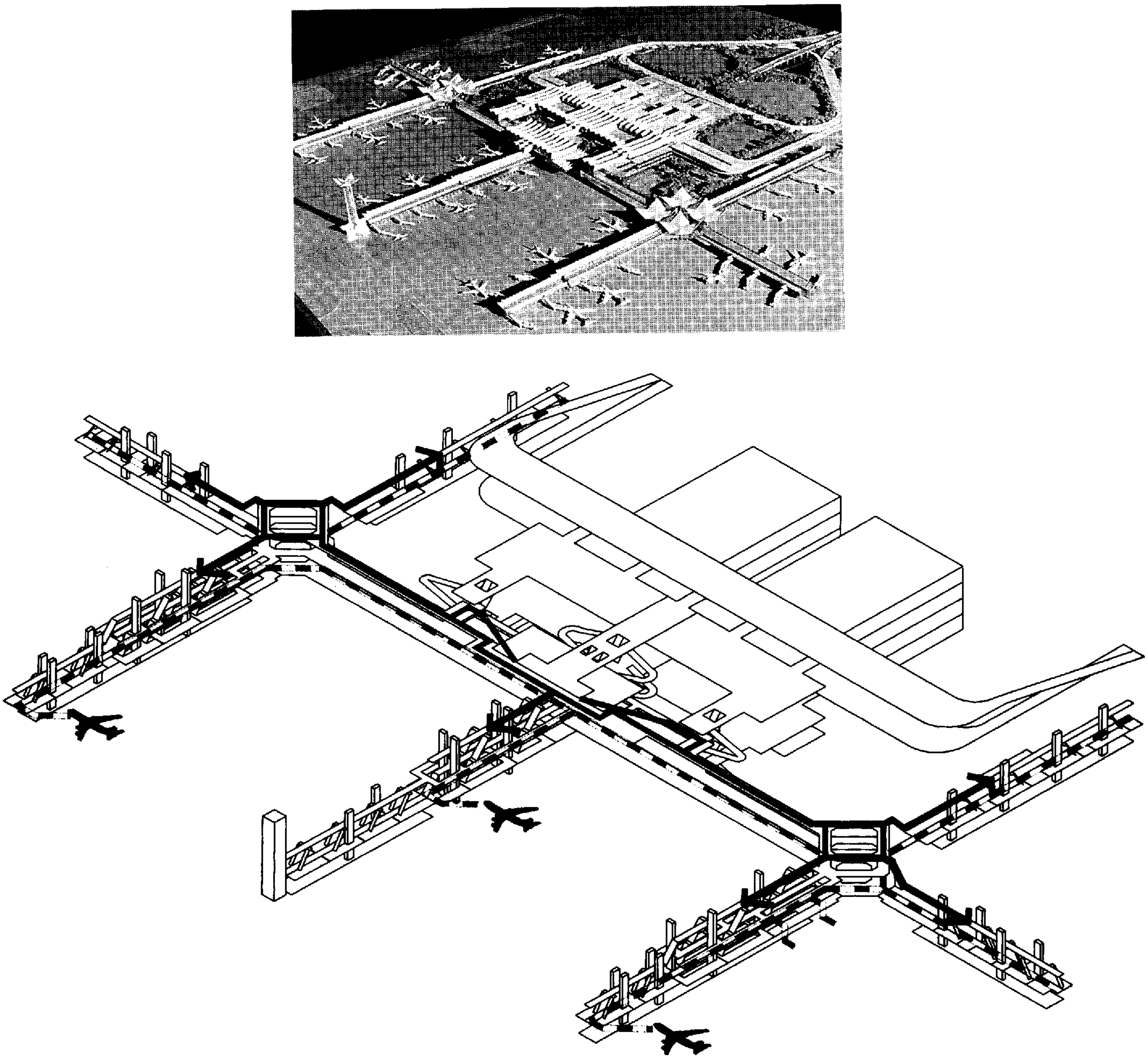
10.9 Diagrammatic representation of plans and passenger flows at Hong Kong. Presentation courtesy of Cathay Pacific Airways, as used in airline/airport dialogue. Architects: Scott Brownrigg & Turner, Guildford, in association with Scott Wilson Kirkpatrick & Co. Ltd, Hong Kong.



10.10 Terminal model. Courtesy of Provisional Airport Authority, Hong Kong. Architect: Sir Norman Foster & Partners.

Aircraft stands: 51 contact gates: 28 to be always international, 7 small stands to be always domestic and the remaining 16 to be 'swing' or interchangeable gates.

Description: competitive designs were submitted early in 1994 for the terminal building for this proposed new hub airport, and these were within the framework of a master plan prepared by a Dutch-American consortium. The first phase capacity of 30 million passengers per year, commensurate with terminal-served stands for 50 wide-bodied jets, demands as compact a hub terminal building as possible with a gross area of nearly 500 000 sq metres. The most compact layout makes the maximum use of double-sided piers, within the



10.11 Second Bangkok International Airport Competition by Mott MacDonald Consortium, 1994. Architects: Scott Brownrigg & Turner in association with Thai architects, Casa.

planned runway separation of 2200 m. Future provision for New Large Aircraft (see Sections 4.4 and 25.2) is achieved by double taxilanes in cul-de-sacs reverting to single centreline taxilanes when necessary in the future.

As well as being responsive to the climatic, environmental and security needs of this vast structure, the illustrated design sought to provide a unique type of flexibility and interchangeability between international and domestic traffic. This was achieved by parts of the building having three passenger levels to provide segregated routes for international and domestic arrivals and departures, Figure 10.11.

11 Satellites: single or multiple

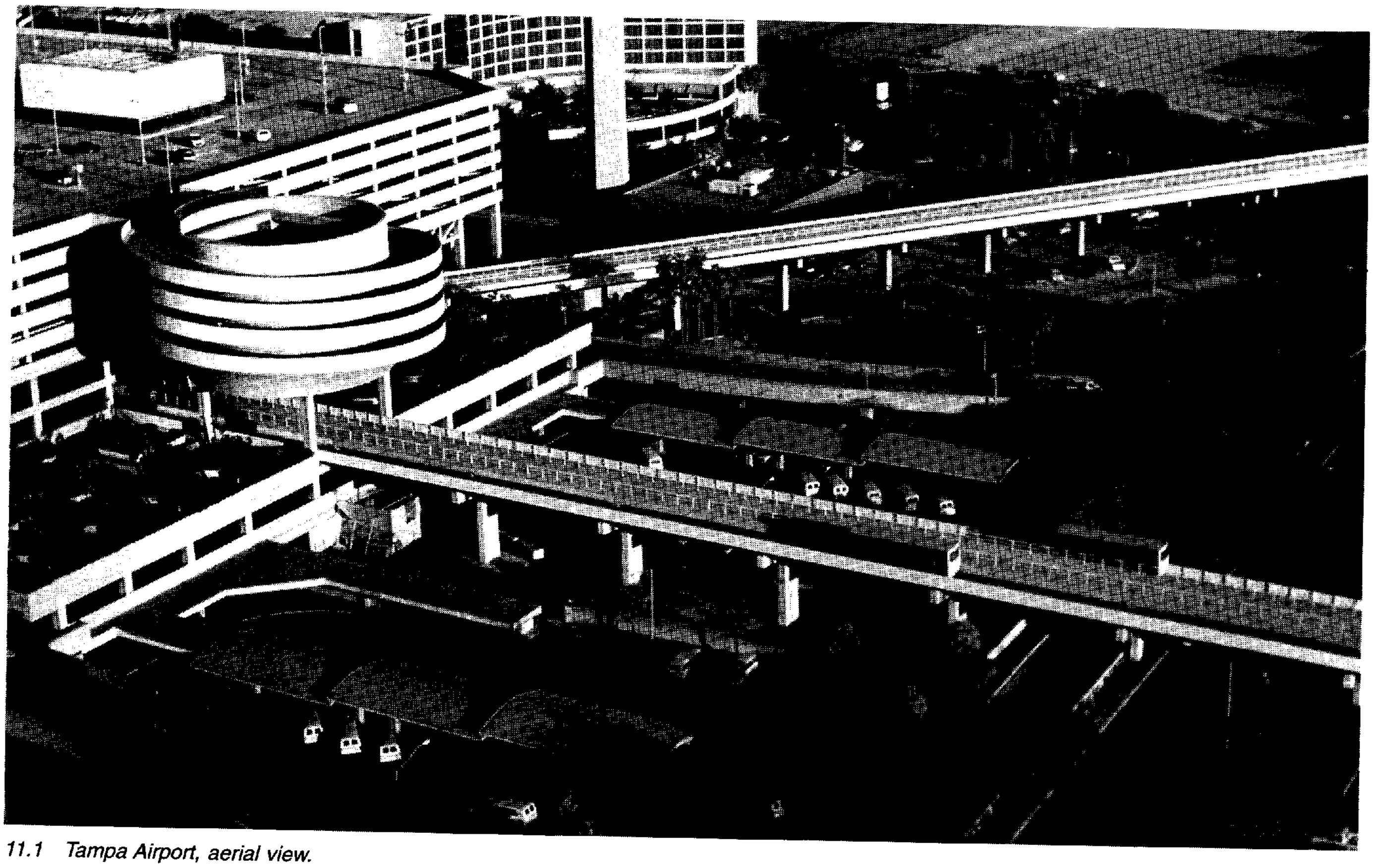
11.1 Tampa

Type: airport-owned (1971 + new satellite added 1987).
Form: multiple satellites, main terminal vertically stacked.
Architect: Greiner Engineering Sciences Inc., Tampa, Florida.

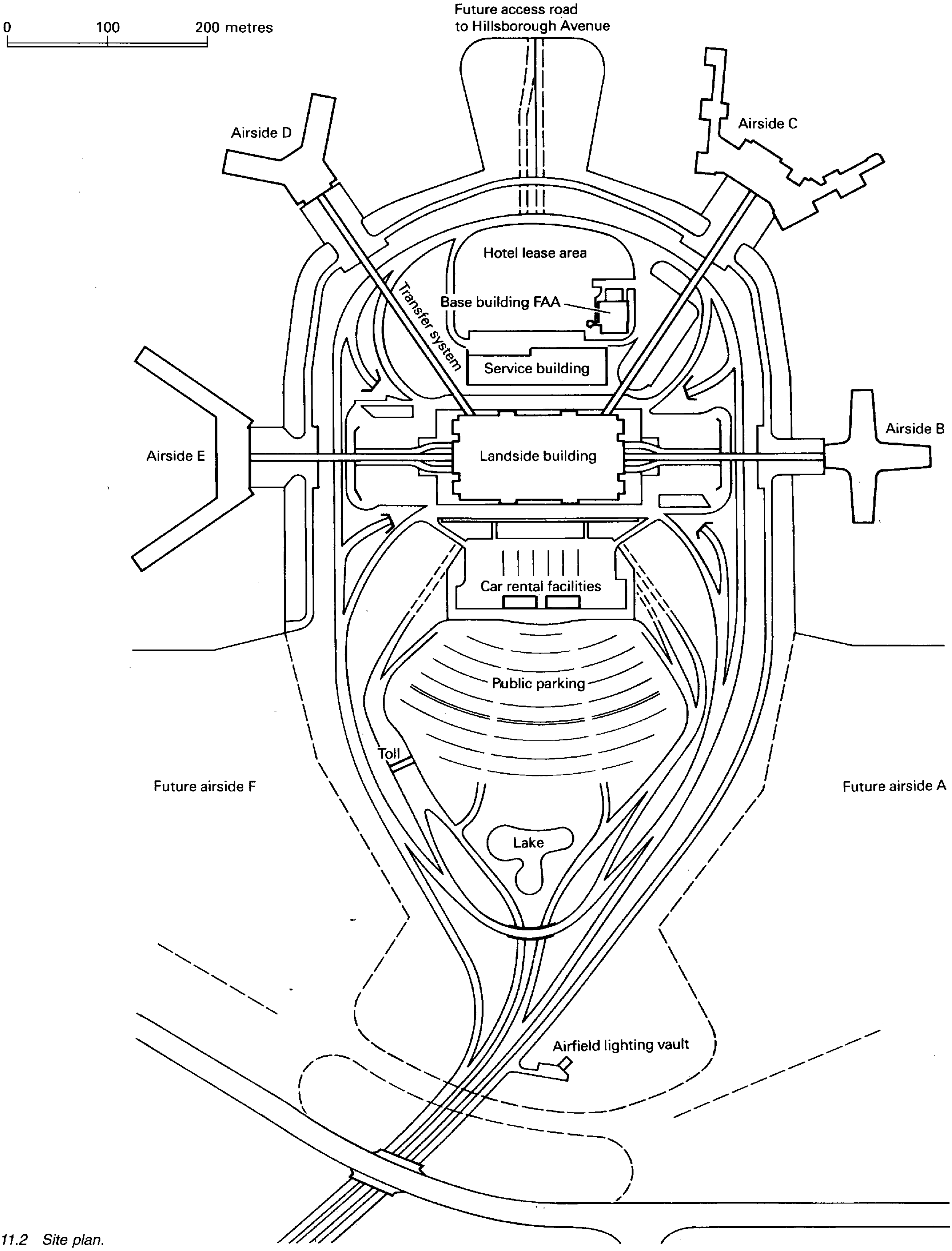
Design standards:
International passengers per hour: 600.
Domestic passengers per hour: no information available.
Transit/transfer passengers: no information available.
Passengers per year: 10 million (5 satellites 1993 actual) with projected 20–25 million (6 satellites).
Aircraft stands: 40 (Airsides B–E) plus 15 (Airside F).

Description: this archetype of a multi-satellite terminal was originally designed with four satellites for individual airline needs, and with provision for a further two. The car park structure is positioned above the terminal. Rapid transit cars link terminal and satellites, Figures 11.1–11.6.

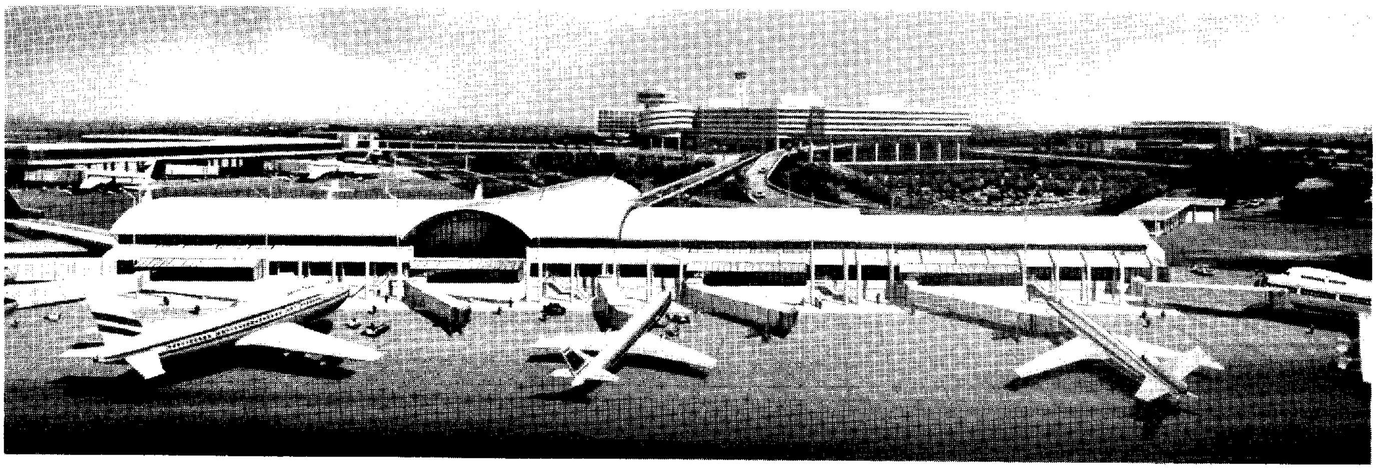
The new satellite is geared to a total international operation and offers the potential for full segregation



11.1 Tampa Airport, aerial view.



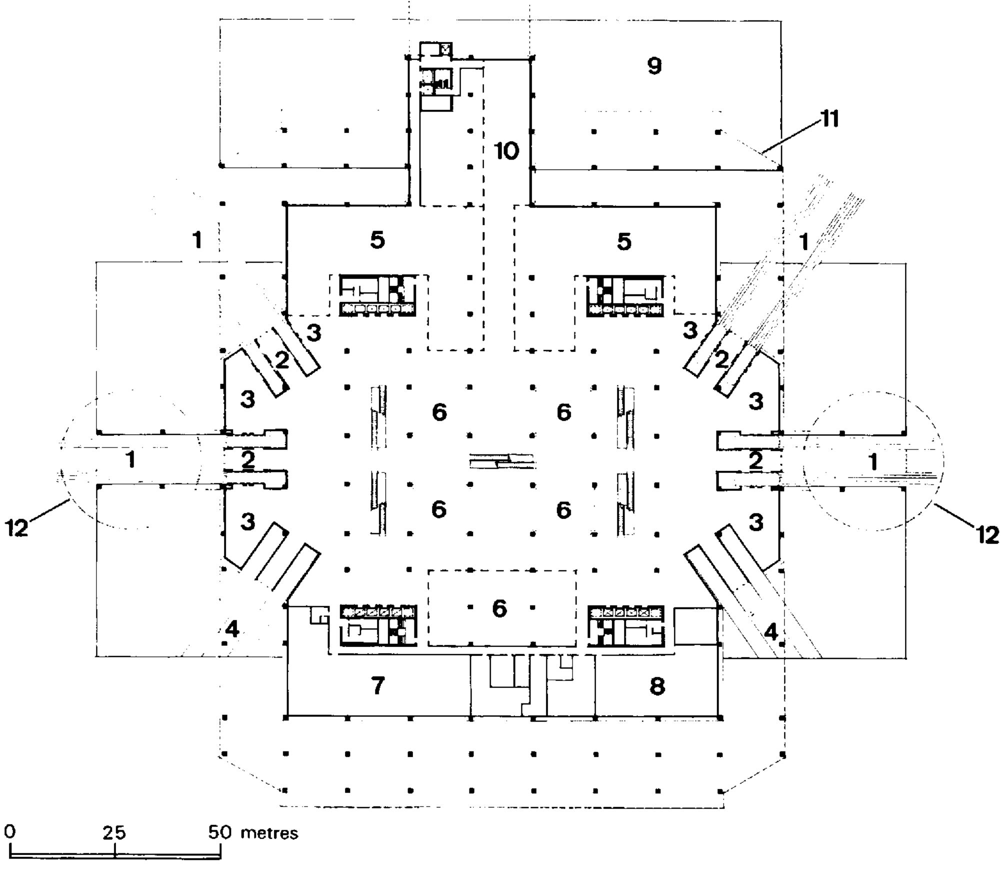
11.2 Site plan.



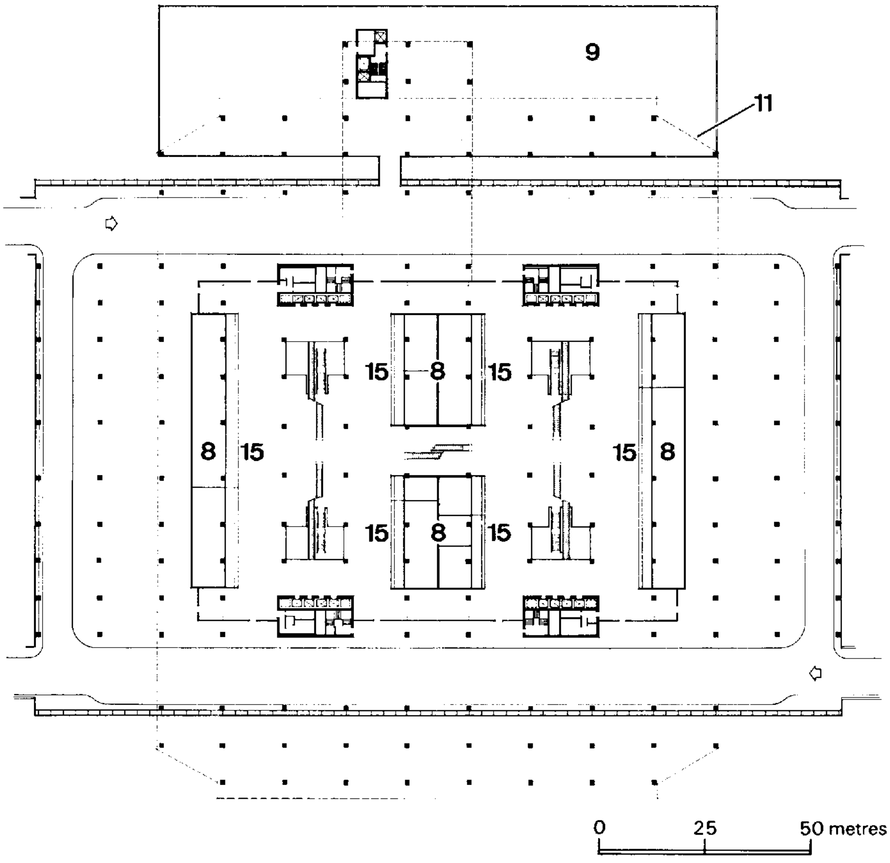
11.3 New satellite F. Figures 11.1 and 11.3 courtesy of Hillsborough County Aviation Authority.

Key to Figures 11.4–11.6

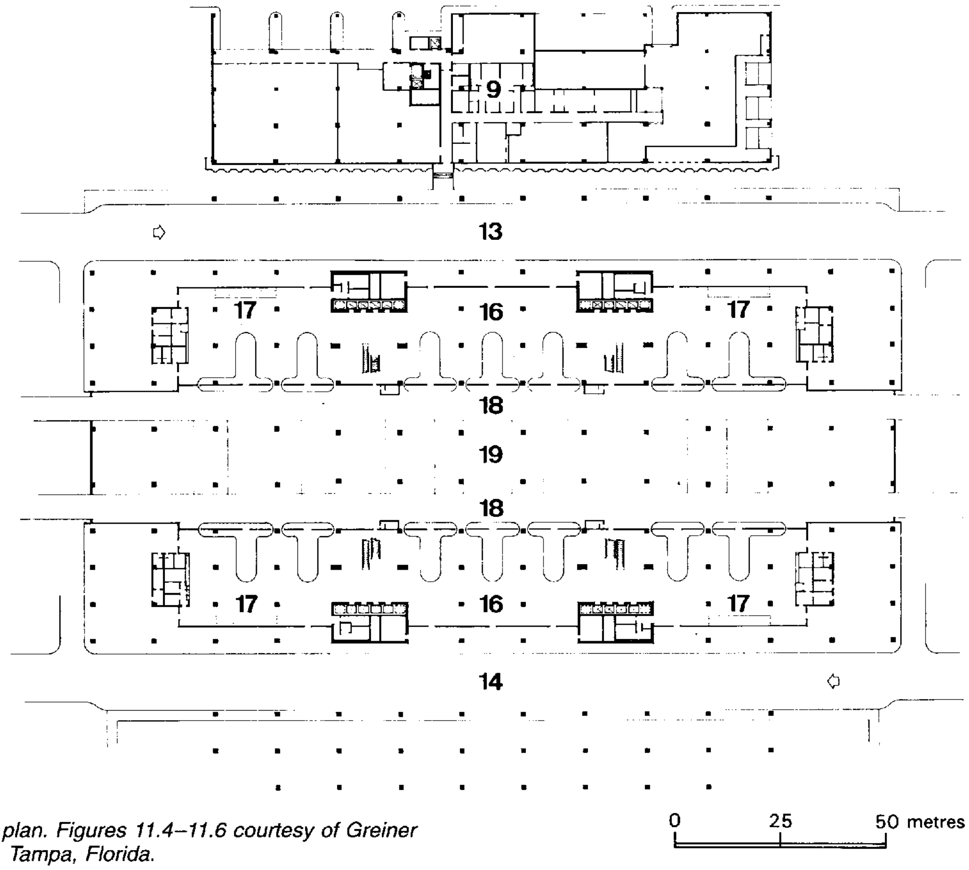
1 Transfer system
2 Enplaning
3 Deplaning
4 Future transfers system
5 Catering
6 Concessions
7 Airport authority offices
8 Airline offices
9 Service building and roof
10 Hotel access
11 Line of parking structure above
12 Helical ramps above
13 Enplaning doorway
14 Deplaning doorway
15 Ticket counters
16 Bag claim area
17 Car rental counters
18 Tug drive
19 Bag make-up area



11.4 Transfer level plan.



11.5 *Ticketing level plan.*



11.6 Bag claim level plan. Figures 11.4–11.6 courtesy of Greiner Engineering Sciences, Tampa, Florida.

of arriving and departing passengers on separate levels. Its structure is a single clear span at departures level.

Further reading

Foxhall, W. B. (1972) Tampa International airport a fresh look at man and machine in transit. *Architectural Record*, October.

Schwartz, A. C. (1985) On expansion course. *Airport Forum*, **1**.

Schwartz, A. C. (1988) Fifth satellite gives Tampa greater capacity, fresh look. *Airport Forum*, **1**.

11.2 Orlando

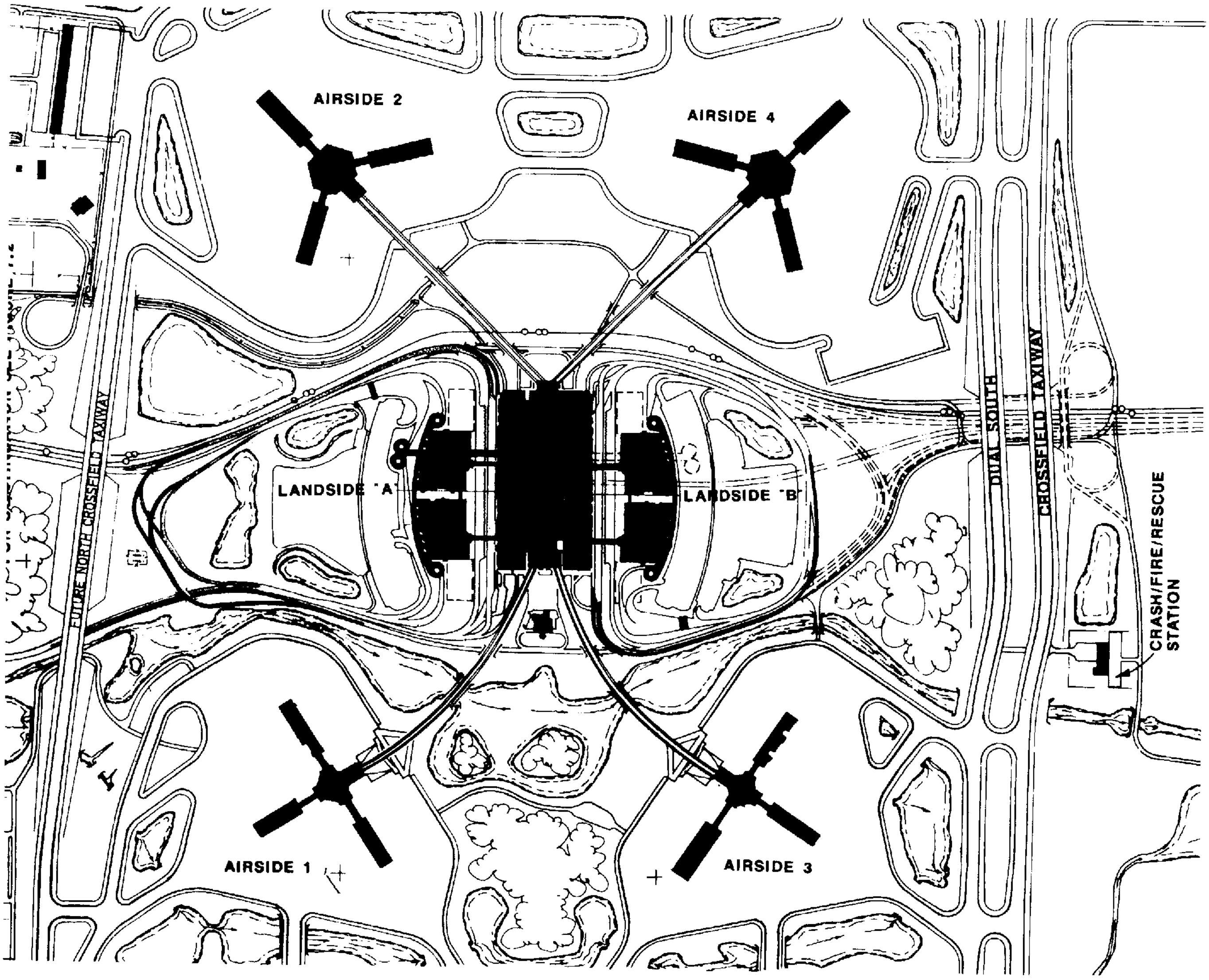
Type: airport-owned (first two satellites 1980, third satellite 1990, fourth projected).
Form: multiple satellite, main terminal vertically stacked.
Architect: KBJ Architects Inc./Schweizer Associates Inc.

Design standards:
International passengers per hour: no data, 11% international.
Domestic passengers per hour: no data, 11% international.
Transit/transfer passengers: no data, 11% international.
Passengers per year: 18 million capacity (planned 1990, actual 22.4 million 1994).
Aircraft stands: 72 (24 per satellite), more projected.

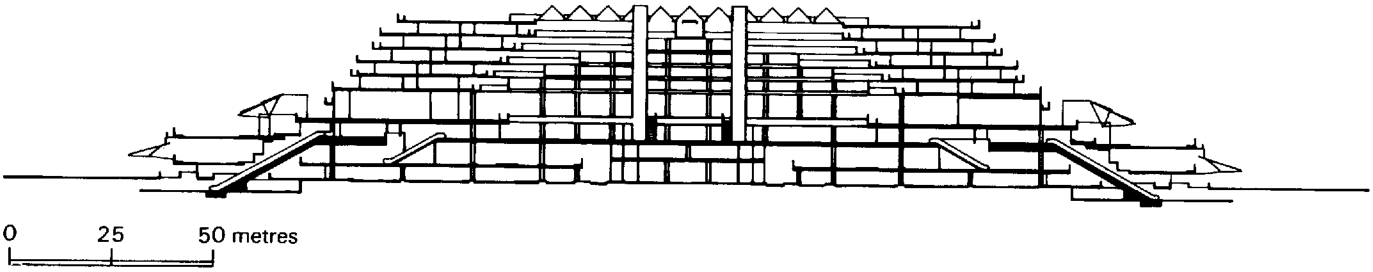
Description: the development in central Florida in the mid 1970s of a unique concentration of tourist facilities with an exceptional international appeal led to the construction of the new Orlando International Airport. The central terminal building is conceived as a three-level building with landside roads serving all three levels on two sides. The whole ground level is given over to an exceptionally high-demand car-hire facility. The mid level houses domestic passengers' baggage reclaim, and the upper level all departures facilities and the entries to three rapid transit systems which link the terminal to three satellites, Figures 11.7–11.12.

When originally built, the projected doubling of traffic within 15 years demanded provision for the enlargement of the central terminal and the addition of a further two satellites. This central terminal expansion was achieved within ten years together with the third

11.7 Orlando International Airport aerial view 1994.



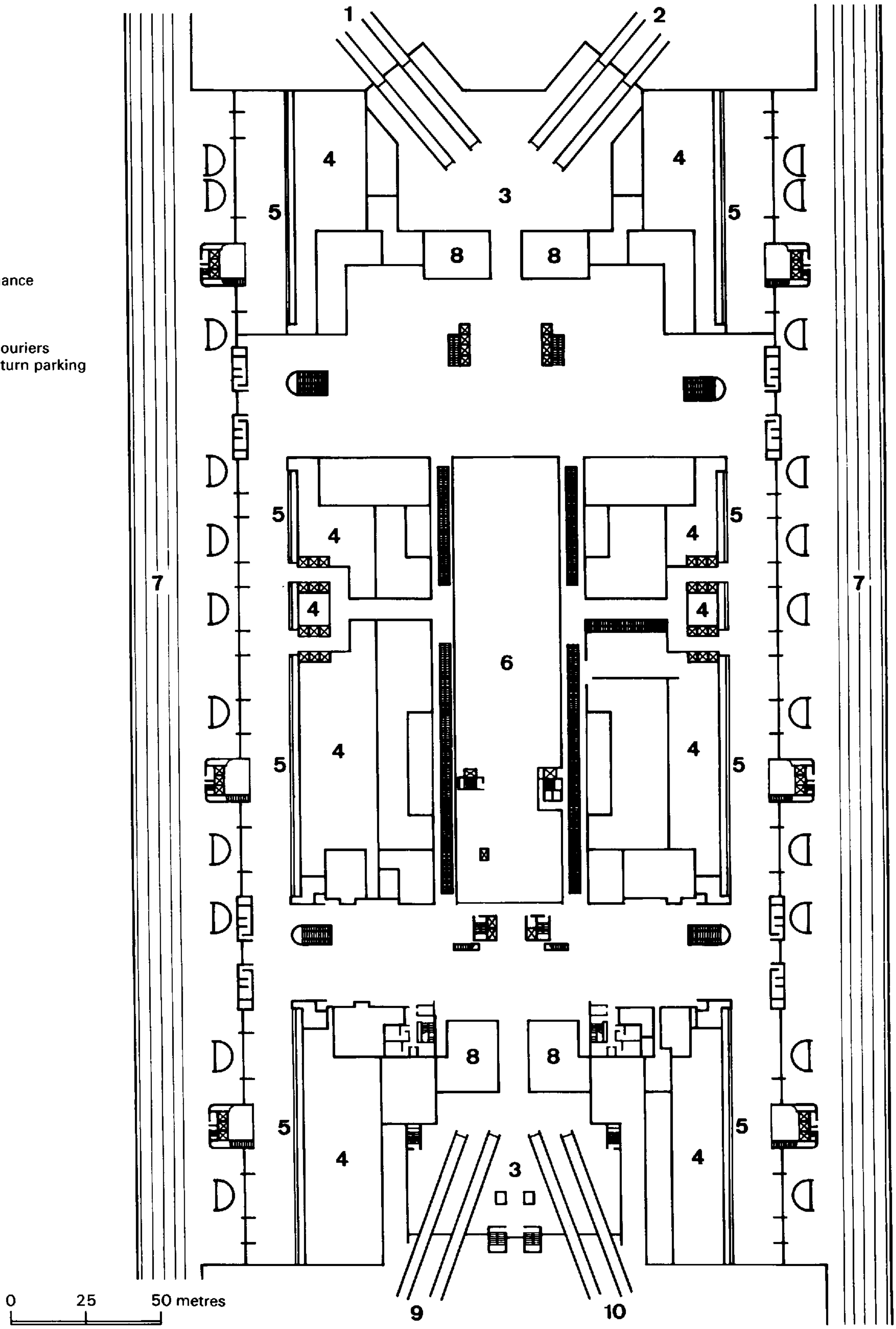
11.8 Site plan. Figures 11.7 and 11.8 courtesy of Greater Orlando Aviation Authority.



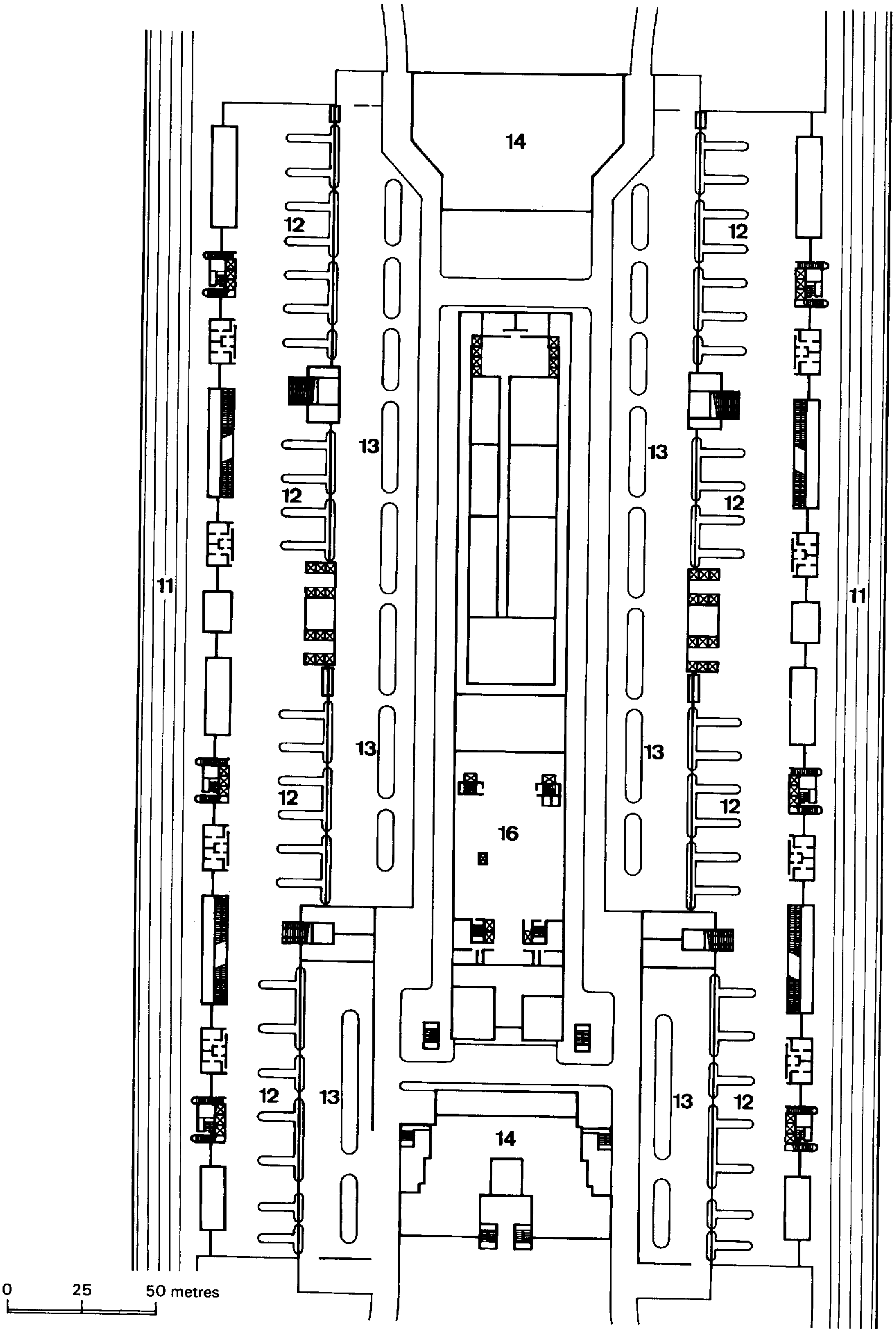
11.9 1990 expansion section.

Key to Figures 11.10–11.12

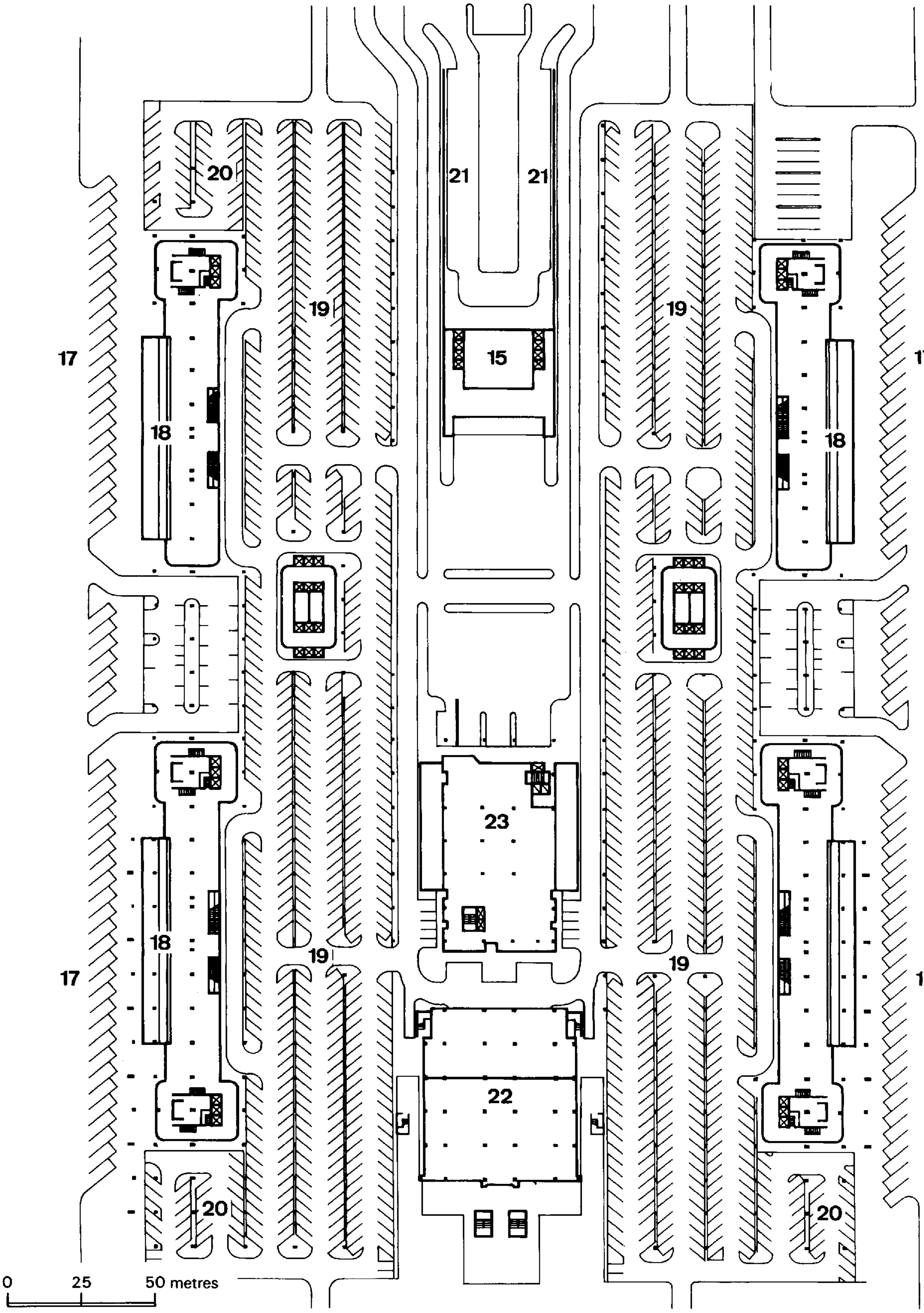
1	To 3rd airside
2	To 4th airside
3	Transit system lobby
4	Airline ticket offices
5	Ticket counters
6	Food and beverages
7	Enplane roadway
8	Security
9	To 1st airside
10	To 2nd airside
11	Deplane roadway
12	Baggage claim
13	Baggage make-up
14	Transit system maintenance
15	Hotel lobby
16	GOAA offices
17	Commercial roadway
18	Car rental offices and couriers
19	Car rental ready and return parking
20	VIP parking
21	Hotel parking
22	Physical plant
23	Kitchen/commissary



11.10 Third level plan.



11.11 Second level plan.



11.12 First level plan.
Figures 11.10–11.12 courtesy of KBJ Architects, Jacksonville, Florida.

satellite. Each satellite has three wings each with eight stands of varying sizes. A hotel with a seven-storey atrium is incorporated in the terminal expansion.

Further reading

Alcock, C. (1989) Living in the shadow of Mickey Mouse. *Airports International*, September.

Schwartz, A. C. (1981) Ambition, ambiance and alligators. *Airport Forum*, **5**.

Schwartz, A. C. (1986) Orlando Airport begins second-phase expansion. *Airport Forum*, **5**.

Schwartz, A. C. (1990) Orlando opens third airside, doubles landside facilities. *Airport Forum*, **4**.

Woolley, D. (1981) New Florida terminal set in subtropical greenery. *Airports International*, December.

12 Multiple linear units

With this arrangement, aircraft dock against several mini-terminals laid out in a line.

12.1 Hanover Langenhagen

Type: airport-owned (1973).
Form: multiple linear units, vertically stacked.
Architect: Dr Heinz Wilke.

Design standards:
International passengers per hour: 2000.
Domestic passengers per hour: 2000.
Passengers per year: 4 million capacity (actual 3.4 million 1993).
Aircraft stands: 12.

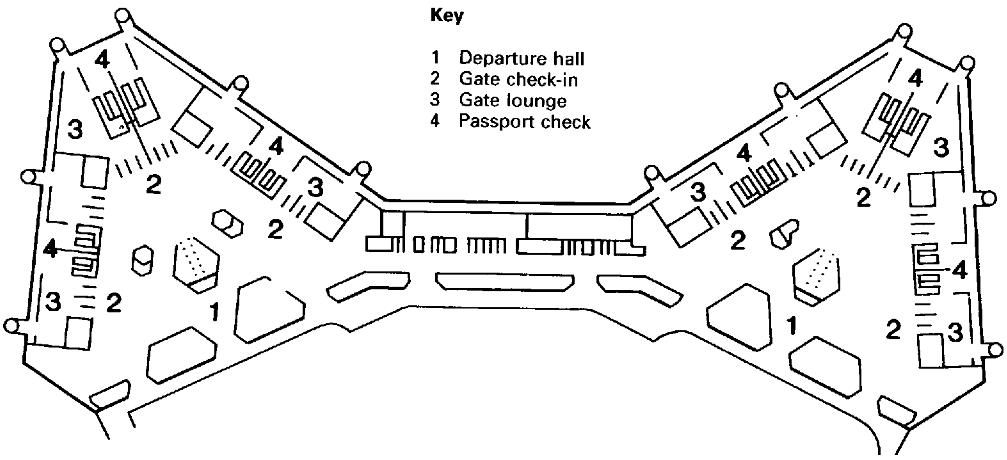
Description: this terminal is in fact a pair of triangular terminals, each with one landside and two airside

12.1 Hanover Langenhagen aerial view.

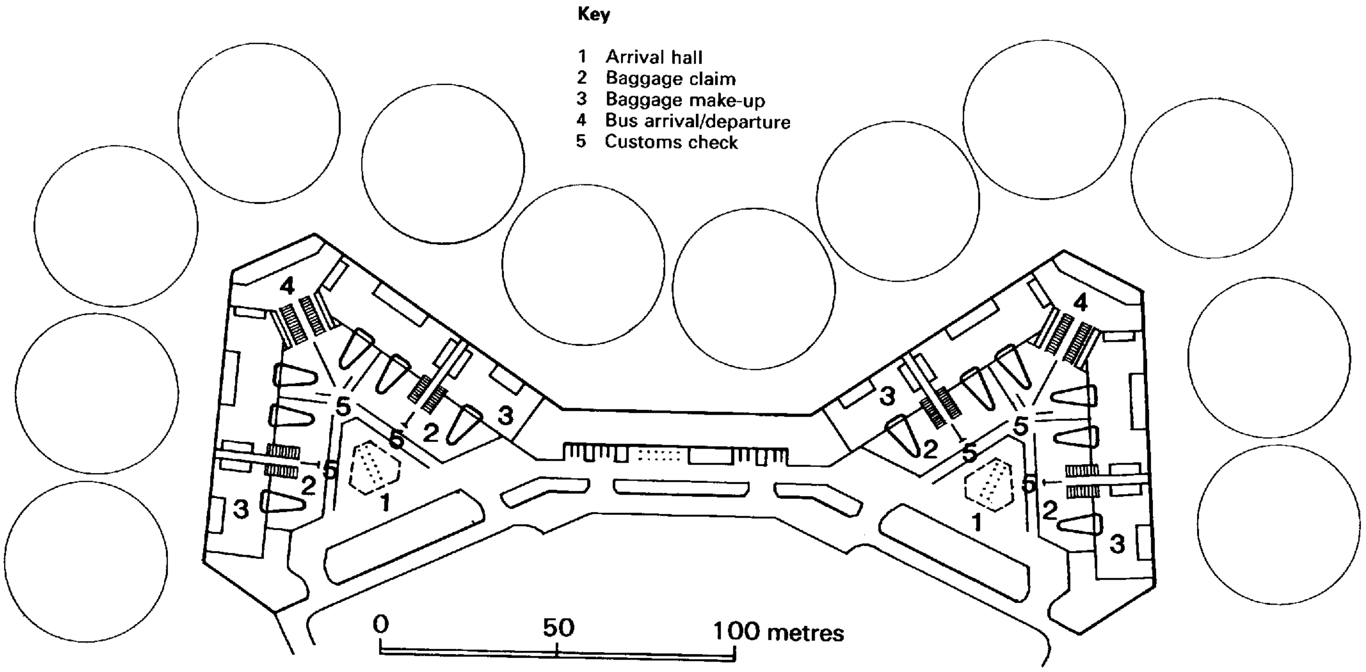
12.2 Interior of departures lounge. Courtesy of Flughafen Hannover-Langenhagen GmbH.

faces. The airside faces are divided into modular passenger processing units against which the aircraft dock direct. Walking distances are kept to a minimum. The design is simple and straightforward although it depends upon decentralized control authority positions. Each of the 12 gates has its own ticket counter, baggage check-in, immigration desk and lounge. Wide-bodied jets use a double module. A corridor running round the entire airside face enables transfer passengers to move airside from one gate to another, Figures 12.1–12.5.

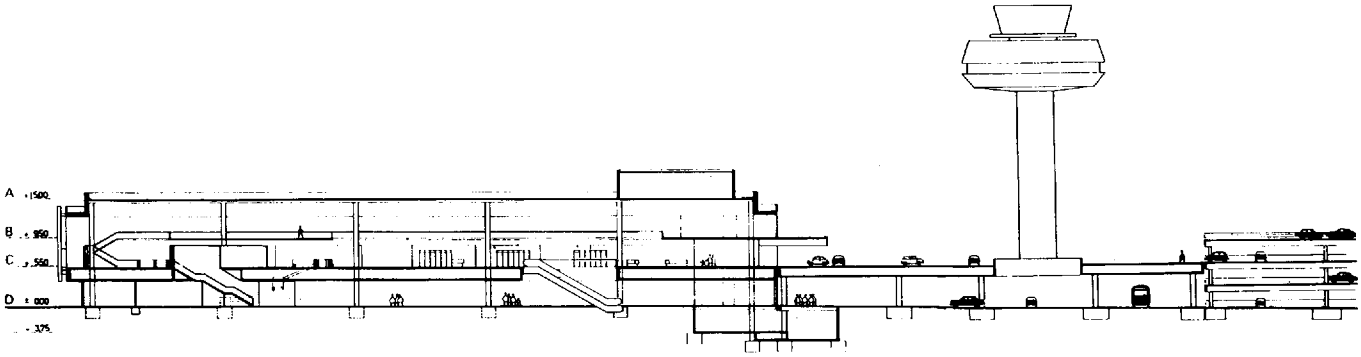
A similar design was adopted in 1978 for the second terminal at Sheremetyevo, Moscow, designed by the same architect.



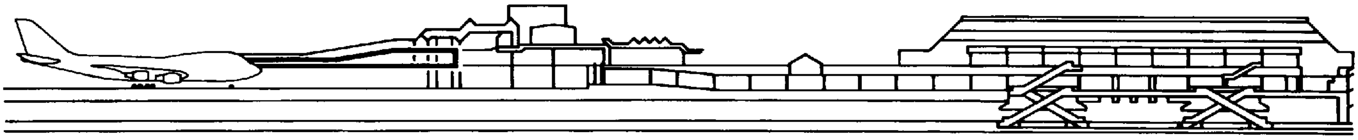
12.3 Departures level plan.



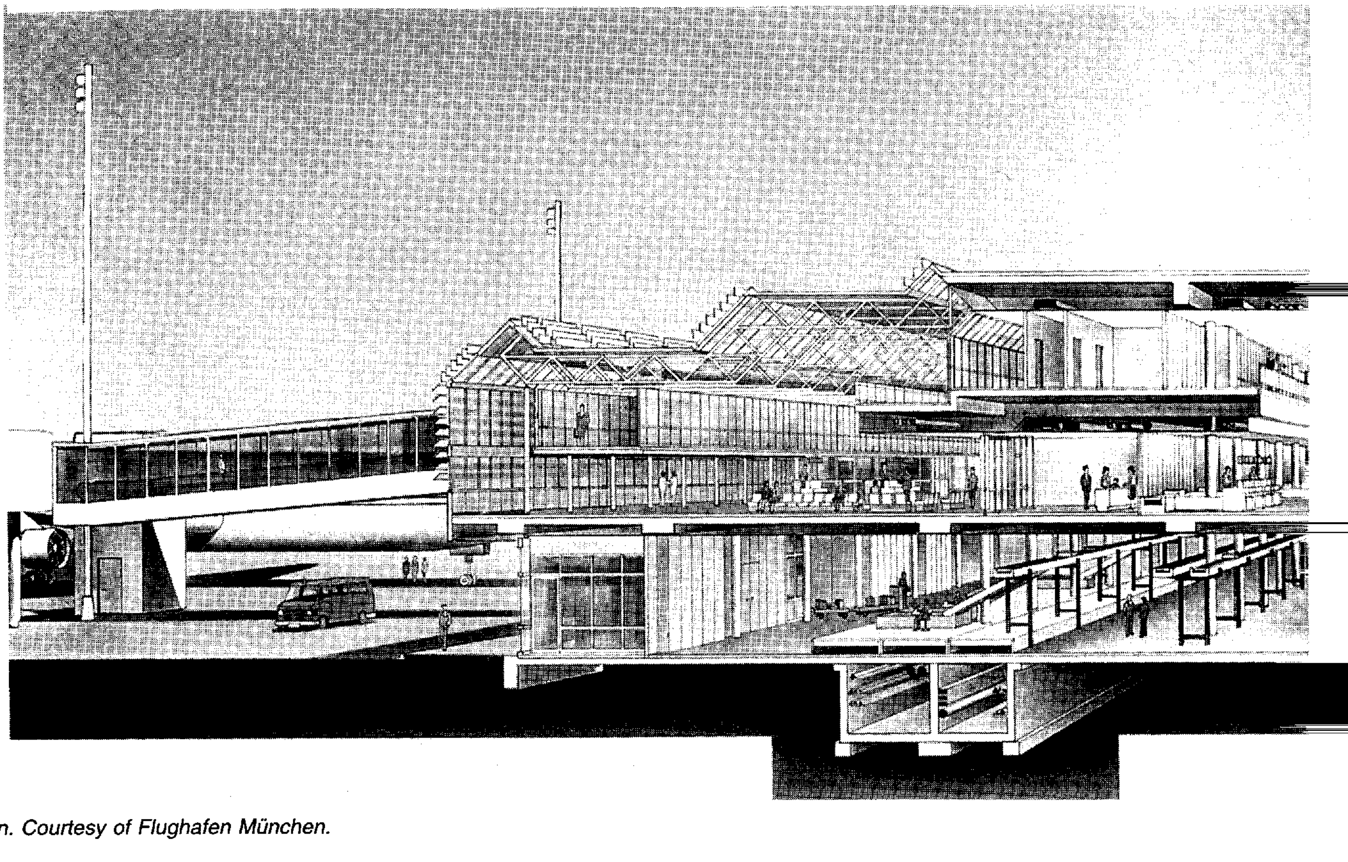
12.4 Arrivals level plan.



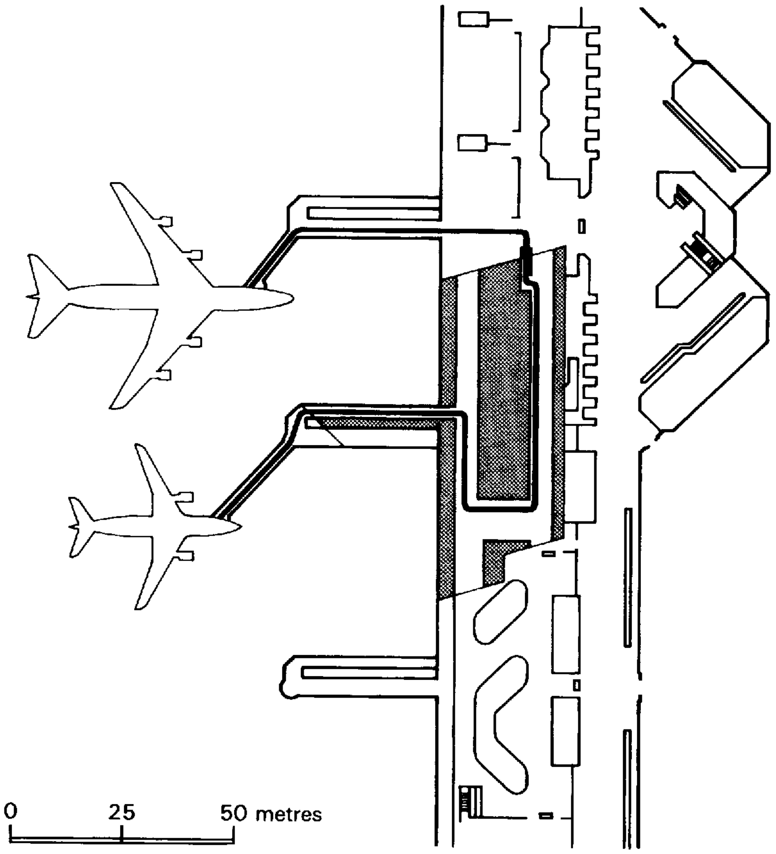
12.5 *Hanover Langenhagen section.*



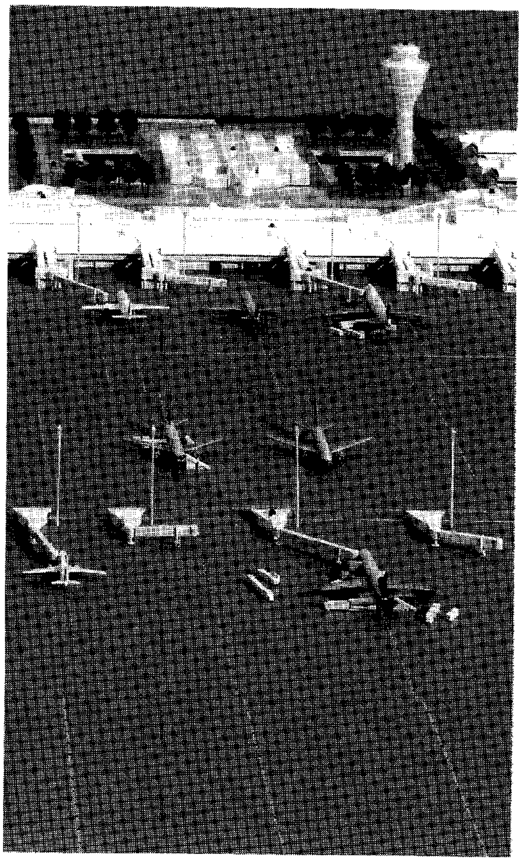
12.6 *Munich, (a) section and (b) plan. Courtesy of Flughafen München.*



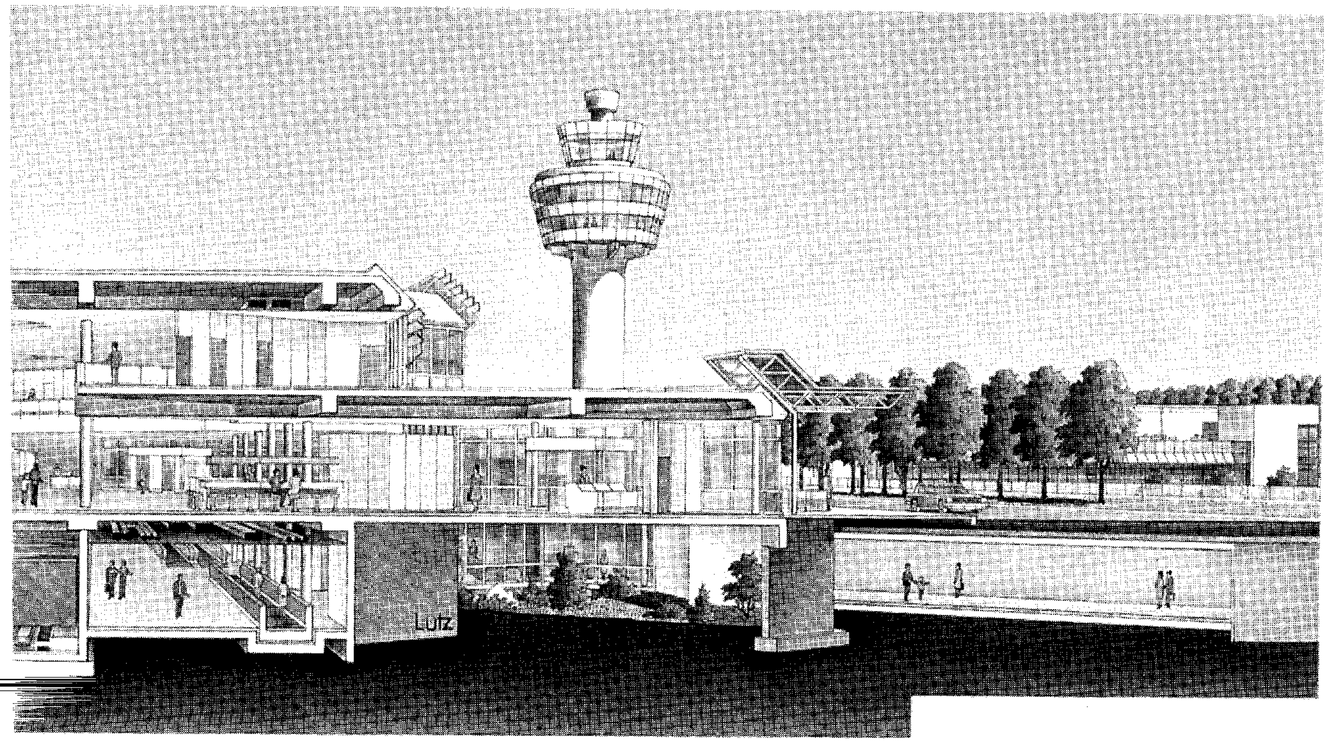
12.7 *Section. Courtesy of Flughafen München.*



12.6 *(b)*



12.8 Munich, model showing remote passenger stations.



Further reading

Hilscher, G. (1973) Hanover presents its new terminal. *Airport Forum*, **2**.

Piper, H. P. (1993) Hannover's compact terminal has stood the test of time. *Airport Forum*, **4**.

Tutty, E. B. (1982) IATA's unit terminal concept. *Airport Forum*, 1.

12.2 Munich

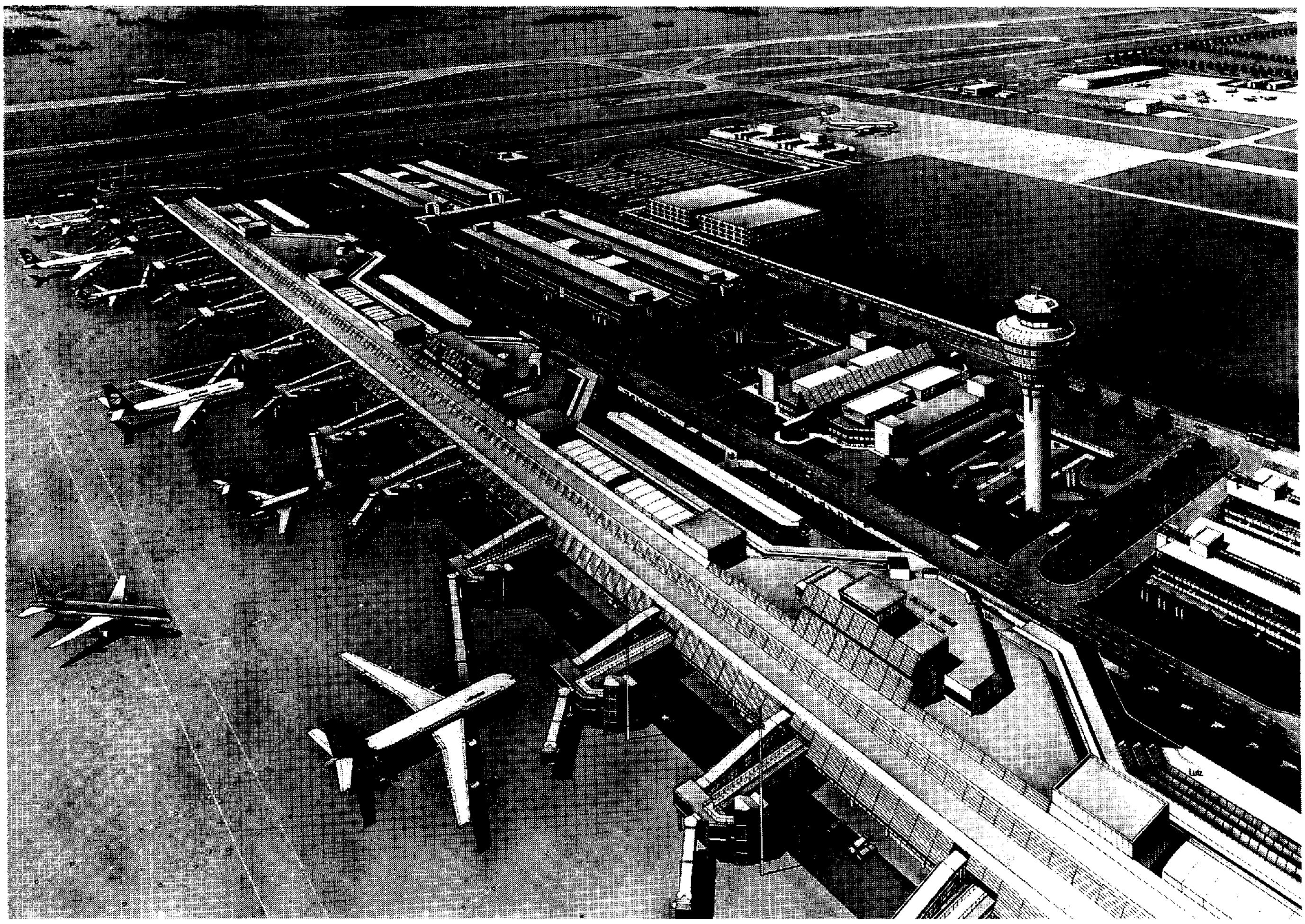
Type: airport-owned (1992).
Form: multiple linear units, airside vertically segregated.
Architect: Prof. von Busse, Blees, Kampmann & Buch.

Design standards:
International passengers per hour: no information.
Domestic passengers per hour: no information.
Transit/transfer passengers: no information.
Passengers per year: 12–14 million capacity.
Aircraft stands: 20 terminal served plus 28 open apron.

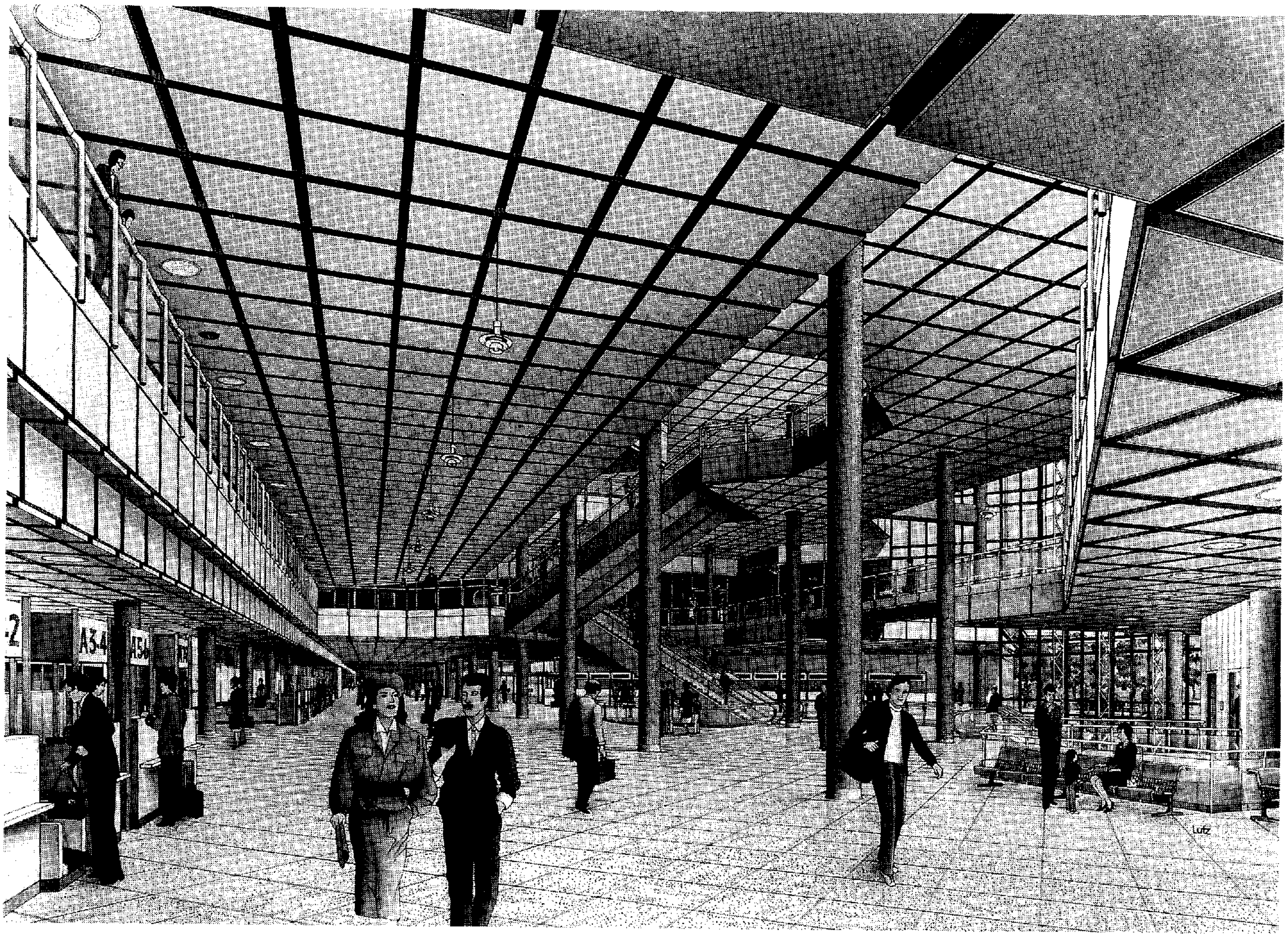
Description: this completely new airport is the first such in Europe for nearly twenty years and replaced the previous Munich Airport at Riem in 1992. The first phase of the terminal is linear in form with alternating arrivals and departures units, four in number and each with full international facilities. The terminal is on one principal elevated level, with pedestrian routes to the central railway station and all supporting functions below, Figures 12.6–12.10.

An unusual feature is that disembarking passengers go up a ramp from each stand to a gallery, which also serves as a transfer route for transfer passengers going to one of the other 19 stands. One vital feature of the complex is the incorporation of a station on the metropolitan rapid transit system, the S-Bahn, and it is forecast that 40 per cent of passengers will use this mode of transport.

Each of the four modular terminals has an annual capacity of approximately 3.5 million passengers. A special feature of the open apron stands is the passenger station at which the passengers alight from buses and mount a loading bridge.



12.9 Munich overall impression. Artist: Erich Lutz. Photographs by Klaus Broszat, Munich.



12.10 Interior impression.

Further reading

Alcock, C. (ed.) (1989) Munich II plans terminal 2. *Airports International*, May.

Prof v. Busse & Partner Blees, Buch, Kampmann (1992) Geometry and light. *Public Transportation*, Summer.

Swartzberg, T. (1992) The new Munich Airport. *Supplement to Jane's Airport Review*, May.

Walters, B. (1989) Eurohub shapes up. *Jane's Airport Review*, April/May.

13 Multiple island piers

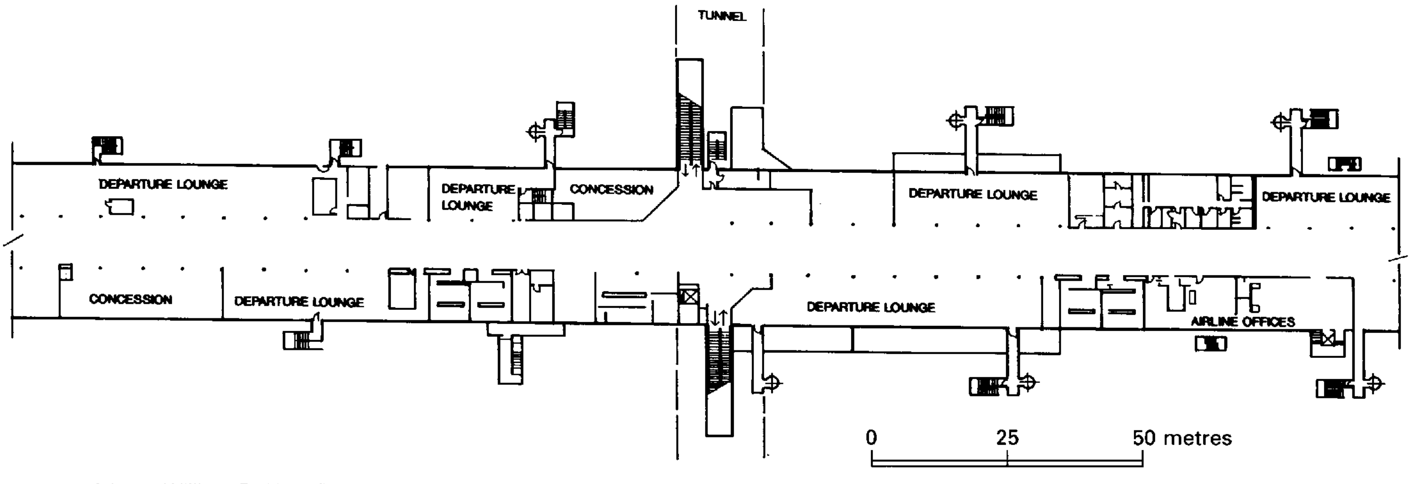
With this arrangement, there are several linear island buildings. Aircraft dock against these buildings, which are linked to the parent terminal by an underground railway or similar.

13.1 Atlanta William B. Hartsfield International

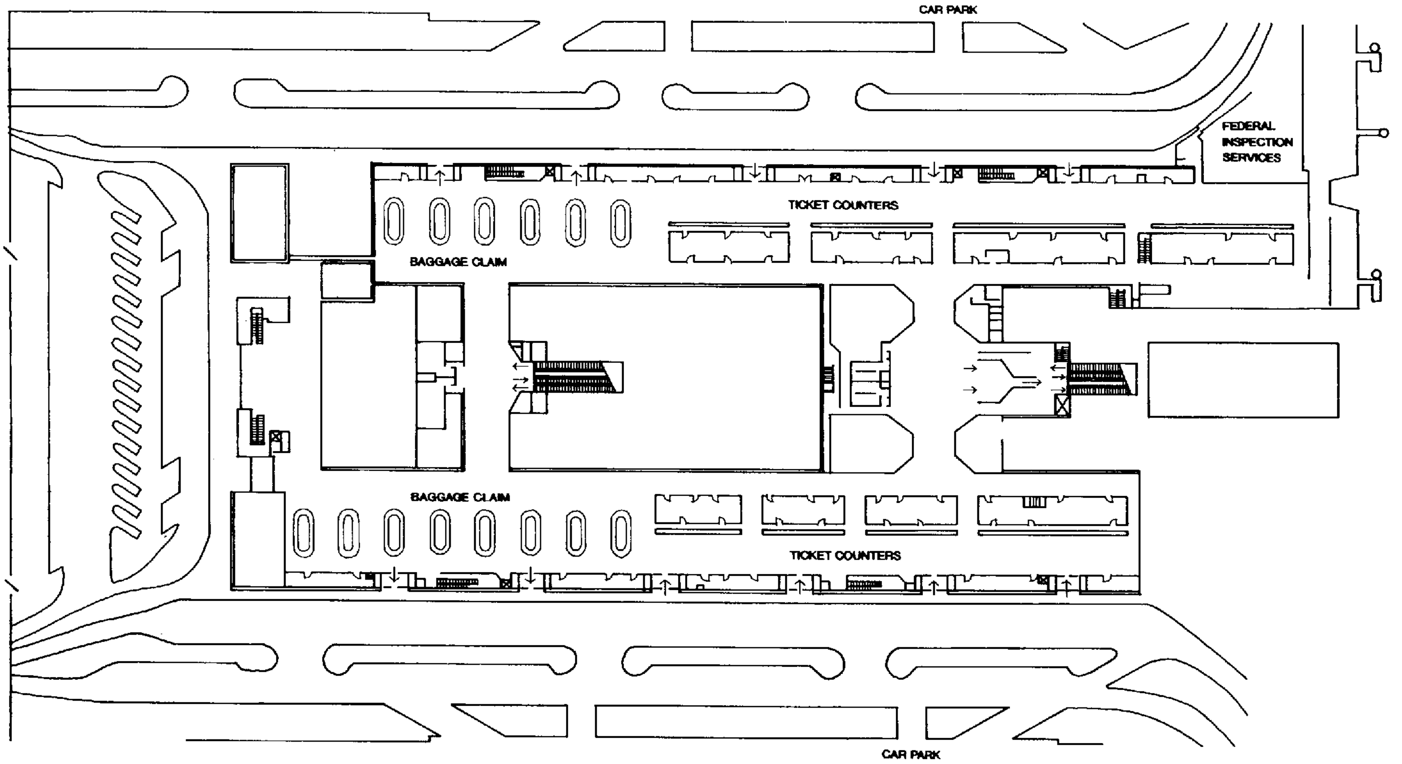
Type: airport-owned major airline hub (1980).
Form: multiple island piers, single-level landside terminal.
Architect: Stevens and Wilkinson/Smith, Hinchman and Grylls/Minority Airport Architects and Planners.
Design standards:
International passengers per hour: 800 original capacity.
The addition in 1987 of 3 wide-body gates to the international concourse and enlarged international passenger controls increased hourly capacity to 3000 passengers.
Transit/transfer passengers: 70%.
Passengers per year: 55 million capacity.
Aircraft stands: 120 (4 domestic piers) plus 6 wide-body (international) in 1989, 170 in 1994 with addition of fifth island pier.

Description: Atlanta is located as an ideal interchange point in the air transport system of the south-eastern United States. When planned as a major hub Atlanta was second only to Chicago in the number of domestic passengers handled. Although handling only 16 million passengers per annum in 1980, the concept allowed a very large factor of growth, Figures 13.1–13.3. In fact the airport has been subject to the fortunes of its airlines and suffered a 21 per cent traffic loss between 1990 and 1991.

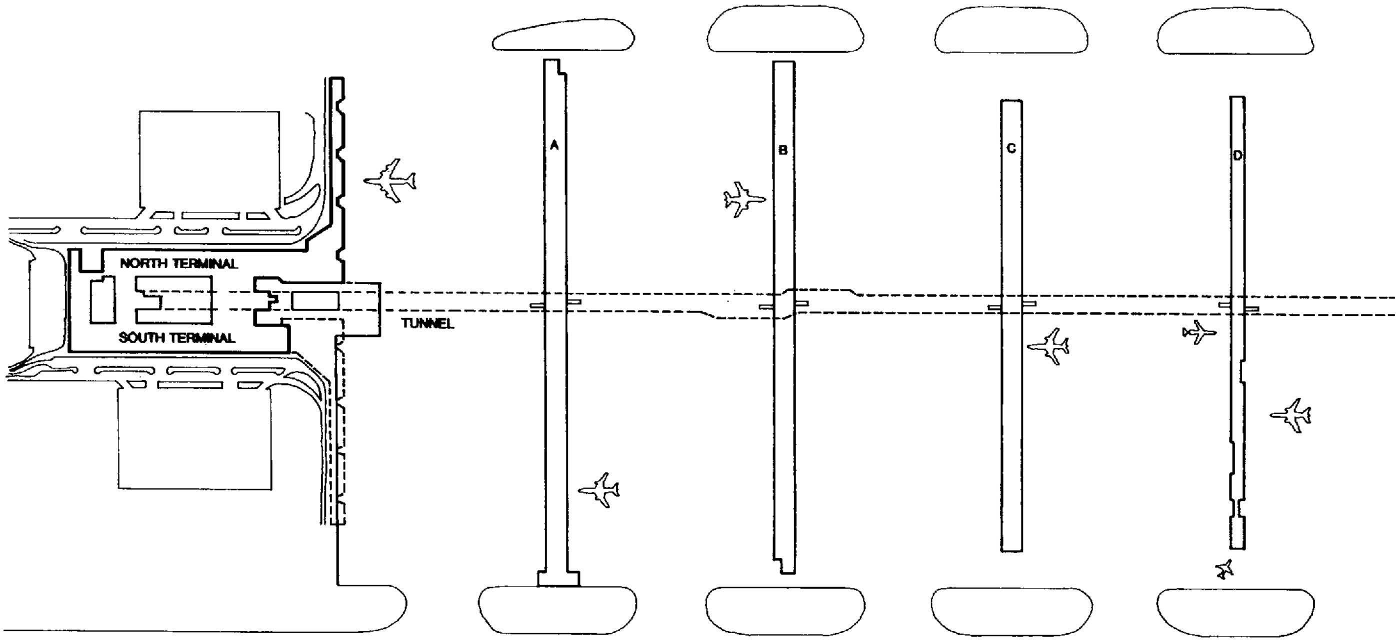
All originating passengers arrive at the kerbside of one of two twin landside terminals. From here passengers are security-cleared centrally and descend into an underground mall. They travel by moving pavement or rapid transit system to four concourses, each 660 m (2200 ft) long and 300 m (1000 ft) apart. Due to the fact that 70 per cent of passengers using



13.1 Atlanta William B. Hartsfield International, part plan of island pier. Architects: Stevens and Wilkinson, Atlanta.



13.2 Landside terminal building, main level plan.



13.3 Atlanta William B. Hartsfield International, site plan.

the airport are transferring between flights, only 30 per cent of passengers use the central terminal facility. The central terminal has been linked to the Atlanta Metropolitan rapid rail system.

Further reading

Alcock, C. (ed.) (1989) Hartsfield prepares for its final development phase. *Airports International*, March.

Dober, R. P. (1980) Welcome and workable. *Building*, 2 January.

Jacobsen, P. S. (1977) Under-apron transit for Atlanta terminal. *Airports International*, October/November.

Schwartz, A. (1992) Atlanta building new international, adjusting to loss of Eastern Airlines. *Airport Forum*, **5**.

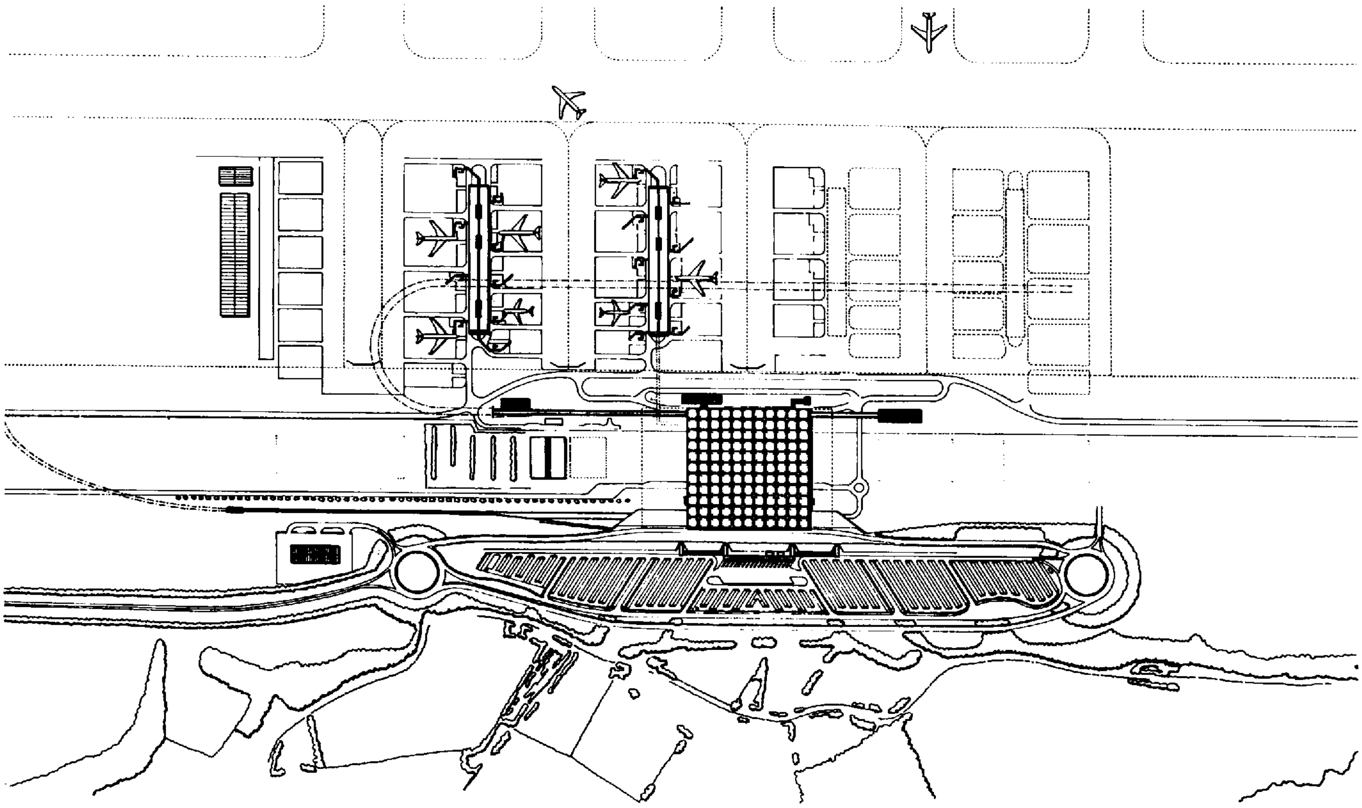
Woolley, D. (1980) Atlanta terminal ready on time. *Airports International*, November.

13.2 London Stansted New Terminal

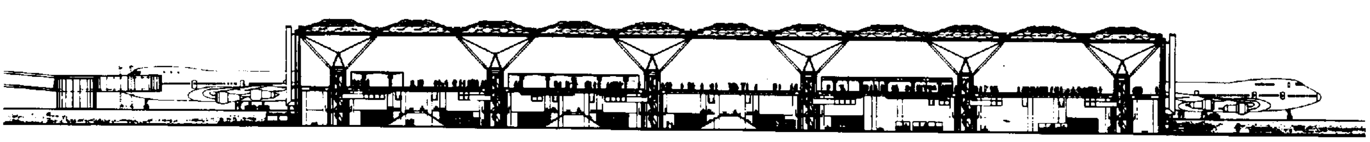
Type: owned, with six other airports, by public company (1991).
Form: multiple island piers, single-level main terminal.
Architect: Foster Associates, London.

Design standards:
International passengers per hour: capacity in Phase 1: 2500 each way.
Domestic passengers per hour: minor facility.
Passengers per year: capacity 8 million with 2 satellites, ultimately 15 million.
Aircraft stands: 10 per satellite (various sizes).

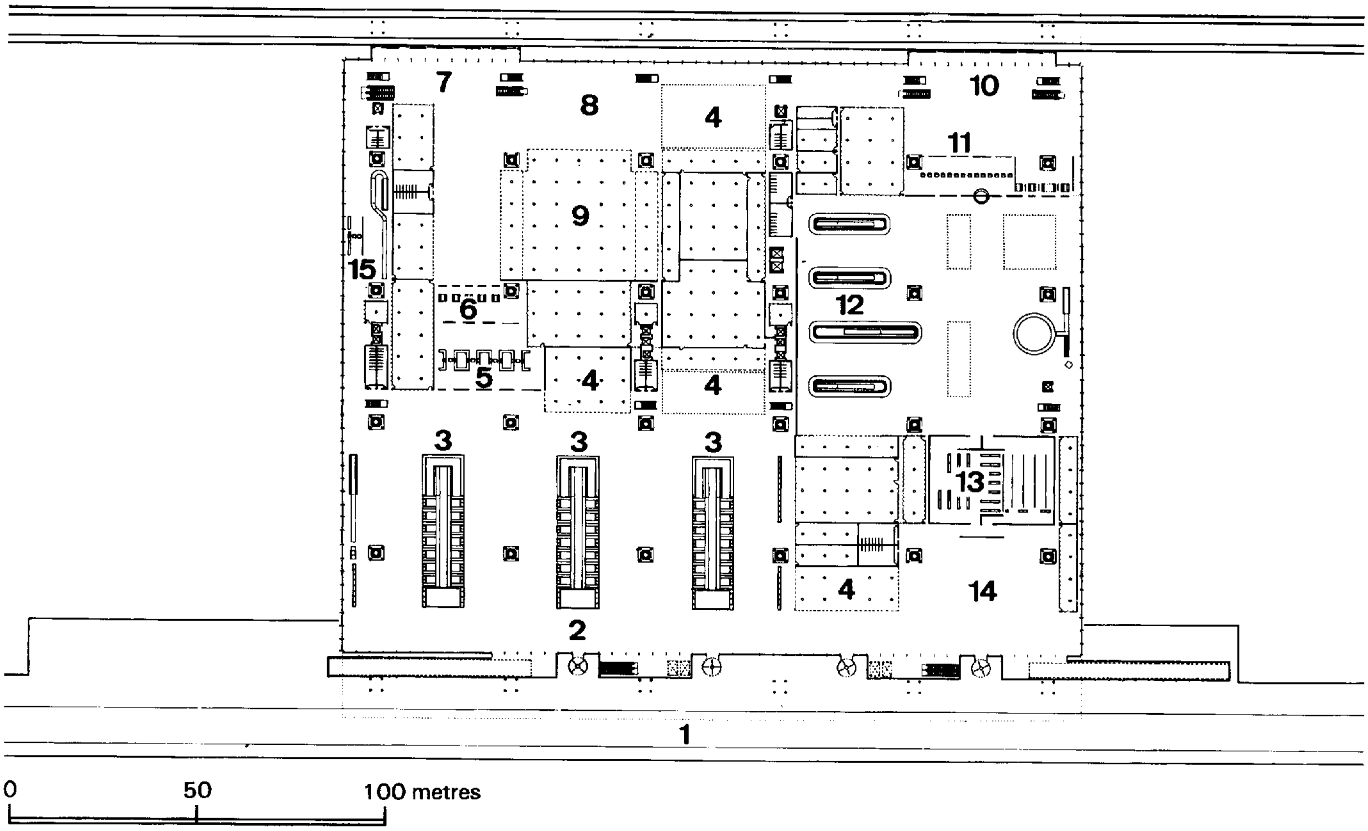
Description: in 1991 this new terminal project increased to seven the number of terminals and to nearly 70 million the annual passenger handling capacity of London's three major airports. The central building is a sophisticated two-storey shed with all



13.4 London Stansted, terminal area site plan. All drawings courtesy of architects: Sir Norman Foster and Partners, London. Client: BAA plc.



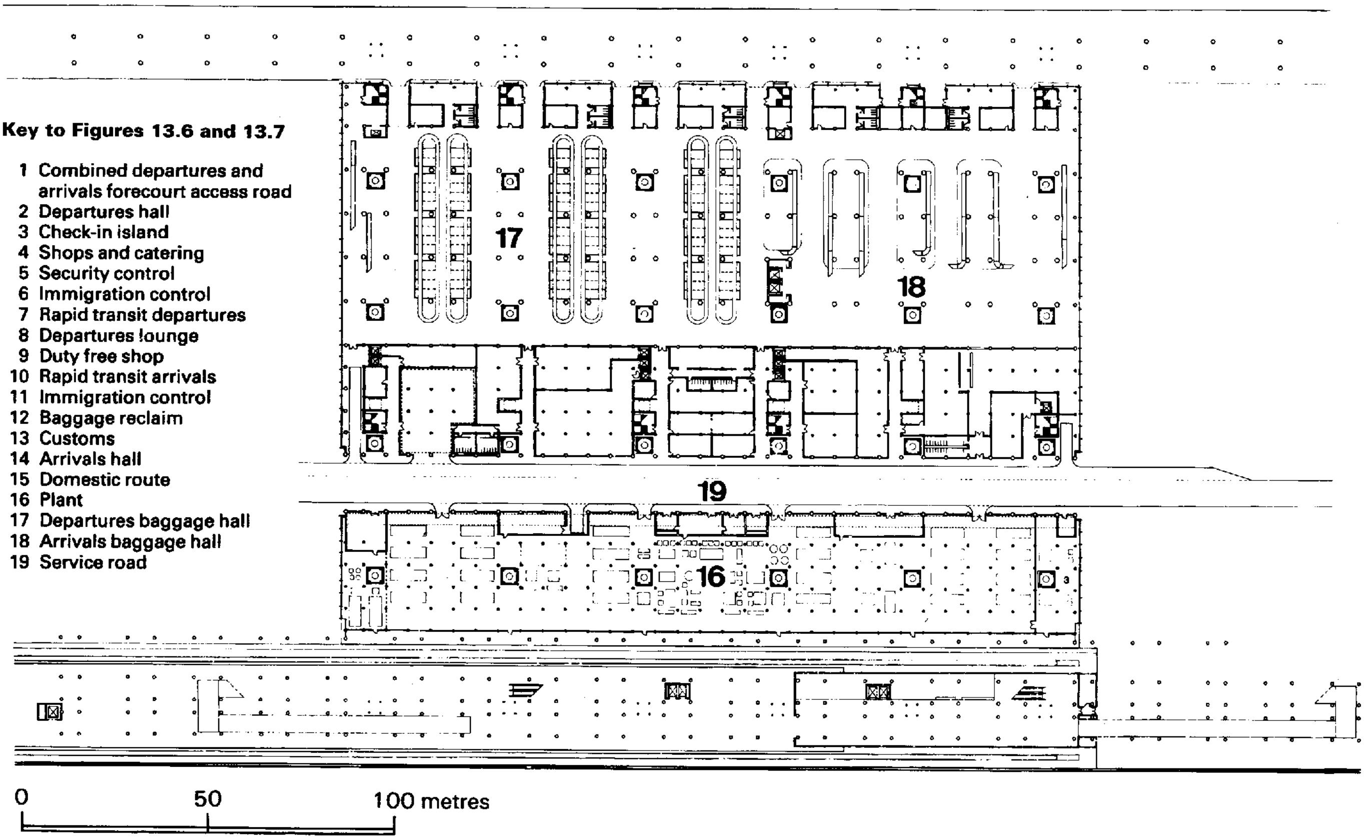
13.5 Section.



13.6 Terminal building concourse plan.

Key to Figures 13.6 and 13.7

1 Combined departures and arrivals forecourt access road
2 Departures hall
3 Check-in island
4 Shops and catering
5 Security control
6 Immigration control
7 Rapid transit departures
8 Departures lounge
9 Duty free shop
10 Rapid transit arrivals
11 Immigration control
12 Baggage reclaim
13 Customs
14 Arrivals hall
15 Domestic route
16 Plant
17 Departures baggage hall
18 Arrivals baggage hall
19 Service road



13.7 Undercroft plan.

passenger functions at the upper level and all supporting facilities at the lower level including a British Rail railway station link. The structural form gives large spans for maximum flexibility and highly disciplined building services. Each structural bay has a central rooflight fitted with reflectors suspended beneath the ceiling. Each 36 m square structural bay is supported on a tree which also contains all artificial lighting, information systems, air supply and extract, etc. Figures 13.4–13.7.

A rapid transit system running beneath the apron links the airside face of the terminal with island satellites.

Further reading

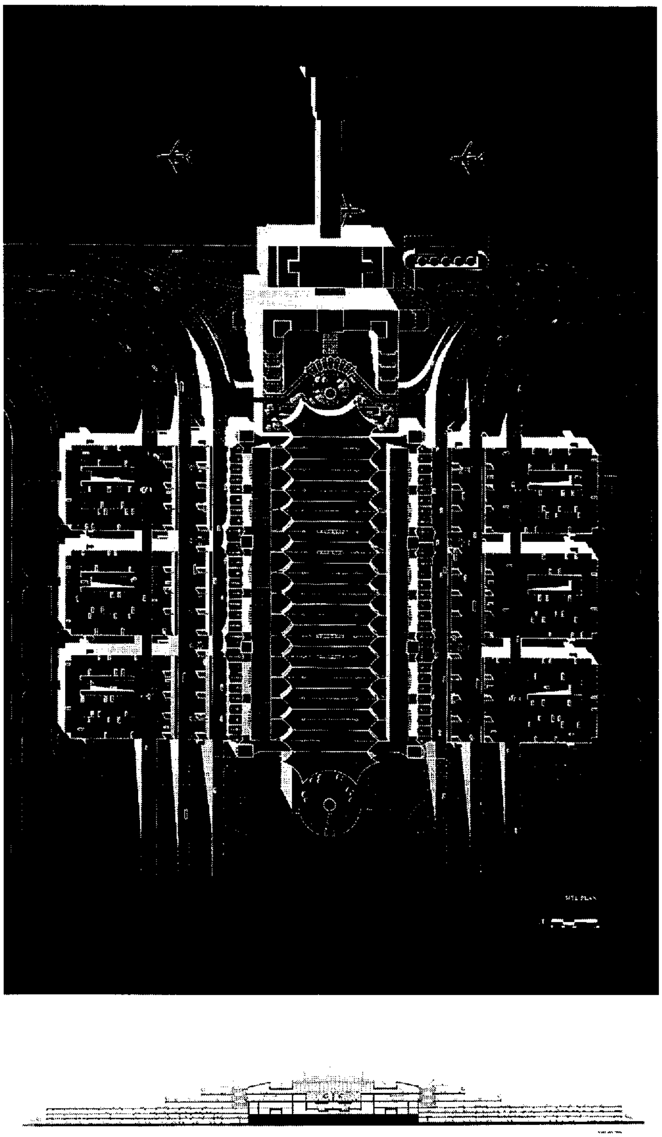
Davey, P. J. (1991) Airports come of age. *Architectural Review*, May.
Hannay, P. (1991) Flight of fancy. *Architects' Journal*, 29 May.
Kaye, D. C. and Manning M. W. (1990) The structure for the new terminal building at Stansted airport. In *Proceedings of the Conference Airports into the 21st Century (Hong Kong, 1990)*. Hong Kong: Hong Kong Institution of Engineers.
Pawley, M. (1991) Stansted Airport. *Building*, 10 May.

13.3 Denver International

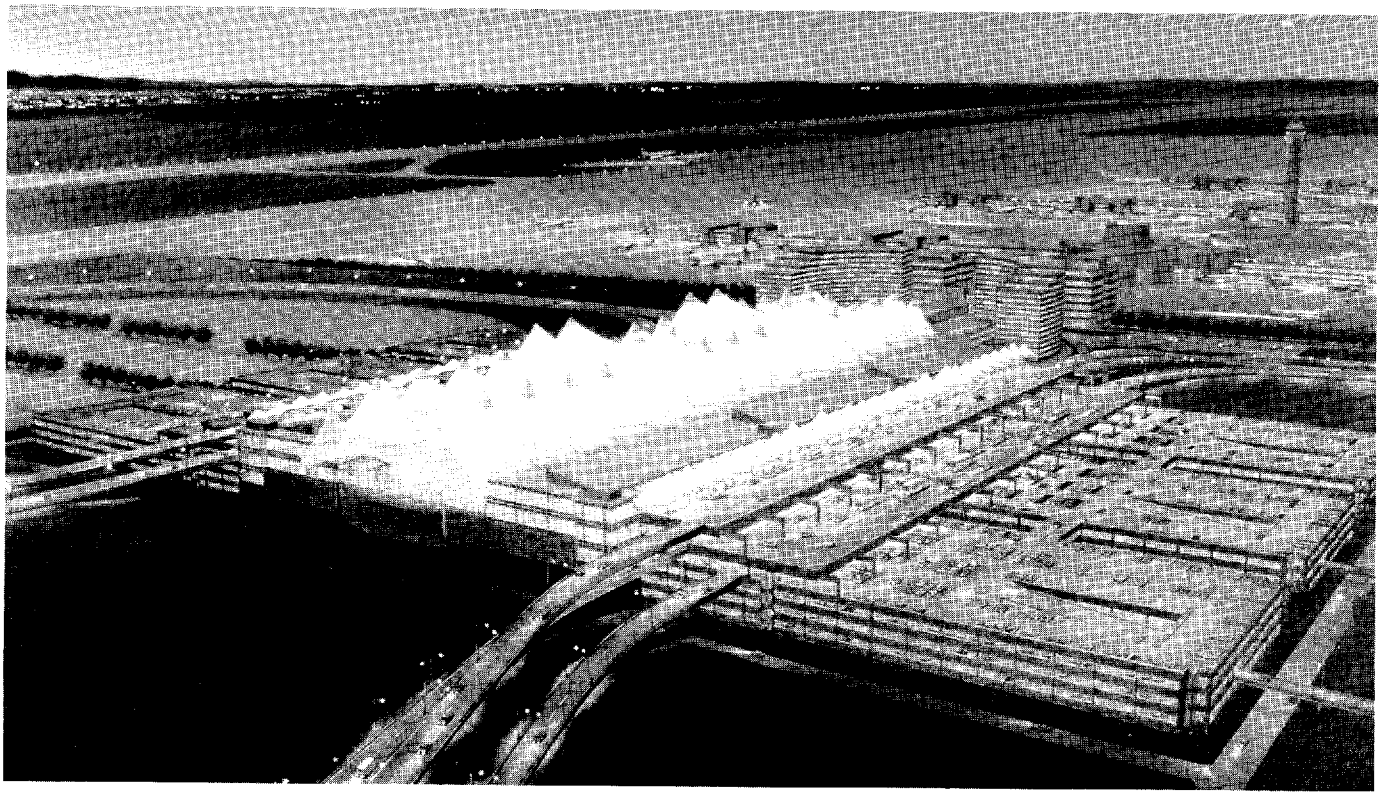
Type: city-owned giant hub for two major airlines (1995).
Form: multiple island piers (or concourses) with two-level two-sided landside.
Architect: CW Fentress, JH Bradburn and Associates, PC (landside terminal) and JV Alfred Seracuse Lawler Partnership of Denver and TRA of Seattle (concourses).

Design standards:
International passengers per hour: 1300 one-way.
Domestic passengers per hour: 3900 one-way.
Transit/transfer passengers: 6900 per hour.
Passengers per year: 60 million capacity (expansion to 110 million by 2020).
Aircraft stands:
28 (Concourse A for Continental, plus 2 international) plus 15 commuter aircraft
40 (Concourse B for United Airline) plus 20 commuter stands
20 (Concourse C for other airlines) plus 3 commuter stands.

Description: this airport and its terminal buildings bristle with superlatives, from its 17 000 ha site (over 15 times larger than London Heathrow) and its 5 initial runways to its 100 m high control tower and its baggage system. Now that the facility is open, albeit many months later than planned, the processes by which it was designed and procured, and in particular those relating to the baggage handling system, will be forgotten. A sub-apron people mover, the latest of over twenty such systems in the world, links the landside terminal and the concourses. Although on a giant scale, the landside terminal and its three satellites would be less remarkable but for two particular features: the translucent fabric roof with its 34 peaks, emulating the nearby Rocky Mountains, and the 13 m high taxilane bridge between the terminal and the first concourse, the first such bridge to straddle an aircraft route. The baggage delivery system includes 4000 Destination Coded Vehicles (DCVs), 35 km of track and an initial acapacity of 1000 bags per minute, Figures 13.8–13.10.



13.8 Denver International Airport.
Figures 13.8–13.10 courtesy of architects: CW Fentress, JH Bradburn & Associates, Denver, Colorado.



13.9 Denver International Airport, exterior.

13.10 Interior. Photographer: Nick Merrick, Hedrich/Blessing.

Further reading

Boulton, J. (1993) State-of-the-art baggage system for Denver. *Airport Forum*, **2**.
Jabez, A. (1994) Denver Airport: special feature. *Building*, 8 July.
Korth, J. and Momberger, N. (1994) Denver opening nears. *Airport Forum*, **1**.
Russell, J. S. (1994) Is this any way to build an airport? *Architectural Record*, November.
Schwartz, A. C. (1992) New Denver International plus Front Range will give city vast airport capacity. *Airport Forum*, **6**.
Stein, K. D. (1993) 'Snow-capped' symbol. *Architectural Record*, June.
Wilson, J. R. (1995) Bags start rolling while the arguments continue. *Jane's Airport Review*, March.

14 Hybrids: combinations of forms

Hybrid terminals may be combinations of the various forms already described.

14.1 Chicago O'Hare, United Airlines Terminal

Type: single airline (1988).
Form: combination of linear plus island pier/satellite.
Architect: Helmut Jahn of Murphy & Jahn.

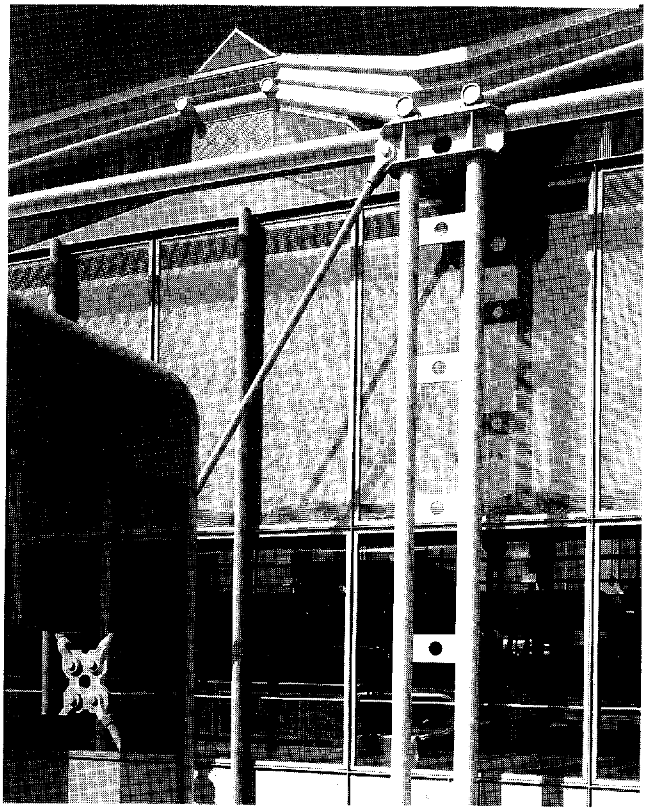
Design standards:
International passengers per hour: nil.
Domestic passengers per hour: 5000.
Transit/transfer passengers: 5000.
Passengers per year: no information.
Aircraft stands: 42.

Description: this terminal is the latest addition to the world's largest airport, which topped 50 million passengers per annum in 1986 and which could handle 75–80 million passengers per annum by the turn of the century. United Airlines has built its own hub terminal. The principle elements in the new terminal are two 480 m (1600 ft) long concourses with soaring glazed vaults. One is adjacent to the two-level forecourt and provides immediate walk-on access to 15 aircraft stands. The other is reached through a sub-apron concourse and has the form of an island satellite with 27 stands. A baggage handling area of 7500 sq m (80 000 sq ft) is located under the apron alongside the subway linking the two concourses, Figures 14.1–14.3.

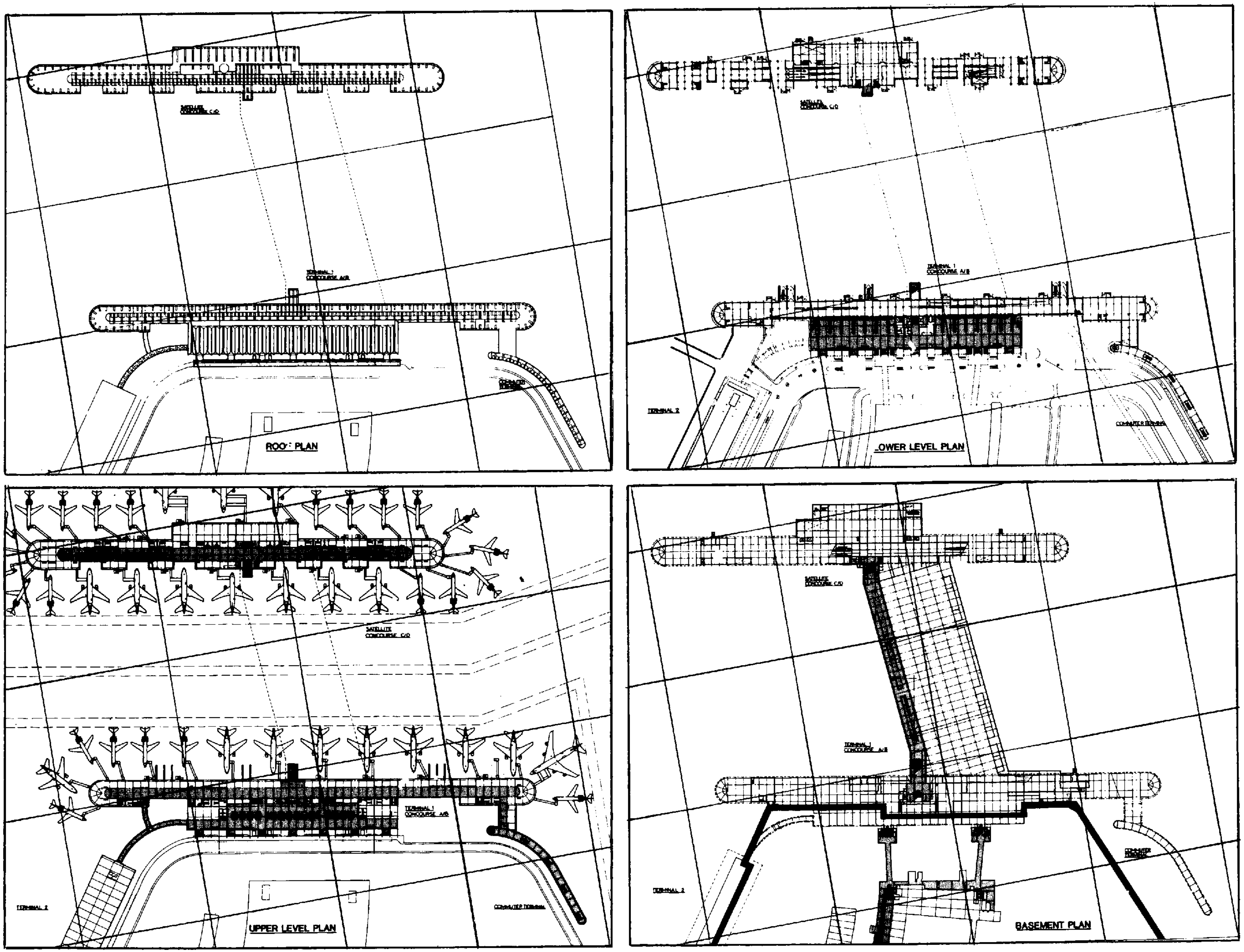
Further reading

Aldersey-Williams, H. (1988) New Departures. *Designers Journal*, November.
Walters, B. (1987) Boeing Places. *Building Design*, October 23.

14.1 Chicago United Airlines Terminal, concourse.



14.2 Detail.



14.3 Plans.
Figures 14.1–14.3 courtesy of architects: Murphy & Jahn, New York.

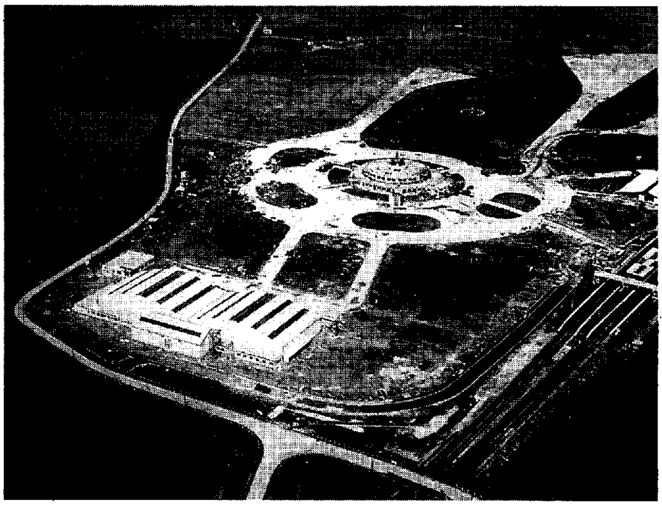
Part III External landside factors

Recognizing that the airport terminal sits between ground transport and air transport, the next three sections consider the ground transport's needs at the terminal, the terminal building itself and then the air transport's needs when on the ground at the terminal.

15 Public transport interchanges

Airport master planning in the 1950s and 1960s was more geared to the motor car than to public transport. In Europe and the USA, railways were starting to decline. National railway plans such as the Beeching Plan in Britain were slimming down the national rail network to high-speed links between main cities. However, since then the unacceptable congestion caused by high motor car usage has led to the extension of existing metropolitan railway networks and the development of new ones.

Few new airport terminals will be built without a railway station of the appropriate sort or without provision for one in the future, and the integration of rail and air travel is proving essential not only for the linking of cities with their airports but for the linking of related airports such as Cologne-Bonn and Dusseldorf.



15.1 Gatwick, 1935, showing railway station.

15.1 The range of possibilities

1 National (surface) rail link

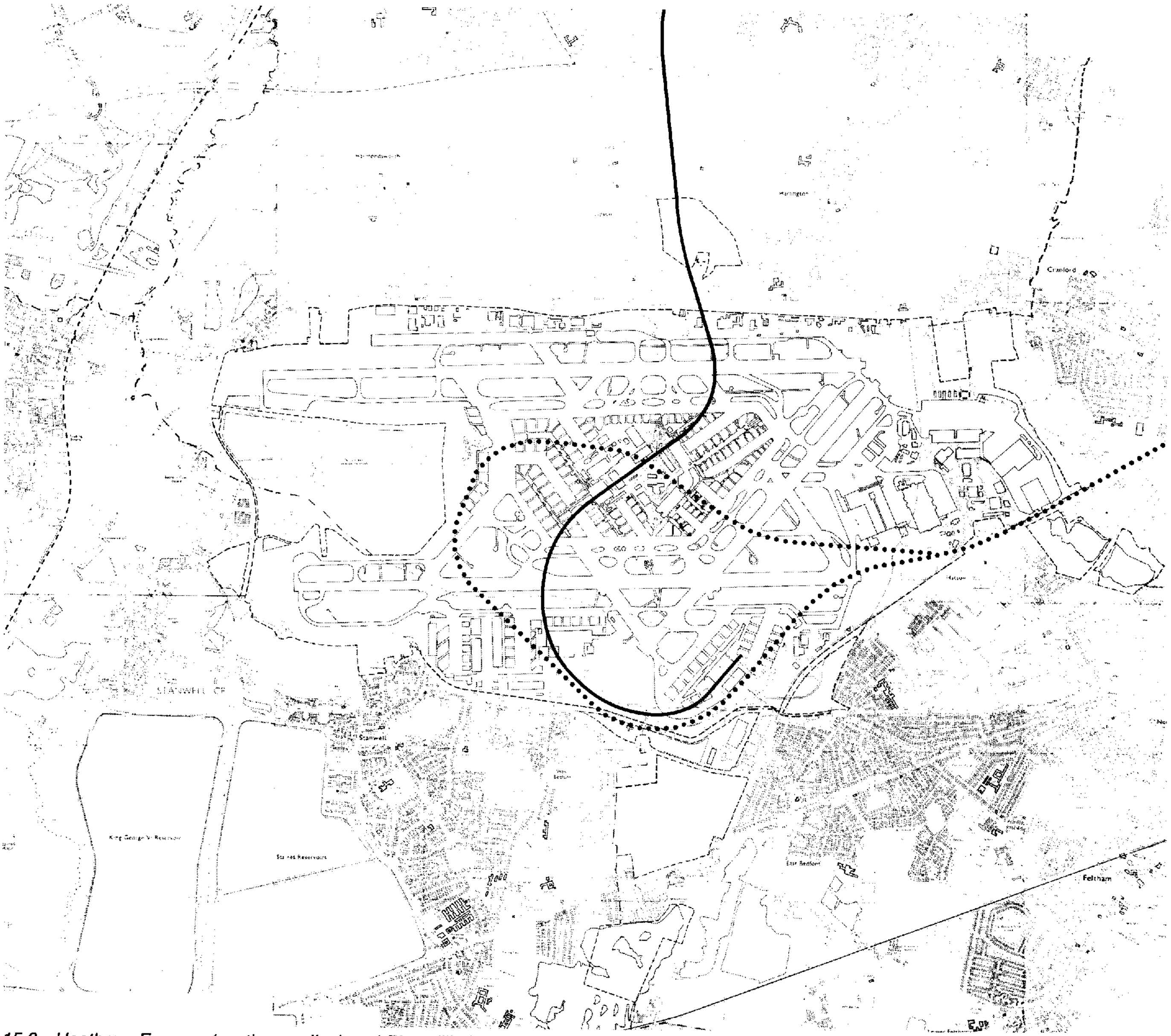
Since the 1930s, Gatwick airport has been served by a station on the main London–Brighton line and joint planning by the British Airport Authority and British Rail has created a station accessed direct from the terminal concourse and a regular 'Gatwick Express' to London's Victoria Station now supplemented by direct rail links to other parts of the South of England. The new railway station, opened in 1977, conceals the fact that the railway was there long before the airport. This is the reverse of the more common sequence whereby the railway comes to the airport, Figures 15.1 and 15.2).

For the first 45 years of its life as an international airport, Heathrow Airport's public transport has had to rely upon buses to link to the national railway network and, since 1976, the London Underground. In 1990 a joint venture between Heathrow Airport Ltd, part of BAA plc, and British Rail completed a proposal to link Heathrow with Paddington Station in central London: the Heathrow Express, Figures 15.3 and 15.4).

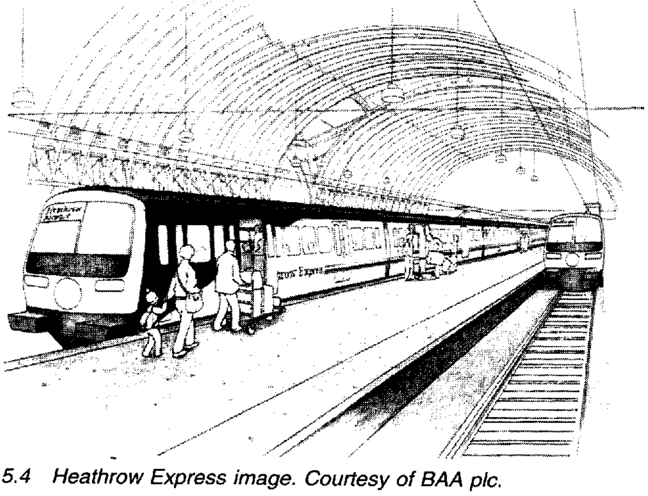
15.2 1980s aerial view, courtesy of YRM Architects and Panners, London.

2 Metropolitan (underground) rail link

Belatedly, Heathrow airport was given a link to the London Underground network when the Piccadilly line



15.3 Heathrow Express (continuous line) and Piccadilly Line (dotted line) approach routes. Courtesy of Heathrow Airport Ltd.



15.4 Heathrow Express image. Courtesy of BAA plc.

was extended to Heathrow Central in 1976. This gave rise to the slogan 'The train now arriving at Heathrow is 41 years late', which was intended to promote Gatwick as London's second international airport rather than to promote Heathrow. This has been replaced by the slogan 'Take a train to catch a plane'. The three original terminals were provided with subway links to a central underground station in the already congested central area. It was only with the opening in 1986 of Heathrow Terminal 4, with a Piccadilly line station under the adjacent multi-storey car park, that the passenger achieved a really convenient service.

The addition of the underground link to Heathrow Terminal 4 is an interesting story. When the Tube was first taken to Heathrow in 1976 the twin tracks ran in bored tunnels from a station at the eastern side of the airport at Hatton Cross serving the British Airways maintenance base, an enormous employment centre.

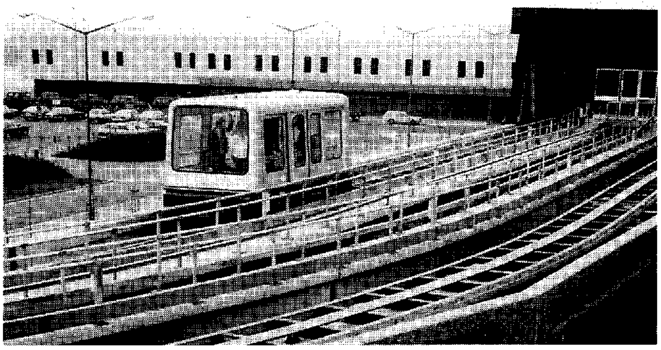
When the opportunity arose ten years later to extend the line from Heathrow Central the disadvantage of the underground terminus, the shortage of space for parking trains, was overcome by creating a loop. Incidentally the loop also makes it possible to provide a station in future for the fifth terminal. Unfortunately, as an economy measure at the end of a long battle to provide a link to Terminal 4, which had in turn led to investigations of the possibility of a British Rail station, the loop was formed as a single-line, one-way, clockwise route. Therefore it is a simple matter to travel from Terminal 4 to the renamed station Heathrow Terminals 1, 2 and 3, but the journey from the Central terminal area to Terminal 4 involves a change of trains at Hatton Cross.

3 Local rail

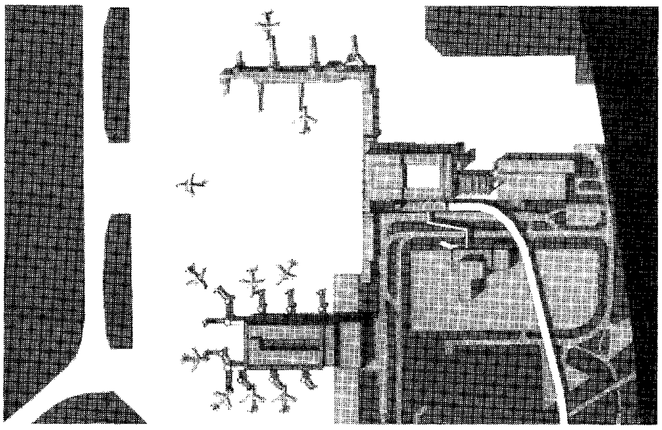
Birmingham airport terminal, opened in 1984, is linked to the adjacent British Rail 'Birmingham International' station, which also serves the National Exhibition Centre, by an experimental Maglev (magnetic levitation) railway. The way that this rail link comes right into the terminal at the upper level, where at least the departing passengers ultimately want to be anyway, is particularly important (Figures 15.5 and 15.6).

The future

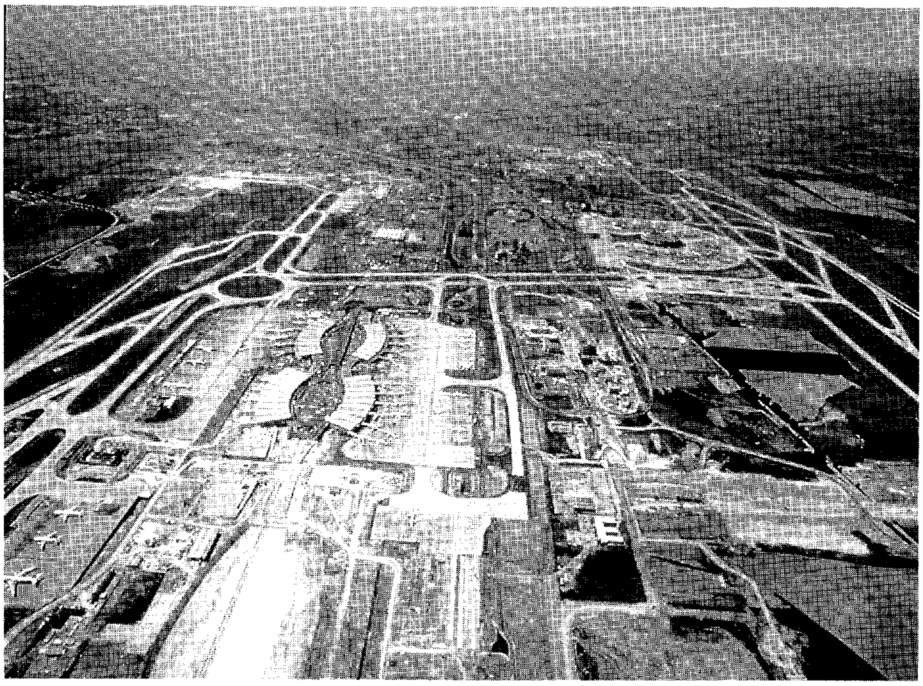
All new airport terminal complexes are being designed with integral provision for metropolitan or national rail



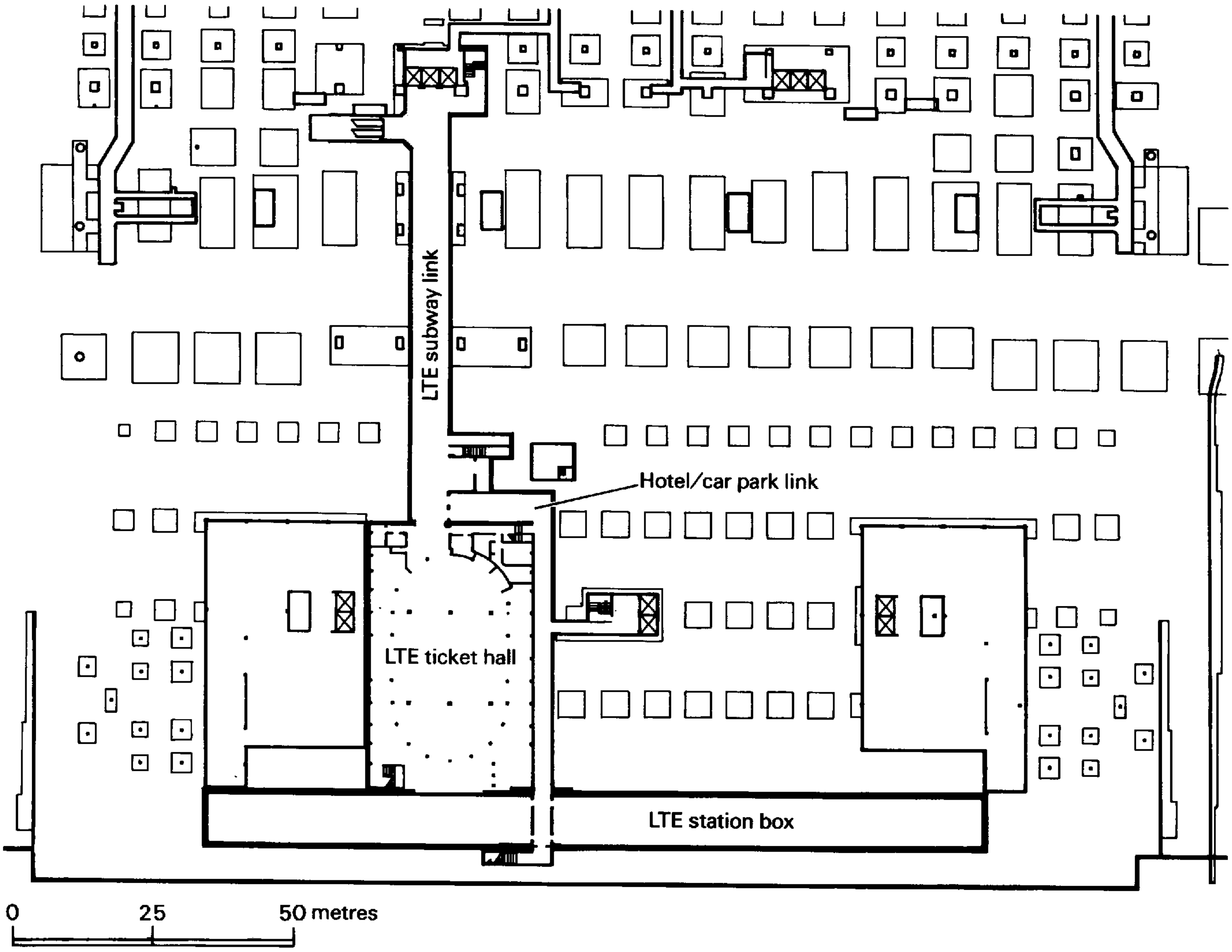
15.5 Birmingham International Airport, GEC Maglev railway, GEC Alsthom Transportation Projects.



15.6 Computer visualization of Maglev route (bottom right).



15.7 Paris Charles de Gaulle aerial view. Architect: Paul Andreu. Top right see Terminal 1 and bottom left see the four units of Terminal 2 and the sites of the TGV station and Terminal 3. Courtesy of Aeroports de Paris. Photographer: Gerard Halary.



15.8 Heathrow Terminal 4, Piccadilly Line station plan.

15.9 Station interior. Architects: Scott Brownrigg & Turner, Guildford, and London Underground Ltd.

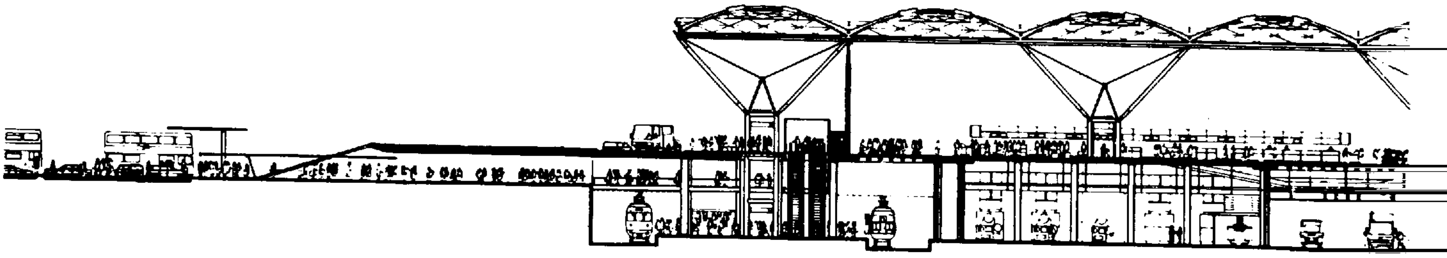
15.10 Piccadilly Line station under construction. Management contractor: Taylor Woodrow. Architects: Scott Brownrigg & Turner, Guildford.

links: Munich 2 (see Chapter 12), London Stansted (see Chapter 13) and Paris Charles de Gaulle, for example. Paris Charles de Gaulle now has a TGV (Train Grand Vitesse) station combined with a new RER (regional express) station. This will in turn be linked to the individual airport terminals by a people mover, Figure 15.7.

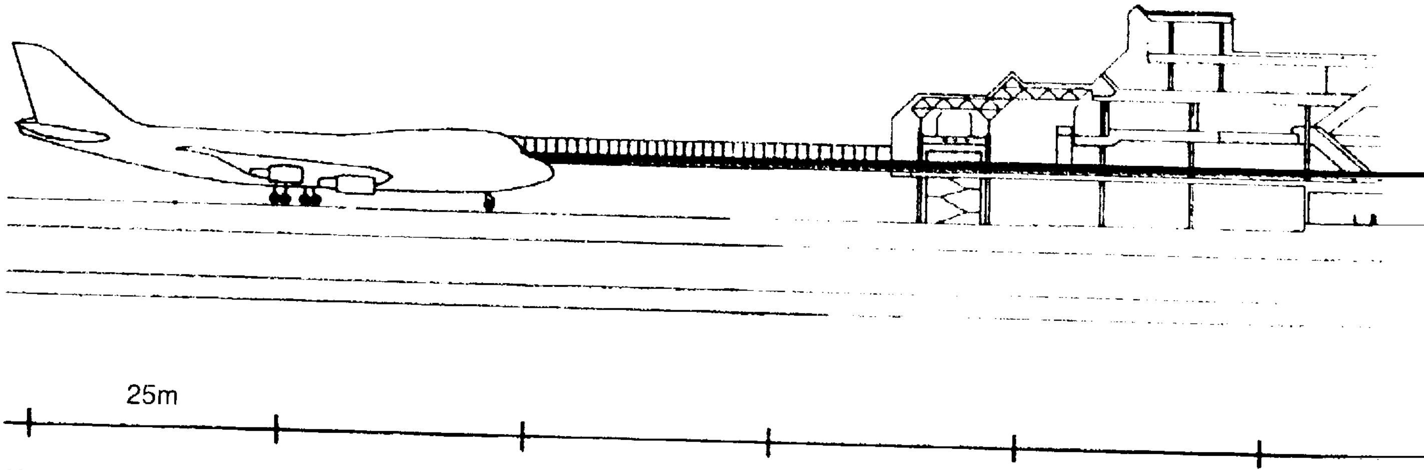
15.2 Railway stations

One indirect advantage of the one-way loop at Heathrow Terminal 4 is that there is only one platform and not two. Passengers can take a baggage trolley to the platform and changes of level are minimized. The station was built as a shell under the multi-storey car park with a direct escalator and lifts to the upper levels of the terminal. The station box was built first, ready to receive the bored tunnel (Figures 15.8–15.10).

At Stansted the twin tracks of the railway come in at ground level below the entrances from the car park direct to the passenger level of the terminal. Rail passengers come up ramps from the central platform to



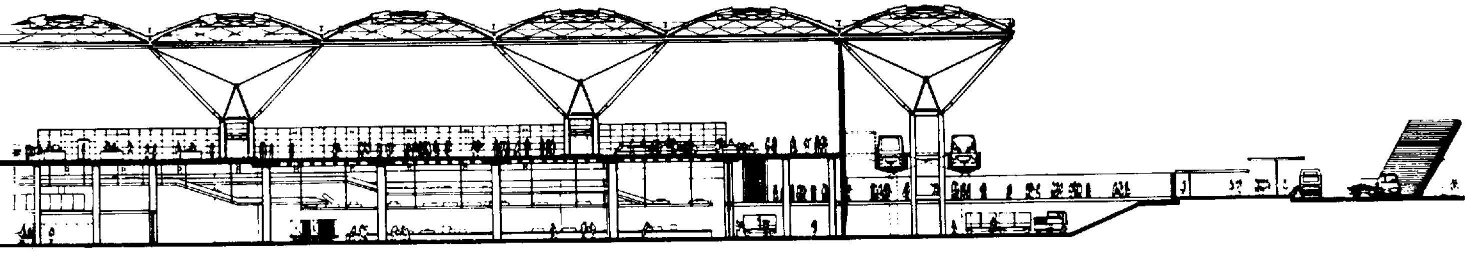
15.11 London Stansted: section through railway station (left side) and rapid transit (right side). Architects: Foster Associates, London.

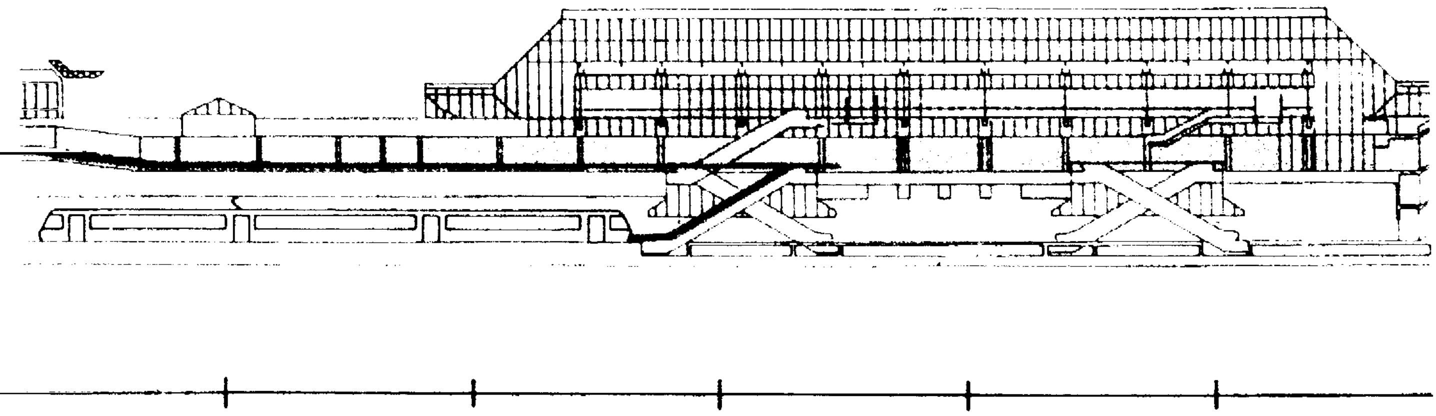


15.12 Munich: section through railway interchange (note travel distances). Courtesy of Flughafen München GmbH.

15.13 Busses at Heathrow Terminal 4.

15.14 Heathrow Central Terminal Area bus station (in background).





the passenger terminal (Figure 15.11). It is less straightforward for the railway to serve the decentralized units of the new terminal at Munich (Figure 15.12).

15.3 Bus stations

Buses can either come to a central point at the individual terminal or to the terminal forecourt itself (Figures 15.13 and 15.14).

Further reading

Blacklock, M. (1992) Rail-Air Interface, *Airports International*, January/February.

Momberger, M. (1995), Paris-Charles de Gaulle on line to express rail network. *Airport Forum*, **1**.

Walters, B. (1991), Changing train of thought on access. *Jane's Airport Review*, November/December.

16 Cars and roads

Notwithstanding the new efforts being made to incorporate public transport systems into airport terminal complexes, good high-speed road approaches and ample car parking are essential parts of the airport terminal context. It is not unusual for the combination of passenger and staff traffic to generate vehicular flows of over 1000 vehicles per hour on the approach roads to terminal buildings. Grade-separated junctions and links to the national motorway network are therefore the order of the day.

Long-term and short-term car parking

The different cost and price requirements of passengers flying away for a few days and short-term visitors to the airport are conventionally met by two types of car parking. Long-term parking is provided on 'cheap' land up to two or three kilometres from the terminal building. These surface car parks are served by courtesy buses to the terminal, the cost of which is included in the charge. This in turn is considerably cheaper than the cost of parking for a few hours in a multi-storey structure immediately adjacent to the terminal. Staff car parking will invariably be provided separate from the terminal building. Provision for car rental companies is increasingly important.

Contiguous parking structures

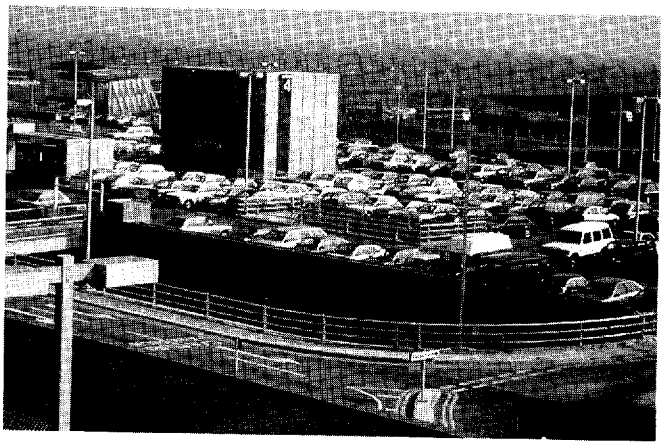
The first multi-storey car park at Heathrow Airport was opened in 1963 set apart from the two terminal buildings which it then served. It was not until the opening of Heathrow's third terminal (Terminal 1) in 1968 that passengers prepared to pay for the greatest possible convenience acquired the integral terminal multi-storey car park.

In the case of a terminal in which the main departures and arrivals levels are vertically 'stacked', car drivers should be able to enter the car park at departures level, either before or after dropping passengers and their baggage at the kerbside. In the former case the dropping-off area is effectively inside the car park and therefore subject to car park charges. Correspondingly, it should be easy for car drivers to pick up passengers and their baggage at arrivals level either before or immediately after leaving the car park, and in the former case the picking-up area is effectively inside the car park and therefore subject to car park charges. Whether a specific pick-up area is provided or whether all passengers take baggage trolleys to their car parking bays, lifts as well as stairs should be provided to all parts of the car park, Figures 16.1 and 16.2.

Further reading

Dykes, P. (1990) Making concessions for airport car rental. *Airport Forum*, **6**.

16.1 London Heathrow Terminal 1 multi-storey car park. Architects: Sir Frederick Gibberd and Partners. Architects for 1980 remodelling: Scott Brownrigg & Turner, Guildford.



16.2 London Heathrow Terminal 4 multi-storey car park. Architects: Scott Brownrigg & Turner, Guildford.

Part IV Terminal design details

17 Policies

17.1 Security policy

The first recorded aerial hijack took place in 1948, and between 1969 and 1978 there were no fewer than 400 aircraft hijacks involving 75 000 passengers. In the same ten year period there were at least seventy-five incidents involving the use of guns or explosives inside aircraft in the air or on the ground. The peak period was in the USA between 1968 and 1972, when 159 hijacks took place of which 85 involved unscheduled visits to Cuba. Thus it was that the authorities in the USA introduced full baggage and passenger searches for all departures from American airports on both domestic and international flights. This was no mean task and was not undertaken lightly. The disruption to hundreds of airport terminals and 150 million passengers per year was, and still is, worth it, for between 1972 and 1974 there was an immediate and dramatic return to air safety: in two years there were only three hijack attempts to planes departing from US airports, and all were unsuccessful.

Whilst accepting that a system is only as strong as the weakest link, high standards have already been set in the prevention of aerial terrorism. This has been achieved by a combination of body-searching, cabin baggage searching and the searching of baggage travelling in the aircraft cargo space. However, no amount of passenger and baggage searching will succeed in keeping undesirable objects off aircraft if unsupported by building layout and policing.

The combination of strict policing and a terminal building layout conducive to security will prevent even the most determined terrorist from breaking the rules. The point is that if the whole area used by passengers who have been checked can be sealed, and this involves also checking staff, then in theory no firearms or explosives can get aboard aircraft.

Passengers and their cabin baggage can either be searched at the entry to the general assembly area for flight boarding or at the point of flight boarding itself. The latter, while minimizing the area to be kept sealed, involves a multiplicity of staff and equipment. Unless arriving and departing passengers can be totally segregated in the airside areas of the building, there is a danger from the mingling of arriving and departing passengers: an already-checked departing passenger can be handed or can pick up a bomb put down by a determined arriving terrorist from a 'dirty' airport.

The advent of the segregated terminal, with the parallel advantage of avoidance of counter-flowing streams of hundreds of passengers, has improved security in the skies.

Prior to the bombing of Pan American Flight 103 over Lockerbie, Scotland, in December 1988, few untoward incidents had involved the placement of bombs in checked-in baggage: a bomb ticking away in an inaccessible aircraft cargo hold is as much a danger to the terrorist who put it there as to the passengers and crew of the aircraft, assuming of course that the terrorist owner of the baggage is on board the aircraft. This latter proviso is the reason for care being taken in ensuring that no checked-in baggage is unaccompanied. However, the only real protection is, and will be, provided by full screening of all baggage, a policy decision made by the British Department of Transport in 1990 for implementation over a six year period. Trials at Glasgow Airport have enabled BAA to perfect a system of progressive

17.1 Security in force. Photograph: Maurice Hudson.

elimination of baggage from any suspicion, and this is being carried out remote from the check-in desk in the most cost-effective way.

17.2 Commercial policy

People who have to wait will want to eat, drink and shop. If the shopping available offers exceptional bargains then they will actually make time to wait. The world's first duty-free store was opened in 1951 at Shannon in Ireland, but the beginnings of the duty-free system go back much further. Duty-free allowances for arriving passengers originated as 'the unconsumed portion of travellers' sustenance' on international journeys. Long and tedious nineteenth-century journeys required alcoholic drinks for all and perfume for the ladies. Customs-free goods for departing passengers involved a different issue. Long ago ships were granted the privilege of selling duty-free goods on the high seas and later the practice developed of selling duty-free goods at seaports on condition that the goods were for consumption on the high seas. After the Irish took the lead, the British followed eight years later with duty-free shops at Heathrow and Prestwick selling only alcoholic drinks. In 1961 the shops were also permitted to sell goods free of purchase tax. In 1964 the privilege was extended to all international airports.

Duty-free and tax-free shops at the point of departure are an institution. They encourage passengers to carry the permitted quantity of inflammable liquids in breakable containers on not just one flight but sometimes several flights in sequence. Some airports are permitted to sell duty-free goods to arriving passengers now.

In an entirely international terminal building the obvious place for a duty-free shop is at the place or places where passengers enter the airside area. They do not carry the goods through the security control and their route is as simple as possible. Extra shops can be provided nearer the aircraft boarding points for last minute purchases if the demand justifies the extra staffing and facilities.

Where international traffic shares areas of the terminal with domestic traffic, a central order point for duty-free goods can supply goods for collection at the aircraft boarding point.

Location of other shops and catering facilities will be determined by demand and commercial logic in relation to prominence. Both on the landside and the airside, shops can either be interposed on the passenger's route through the terminal or placed so that passengers have to choose to pass them, Figure 17.2.

The floorspace allocated to retailing, catering and other amenities (see Chapter 23) will vary enormously, but 10 per cent or even 12 per cent of total building area is not exceptional in view of the high dependence of the airport's business plan upon revenue from concession fees and rents. Provision for growth and change is essential.

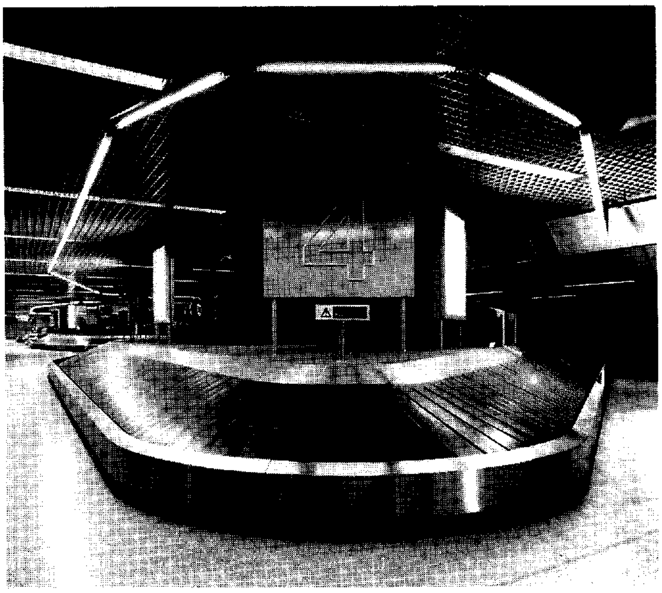
17.2 London Heathrow Terminal 4 catering area. Architects: Scott Brownrigg & Turner, Guildford.

17.3 Baggage handling policy

Checked-in baggage can either be routed direct from the single-flight check-in desk to the container or trolley en route to the aircraft or collected on multi-flight belts to be carried to a sorting area for assembly of flight loads. Baggage sorting can be:

- manual, with staff reading labels and lifting items into place,
- semi-automatic, with staff reading labels and directing automatically to flight loading positions, or
- fully automatic, with electronic reading of labels and direction to flight loading positions.

Upon arrival flight loads of baggage can be taken to a central reclaim area, Figure 17.3, with high-cost,



17.3 London Heathrow Terminal 4 baggage reclaim area. Courtesy of Messrs Logan Fenamec. Architects: Scott Brownrigg & Turner, Guildford.

high-volume equipment. Alternatively passengers can reclaim their baggage at the point of disembarkation from the aircraft. The need to centralize immigration and customs controls for arriving international passengers militates against decentralized baggage reclaim.

17.4 Government controls: immigration, customs and traffic

All air passenger traffic classed as international demands the interposition of immigration control for departing passengers and immigration and customs control for arriving passengers. This can either be centralized, for economy of staffing, as illustrated by Heathrow Terminal 4 or decentralized, as illustrated by the examples of multiple linear units in the taxonomy in Chapter 12.

The freedom in terminal design offered by 'domestic' processing, as witnessed by the drive-to-the-gate convenience of many US examples such as Dallas Fort Worth in Chapter 6, is considerable. Concentration or grouping of the government control systems determines so much of terminal design. The changes in the European Union's internal border controls are leading to major rethinking of terminal designation as well as multiple channeling of passengers. The introduction of an intra-Europe 'blue' customs channel is one result. Amsterdam Schiphol is effectively acquiring a second terminal after 70 years of development (see Chapter 4) and adaptability is the keynote of the new hub terminal at Birmingham International Airport (see Chapter 6).

Government policy can determine the type of traffic at a particular airport. For example, the islands of Seychelles and Mauritius forbid charters, with a major effect on scheduled airlines and terminal demand.

17.5 Airline policy requirements

A terminal totally dedicated to traffic of one airline, or operated by one airline, will reflect that airline's policies. Increasingly airlines are 'putting their stamp' on the elements of terminals which they use, in order to show a seamless service to their passengers. Otherwise, airlines accept the policies of design and operation laid down by the terminal operator. Matters of detail in operation that affect the terminal are:

- provision of waiting rooms for CIPs (commercially important passengers), generally those paying first class or enhanced fares,
- provision of office accommodation,
- provision of ticket desks,
- provision of workshops, stores and staff accommodation related to the aprons,

Airlines may be given the freedom to 'handle' their own passengers and to have their own check-in desks permanently allocated. Otherwise in the case of small airlines their only presence in the terminal may be a sales office.

Common-user terminal equipment (CUTE) is increasingly used by airlines in a flexible style of operation whereby computer equipment, VDUs, boarding pass printers, etc., are shared, although accessing individual airline host computers elsewhere.

17.6 Overall passenger processing standards

How many passengers are to be catered for in the terminal and how far ahead can traffic growth be projected and invested for? The key is the choice of design year. A terminal designed in 1990 for 4 million passengers per year to replace an out-of-date terminal handling 4 million passengers in 1990 will not last very long. A glance at the pattern of development of Schiphol Airport Amsterdam in Chapter 4 shows that capacity has been provided up to 15 years ahead of demand.

How many passengers per aircraft? As well as being a determinant of the ratio between the size and capacity of the apron and the size and capacity of the terminal, this factor will determine gate assembly areas, baggage reclaim units and any other part of the terminal where the single flight is the processing unit.

It is a positive disadvantage for the layout of a terminal to be determined by the number of passengers per aircraft. There is no fixed or permanent relationship between the apron frontage and the number of passengers served. From the Appendix the following ranges can be deduced as shown in Table 17.1.

Note that the calculations in Table 17.1 are maxima based on 100 per cent load factors and airside frontage calculated as aircraft wingspan plus 7.5 m aircraft separation. These ranges have variations of factors of 2, demonstrating the difficulty of relating gate assembly areas to gates. However, thankfully, the composite criterion for designing passenger and baggage processing spaces is the hourly flow resulting from a multiplicity of flight departures and arrivals. Traffic patterns can vary enormously, as highlighted in Chapter 4.

- Manchester Terminal 2 Phase 1, Heathrow Terminal 4 and the full design for Gatwick North Terminal, range from 1850 to 2500 passengers per hour each way and from 6 to 9 million passengers per year. They are international terminals with similar types of traffic.
- Zurich Terminal B and Hanover, with less constant but high peak expectation, have hourly capacities of

Table 17.1 *Ratio of passengers per unit apron frontage*

Aircraft type	*Passengers per m*
Narrow-bodied jet transports	2.3–5.2
Wide-bodied jet transports	5.4–9.1
Turboprop transports	1.1–2.1

3500 and 2000 respectively but annual capacities of only 6 and 4 million. Incidentally neither of these capacities have been matched by demand even in the second decade of use.

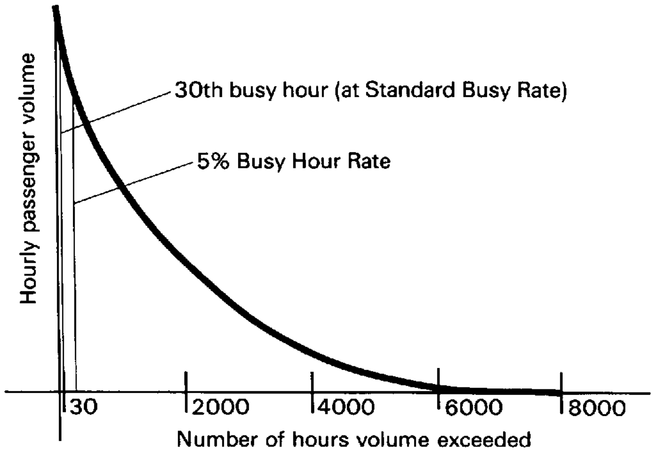
It has been common for terminal design criteria to be related to the hourly capacity or the number of passengers due to be handled in the thirtieth highest hour of scheduled use. This means that in the 29 hours in the year in which demand is greatest the facilities will not match the requirement, but ensures reasonable standards and economy.

Figure 17.4, culled from the research base of Professor Norman Ashford at Loughborough University, shows the location of the thirtieth highest hour on the passenger volume distribution curve. A Standard Busy Rate (SBR) set at the thirtieth highest is a result of applying standard highway engineering practice to the design of pedestrian facilities. Different airport authorities favour different standards. Schiphol Airport Amsterdam uses the twentieth highest hour and Aeroports de Paris the fortieth highest hour. US practice tends to favour averaged conditions such as the peak hour of the average day of the peak month. British Airports Authority now favours a 5 per cent Busy Hour Rate whereby 5 per cent of the total annual passenger traffic operates at volumes in excess of the design level.

17.7 Levels of service

There is a fine line between congestion standards and efficient use of space. One man's congestion is another man's profit. Nevertheless, in passenger terminal design congestion is not a planned state and is counter to efficiency, economy and profit.

Designers have needed to introduce a degree of sensitivity into the processes of design and capacity analysis for transport facilities. This is provided by the concept of level of service, initially developed in the area of highway capacity analysis. In passenger handling, level of service has been applied by Canadian analysts to space standards (square metres per passenger) in queuing and waiting areas as tabulated in Table 17.2.



17.4 Passenger volume distribution curve.

Table 17.2 *Levels of service and space standards*

Level of service	*A*	*B*	*C*	*D*	*E*	*F*
Areas with trolleys (m^2 per passenger)						
Check-in and Baggage reclaim	1.6	1.4	1.2	1.0	0.8	
General waiting in concourses	2.7	2.3	1.9	1.5	1.0	
Confined waiting	1.4	1.2	1.0	0.8	0.6	

Level A Excellent service, free flow, no delay, direct routes, excellent level of comfort.
Level B High level of service, condition of stable flow, high level of comfort.
Level C Good level of service, condition of stable flow, provides acceptable throughput, related subsystems in balance.
Level D Adequate level of service, condition of unstable flow, delays for passengers, condition acceptable for short periods of time.
Level E Unacceptable level of service, condition of unstable flow, subsystems not in balance, represents limiting capacity of the system.
Level F System breakdown, unacceptable congestion and delays.

Source: Ashford, N. J. (1987) Level of service design concept for airport passenger terminals – a European view. *Transportation Planning and Technology*

These linear scales do not necessarily relate to passengers' perception of standards resulting from the combination of space standards and 'dwell' times. Based upon perception-response modelling, levels of service ranges can ultimately be defined for processing times.

For many passengers, the criteria by which airport terminals are judged are the walking distances involved between car or public transport and boarding the aircraft. No standards comparable to those for levels of service have been derived or proposed. Although there is an inevitability about the lengths of piers resulting from the aggregate wingspans of parked aircraft, design can mitigate the strain of walking distance by the provision of moving pavements.

Further reading

Ashford, N. J. (1987) Level of service design concept for airport passenger terminals – a European view. *Transportation Planning and Technology*, June.

BAA explains screening strategy. (1994) *Airports International*, May.

Blacklock, M. (1991) The big screen. *Airports International*, July/August.

Blacklock, M. (1993) Airlines invest in terminal trademarks. *Airports International*, February.

Danielson, B. and Schano, R. (1988) Adding quality and professionalism to airport restaurants, *Airport Forum*, **1**.

Doganis, R. (1994) Airport economics – current and future issues. Paper at 10th World Airports Conference, Hong Kong, November 1994.

Wallis, R. (1994) The Glasgow experiment. *Airports International*, April.

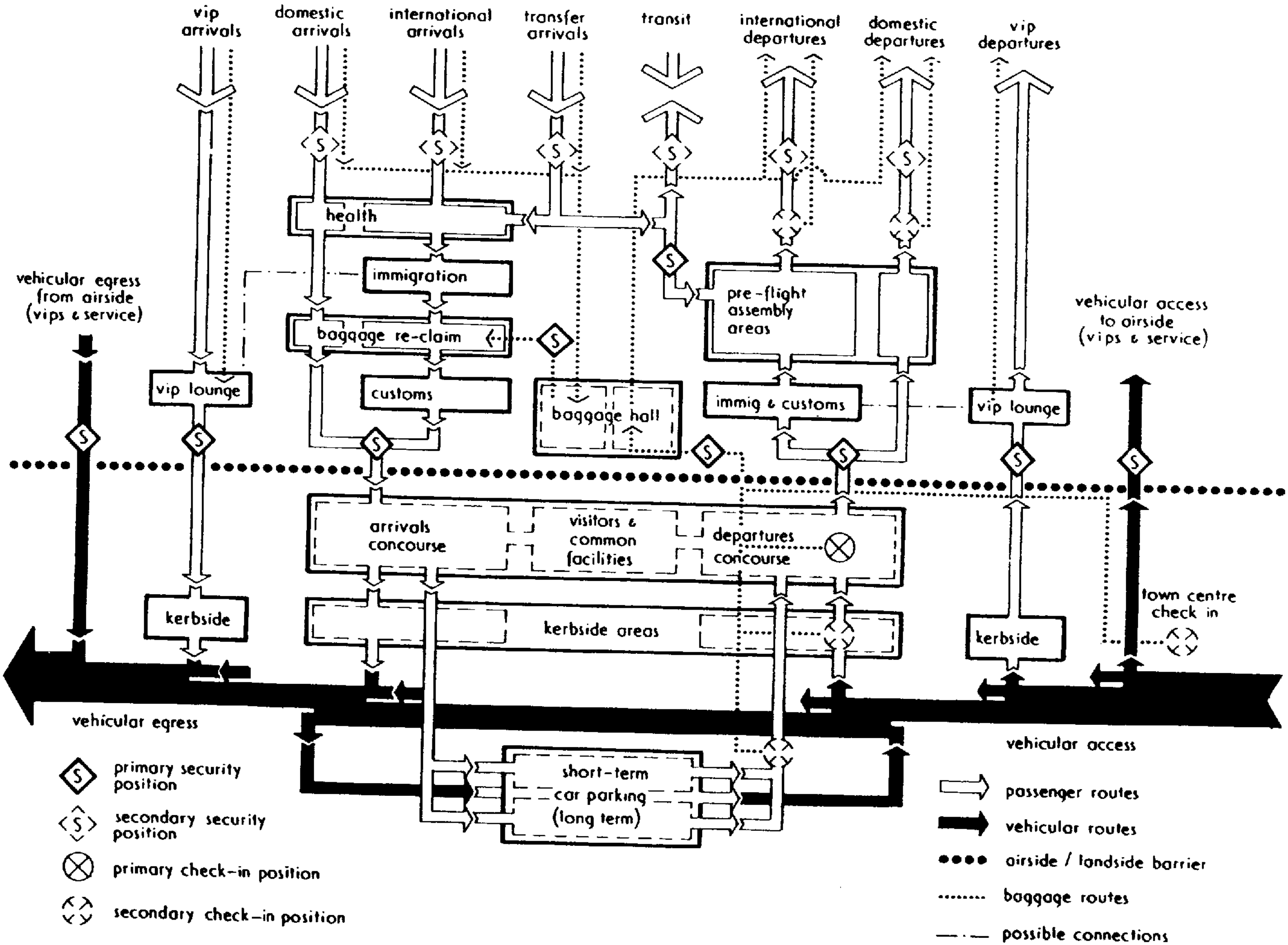
Wheatcroft, S. (1994) Aviation and tourism policies. London, Routledge.

18 Layouts and configurations

Outline of overall and individual passenger processing configurations:

18.1 Overall circulation

Figure 18.1 illustrates the overall relationship between all functions in both domestic and international terminals and related car-parks and VIP facilities. Also included are service roads entering the airside to give controlled access for the whole range of service vehicles shown in Figure 25.1, as well as airside deliveries to the terminal and air couriers, etc.



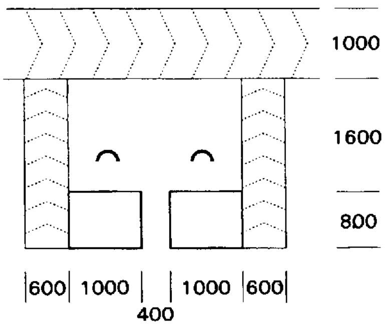
18.1 Overall relationship between all functions. From Butterworth Architecture, New Metric Handbook, *1979.*

18.2 Check-in, tickets and baggage, central and gate

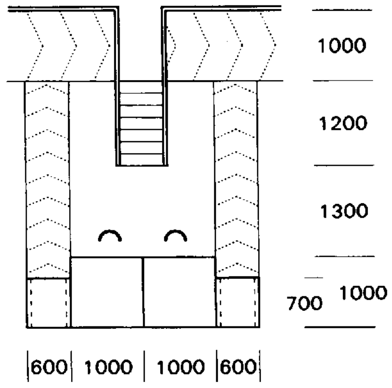
The following possibilities are available for sets of desks, whether located centrally (the primary position) or at or near the departure gate (the secondary position):

Linear, front staff access: Figure 18.2.
Linear, rear staff access: Figure 18.3.
Single island, pass through: Figure 18.4.
Multiple island, orthogonal: Figure 18.5.
Multiple island, chevron: Figure 18.6.

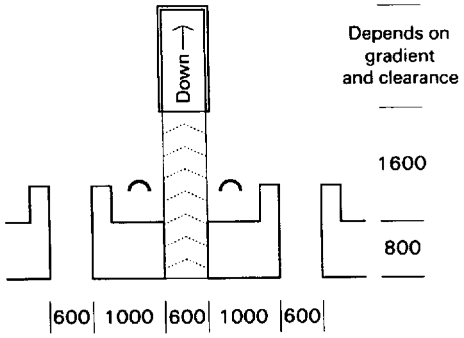
Note that a maximum of ten check-in desks should feed on to one collecting belt.



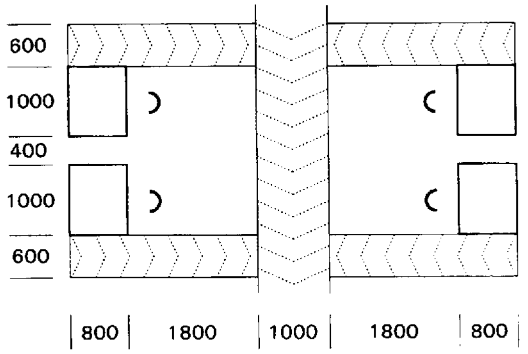
18.2 *Linear check-in, front staff access.*



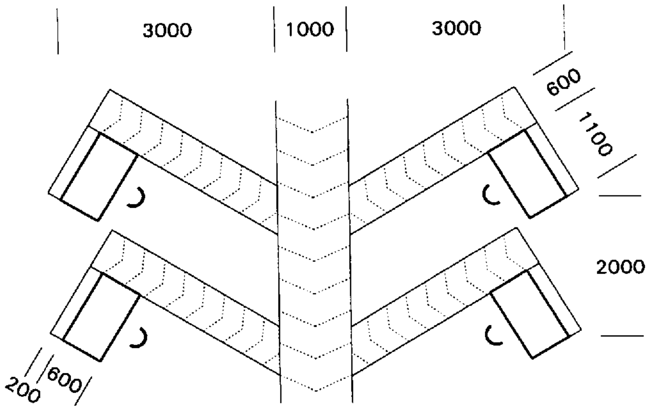
18.3 *Linear check-in, rear staff access.*



18.4 *Single-island check-in, pass through.*



18.5 *Multiple-island orthogonal check-in.*



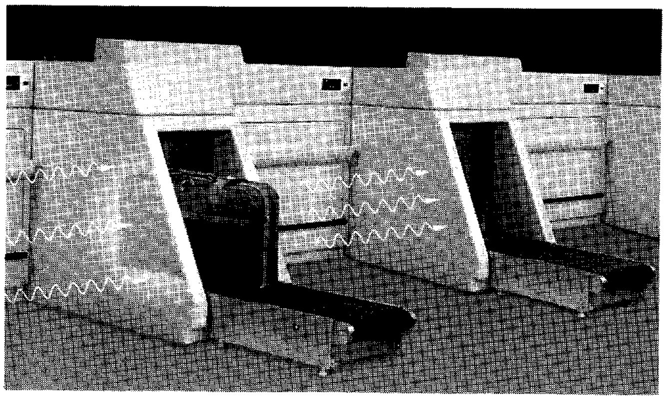
18.6 *Multiple-island chevron check-in.*

18.3 Security

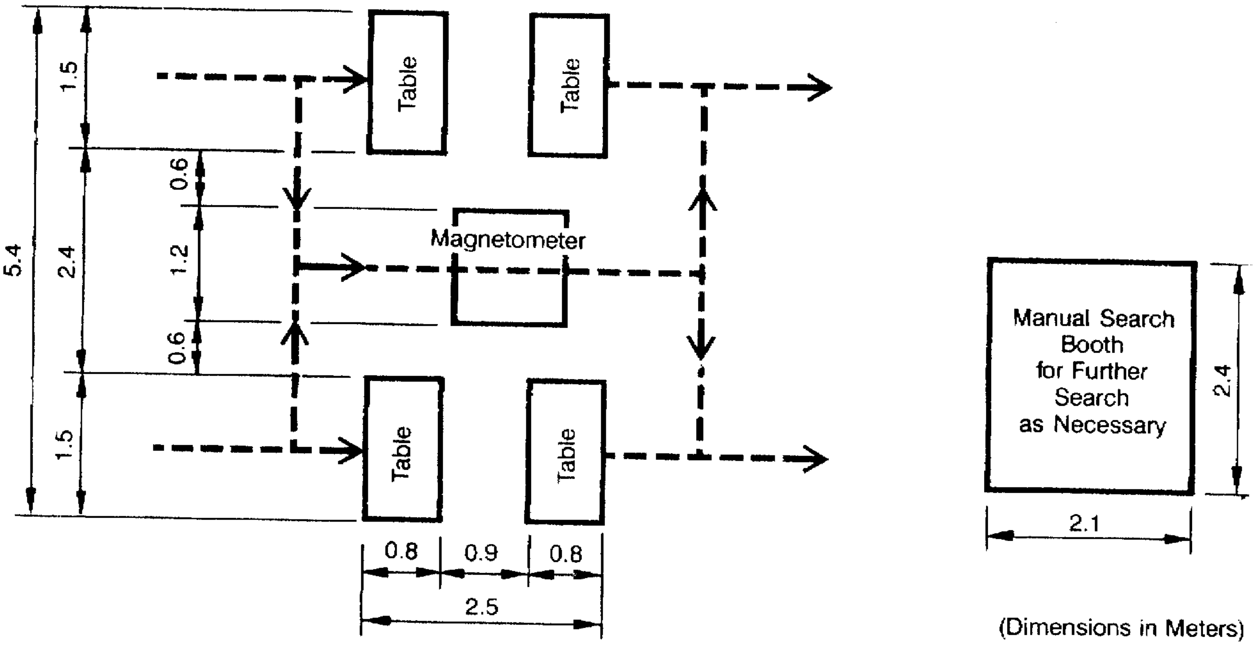
The primary security control point for personnel searches is at entry to the 'sterile' airside concourse area, and this is essential for all entries to that area. Secondary search positions may be located as well or instead at the entry to the aircraft boarding position or the aircraft itself. Security, to be thorough and therefore worthwhile, is labour intensive and costly and best carried out in the greatest volume practicable.

Policy dictates that consideration be given to total checking of checked-in baggage at or adjacent to the check-in desk. The following figures show:

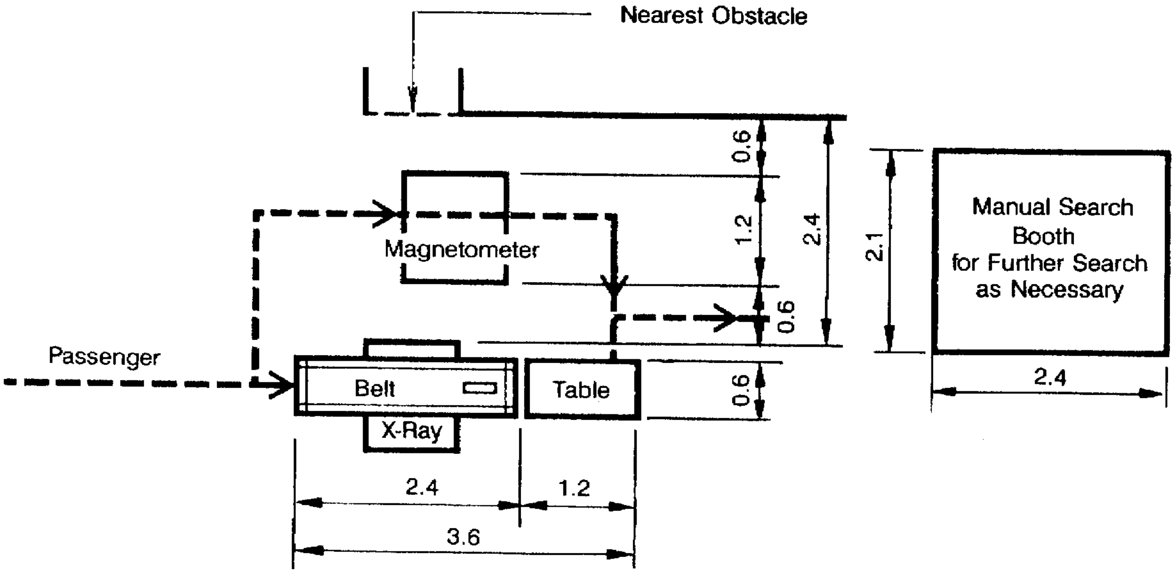
X-ray of baggage at check-in desk: Figure 18.7.
Manual search of passenger and hand baggage: Figure 18.8.
X-Ray unit search of passenger and hand baggage: Figure 18.9.



18.7 X-ray of baggage at check-in desk. Courtesy of manufacturer Heimann.



18.8 Manual search of passenger and hand baggage.
Figures 18.8–18.16 from IATA Airport Development Reference Manual, *1995.*

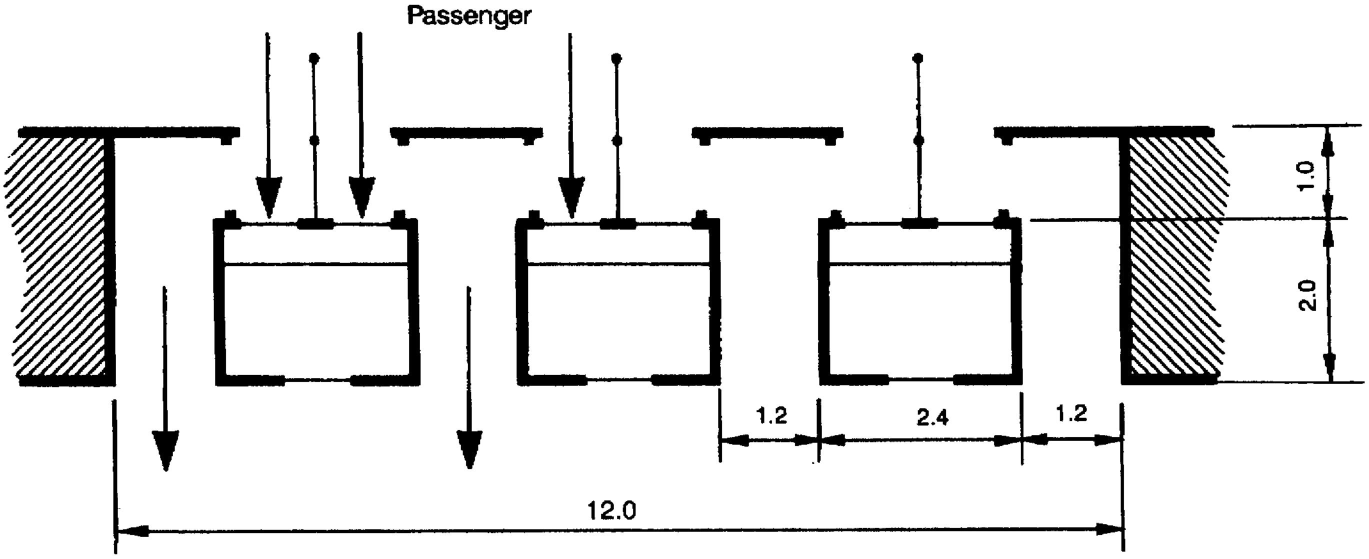


18.9 X-ray unit search of passenger and hand baggage.

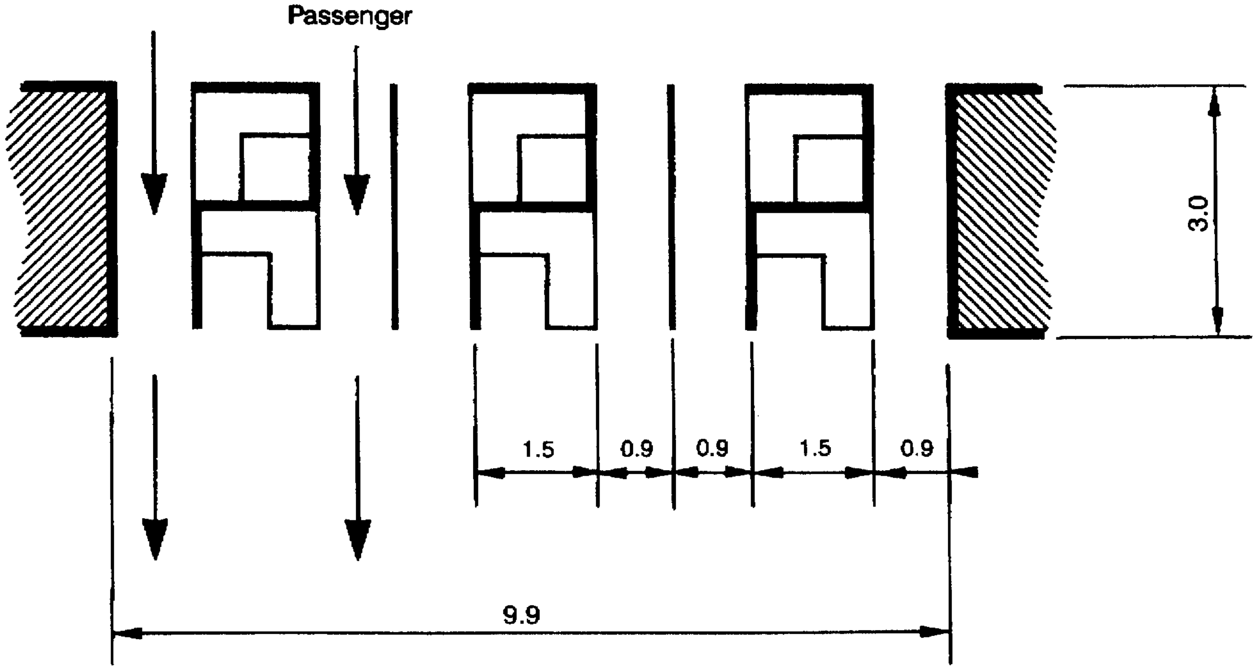
18.4 Outbound and inbound immigration

The checking of passports and entry documents is central to national security, and the layout of the 'comb' through which passengers must pass is critical. The following figures show:

Frontal presentation, booth or open plan: Figure 18.10.
Side presentation, booth or open plan: Figure 18.11.



18.10 Frontal presentation immigration desks, booth or open plan.



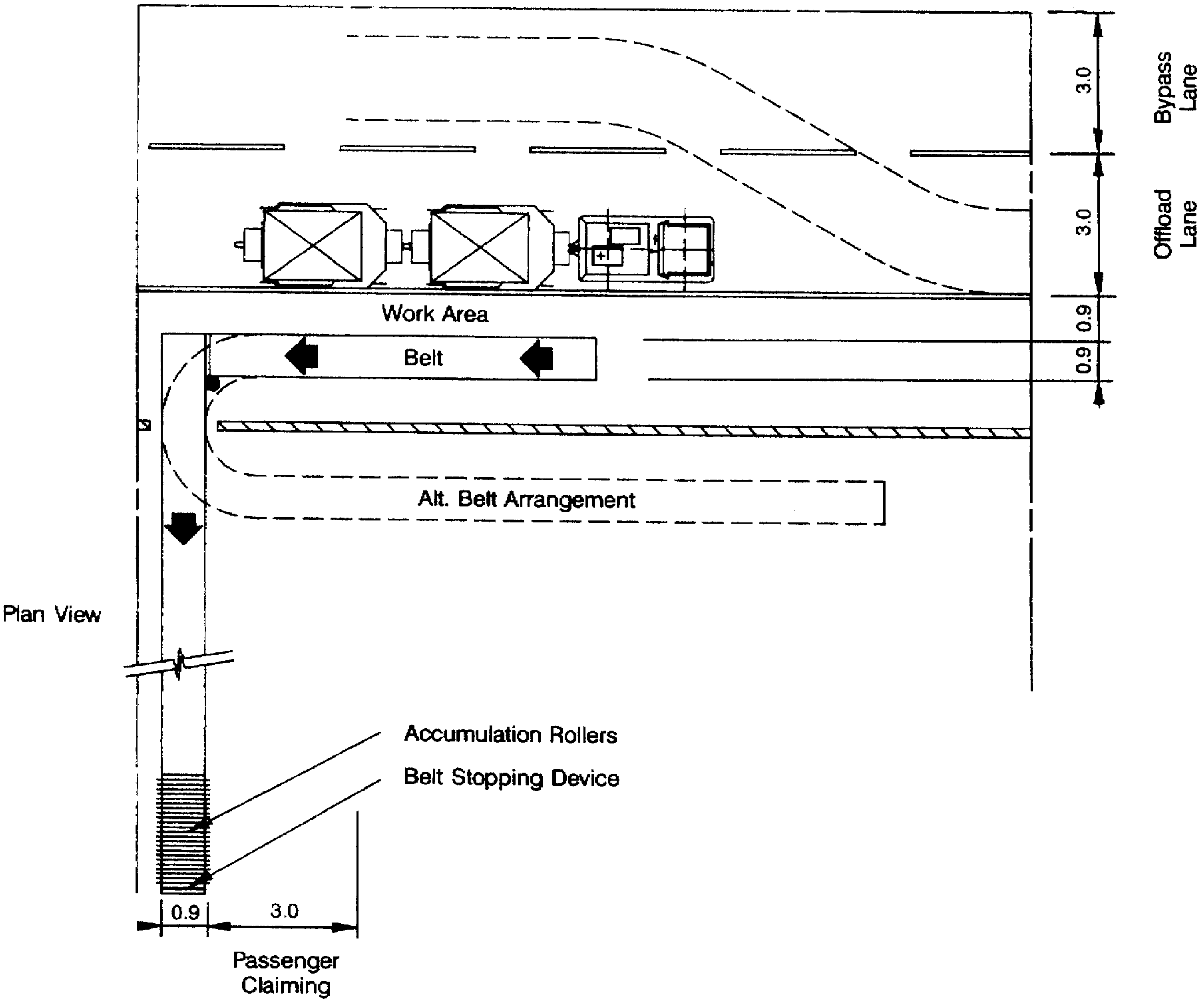
18.11 Side presentation immigration desks, booth or open plan.

18.5 Baggage reclaim

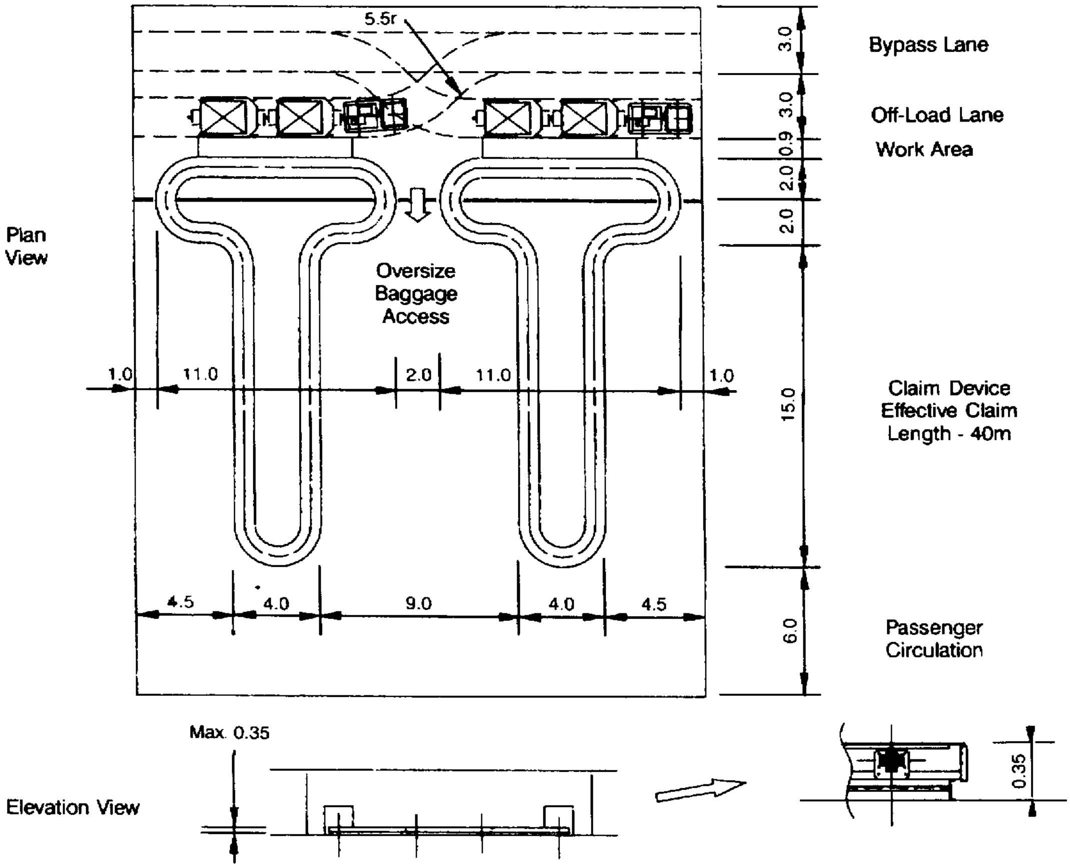
On international routes all items of baggage which have been checked-in for transport in the hold of the aircraft need to be returned to their owners before they pass through the customs check on entry to their destination country. The activity of reclaiming baggage therefore takes place as late as possible in the arrivals sequence.

Three basic types of mechanical unit display the baggage for passengers to pick their own items choice of mechanism depends upon the volume of passengers involved and the configuration of levels in the terminal building. The different methods are shown in the following figures:

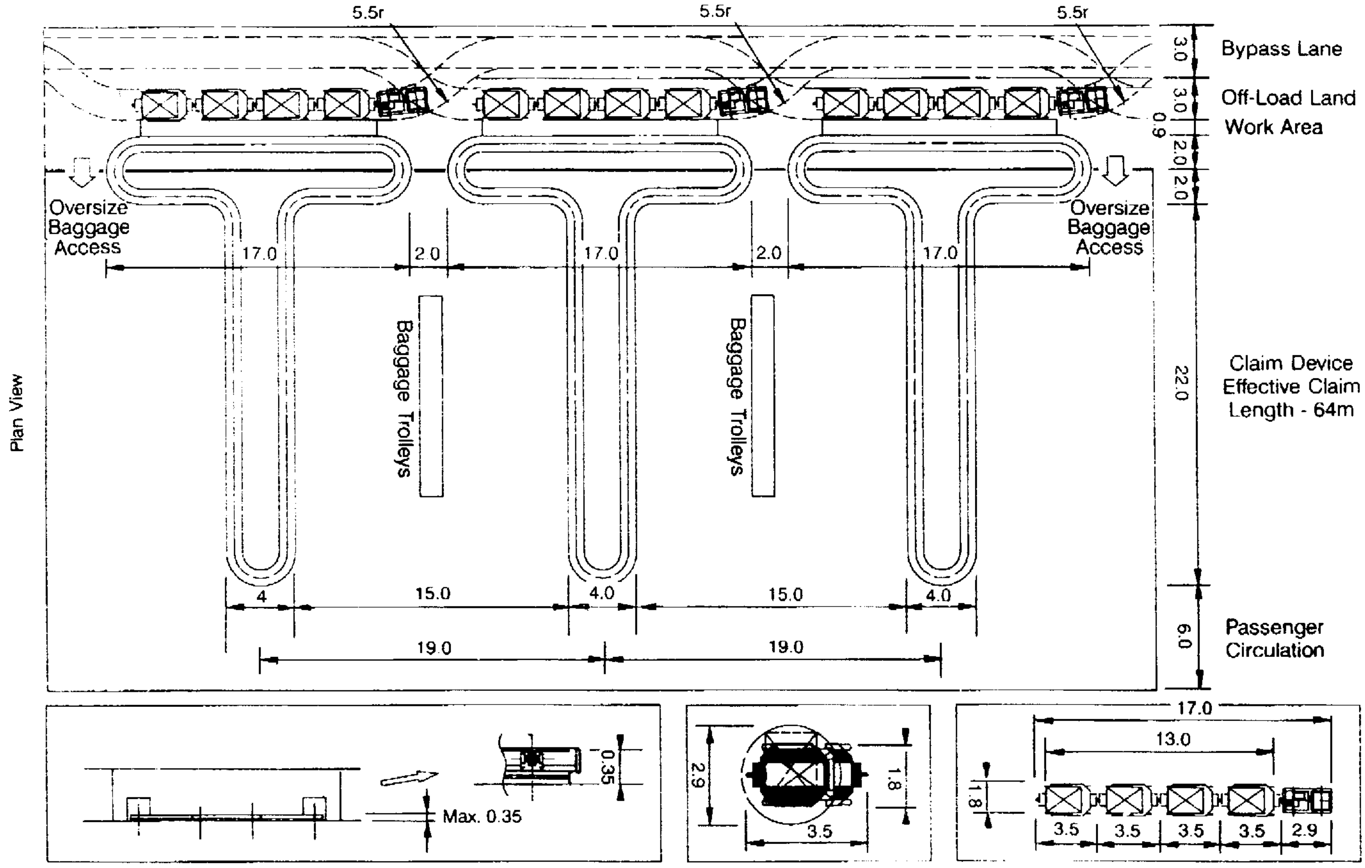
Straight belt: Figure 18.12.
Circulating unit, direct feed on one level
  suitable for narrow-bodied aircraft: Figure 18.13
  suitable for wide-bodied aircraft: Figure 18.14.
Circulating island unit, fed from below (or above):
  Figure 18.15.



18.12 Straight belt baggage reclaim.



18.13 Circulating baggage reclaim unit, direct feed on one level suitable for narrow-bodied aircraft.

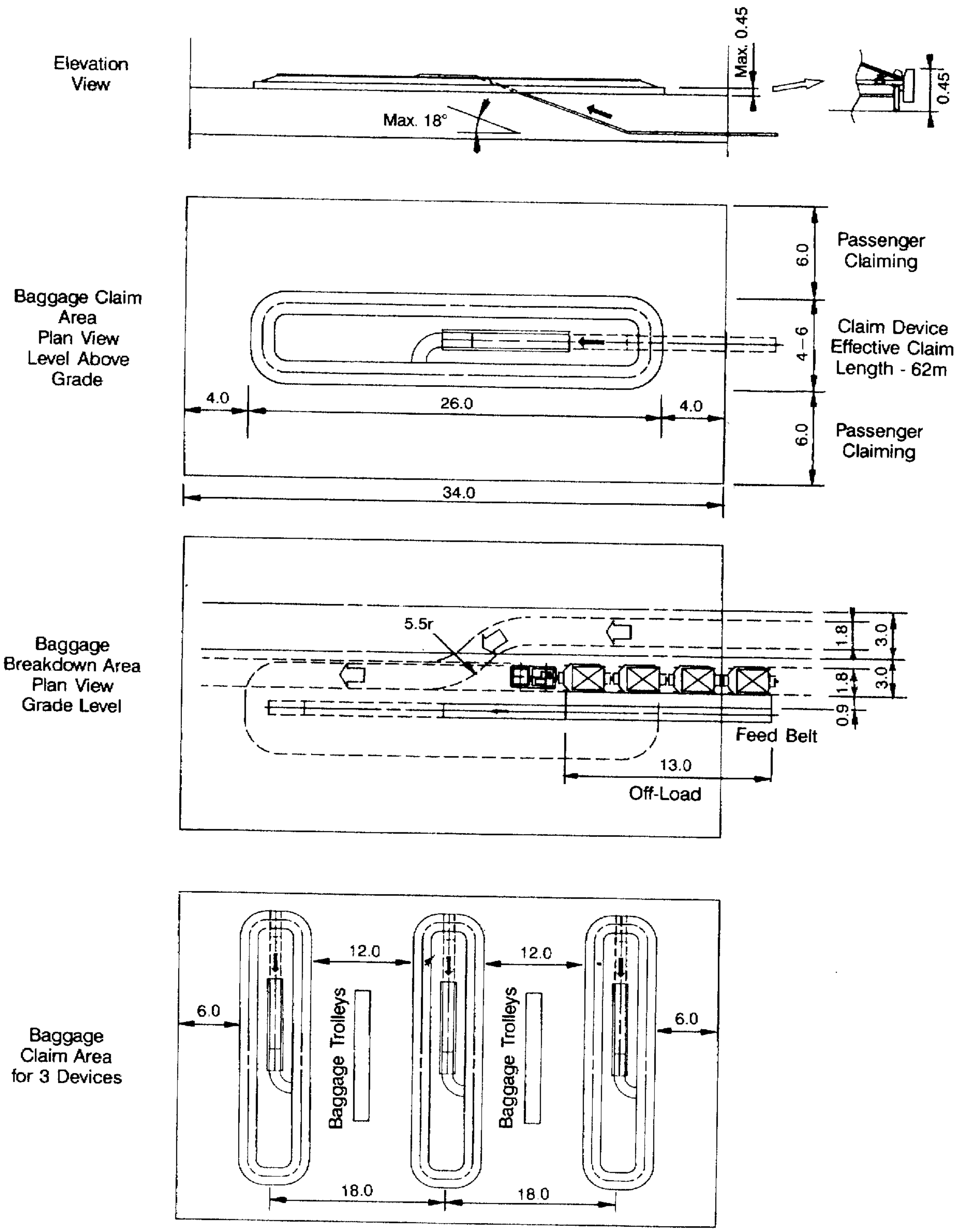


Claim Device – Elevation View

Container & Dolly

Container Dolly Train

18.14 Circulating baggage reclaim unit, direct feed on one level suitable for wide-bodied aircraft.



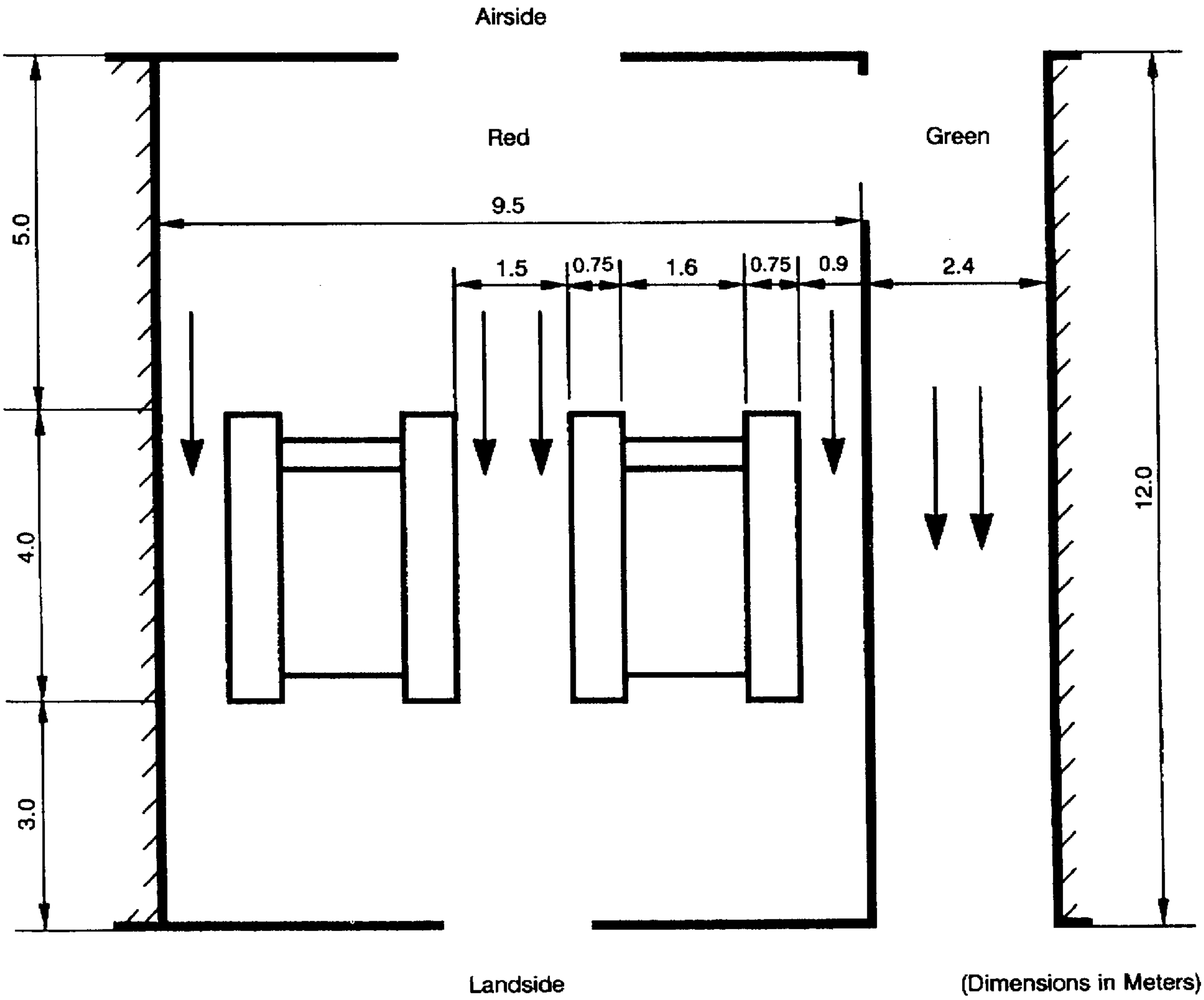
18.15 Circulating island baggage reclaim unit, fed from below or above.

18.6 Customs

Almost universally adopted are the conventions of a 'green' channel for passengers with no goods to declare and a 'red' channel for those with goods to declare. A possible layout for green and red channels is shown in Figure 18.16, with benches for examination of baggage only in the red area. Many variations are possible: customs checks may be carried out on exit and X-ray units may be integrated for example. The common element will be the care taken in meeting the local requirements of the relevant authority for line of sight over the control area and search areas and the special rooms for the examination of passengers who may be suspected of carrying drugs.

References

International Air Transport Association (1995) *Airport Development Reference Manual* (8th edition). Montreal, IATA.



18.16 Customs layout.

19 Data sheets

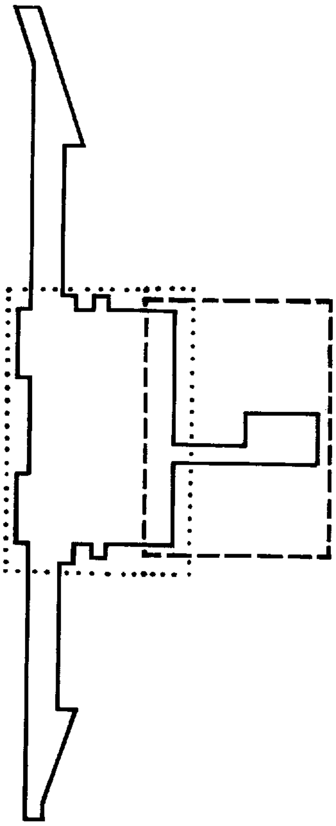
These data sheets concern the detail of individual passenger processing standards: there are no universally accepted space standards or universally achieved processing rates in airport terminals any more than in any other type of functional building. These analyses are based on and attributed to airline and airport operators and their experience related to acceptable levels of service (see Chapter 17).

The context of each piece of functional briefing will be set by the overriding decisions on the type of terminal concerned, whether it be airline-specific, international or domestic or both, single-level or multi-level, centralized or decentralized and whether or not it is to cater for a high proportion of transfer passengers. Examples of these types of terminal are given in Chapter 6.

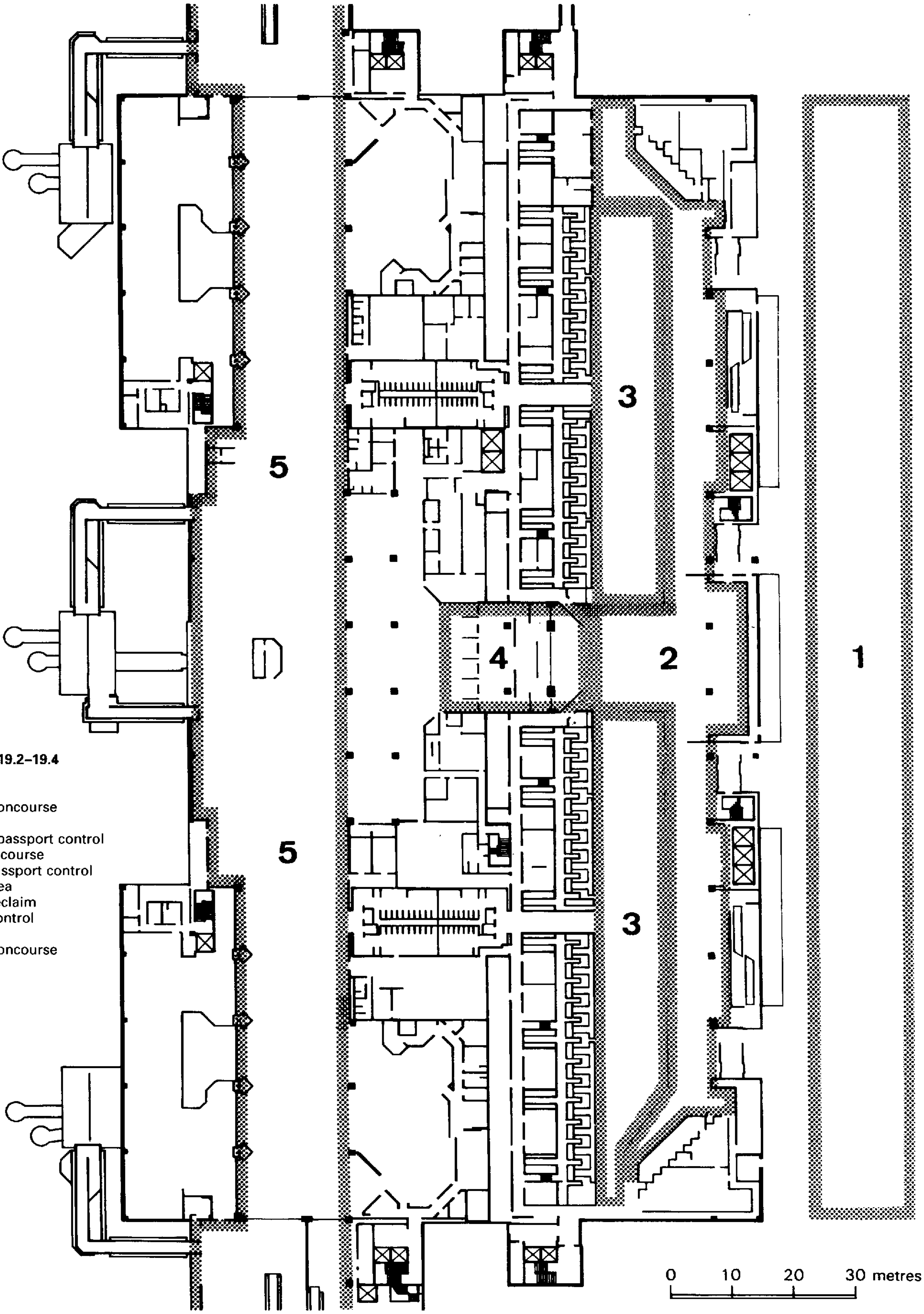
The scale of the operation will be set by the attitude to providing for the peak of traffic, as outlined in Section 17.6, and the amount of in-built growth represented by the design year. Each data sheet contains:

- policy decisions to be applied (Chapter 17),
- quantity factors to be assessed,
- typical space calculation based on choice of configuration (Chapter 18),
- IATA Airport Development Reference Manual references,
- layout example, and
- photographs of noteworthy examples.

Information is also provided on facilities for special classes of passenger: the disabled and commercially important passengers (CIPs: first class ticket holders, given special facilities by the airlines) and very important passengers (VIPs) given special facilities by the airport.



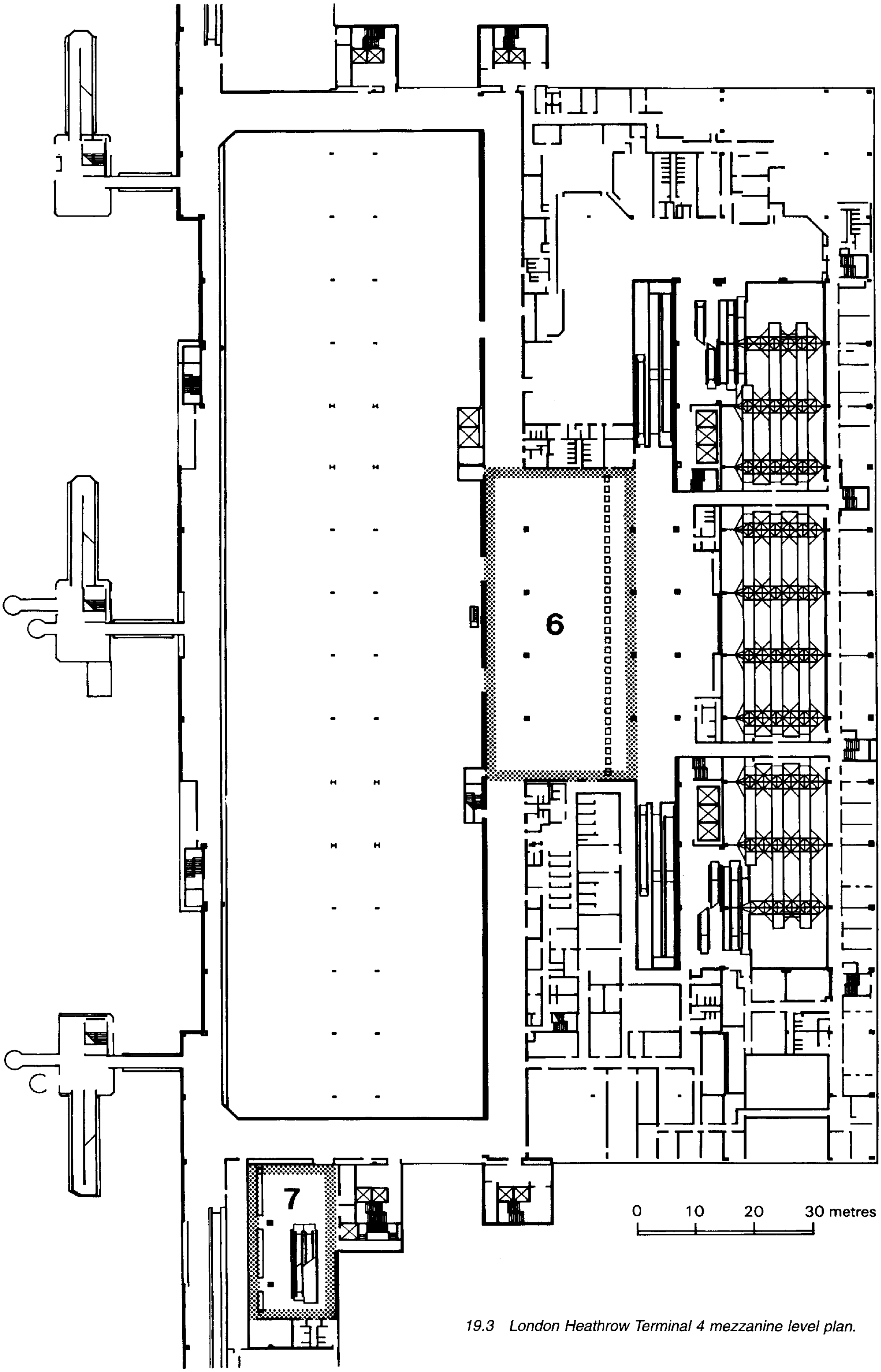
19.1 London Heathrow Terminal 4 general plan. The dotted line indicates the area covered in Figures 19.2–19.4; the dashed line the area of the station plan in Figure 15.8. Architects: Scott Brownrigg & Turner, Guildford.



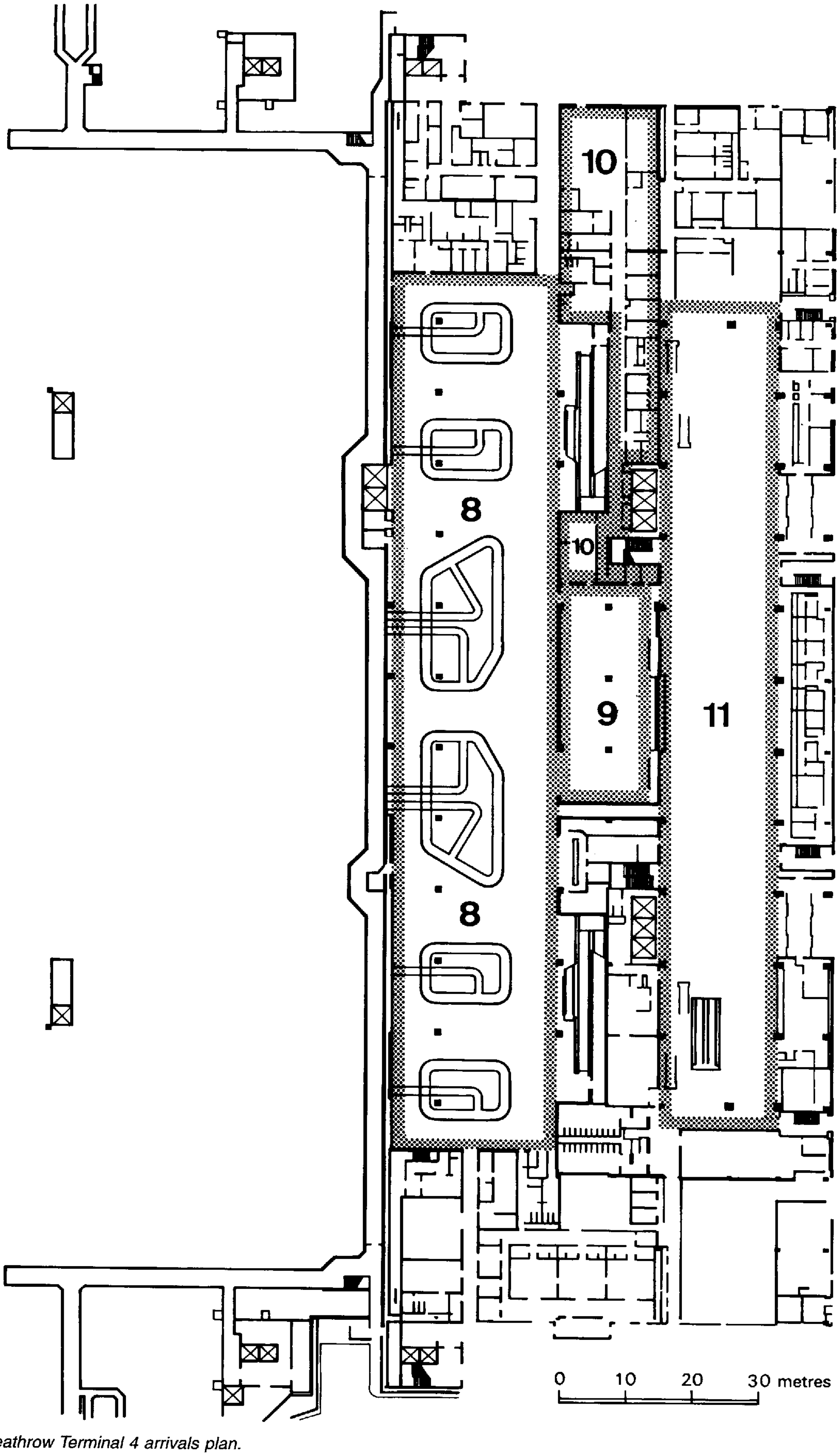
Key to Figures 19.2–19.4

1 Forecourt
2 Landside concourse
3 Check-in
4 Outbound passport control
5 Airside concourse
6 Inbound passport control
7 Transfer area
8 Baggage reclaim
9 Customs control
10 Office area
11 Landside concourse

19.2 London Heathrow Terminal 4 departures level plan.



19.3 London Heathrow Terminal 4 mezzanine level plan.



19.4 London Heathrow Terminal 4 arrivals plan.

19.1 *Function*: Arriving by car or bus at the terminal

Context factors

International or domestic or both: not relevant.
Single-level or multi-level: a single-level forecourt may mix arrivals and departures (see Section 19.11).
Centralized or decentralized: if processing is decentralized, the set-down areas may be dispersed.
Percentage of transfer passengers: if high the forecourt will probably be single-level.

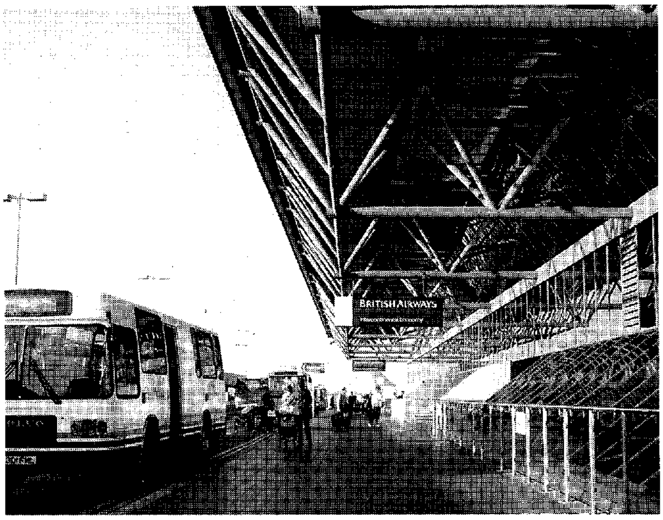
See Figures 19.2 area 1, 19.5 and 19.6.

Policy decisions to be applied

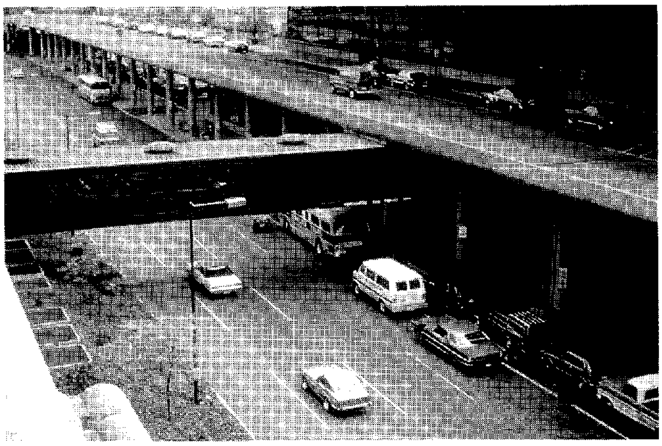
Security: the creation of terrorist vantage points should be avoided in the design.
Commercial: for commercial reasons the whole forecourt or at least the private car section may be incorporated in the short-term or nearest car park. This will force motorists to pay for the privilege of parking close to the check-in area.
Baggage: for high volumes of inclusive tour traffic, with coaches setting down large pre-sorted volumes of baggage, it may be appropriate to have a dedicated area and a route to the baggage areas. Baggage trolleys should be available at intervals for passenger use.
Government controls: not relevant.
Airline: for large terminals shared by many airlines it may be appropriate to have signed sections of forecourt.
Information systems: as above.
Predicted changes: take account of any predictable changes in traffic mix which may affect the modal split (the percentages of passengers arriving by car or bus).

Quantity factors to be assessed

Hourly passenger flows: in the case of a combined departures and arrivals forecourt a planned two-way rate will be relevant.
Visitor ratio: not relevant. Numbers of people seeing passengers off will not be a determinant of the forecourt.
Processing rate: not relevant.
Estimated dwell time: an average of 1.5 minutes may be allowed for cars and taxis.
Modal split: subject to local conditions, 50 per cent of passengers may use private cars and taxis. Many types of bus and coach will call at the departures forecourt, but do not need dedicated set down positions. In order to provide the shortest route for the greater number of passengers, coach and bus bays should be located closest to the terminal doors. However, in the case of a single-level forecourt it may be appropriate to designate pick-up and set-down bays for specific types of bus and coach.



19.5 London Heathrow Terminal 4 forecourt. Architects: Scott Brownrigg & Turner, Guildford.



19.6 Seattle, Tacoma Terminal forecourt. Architects: The Richardson Associates, Seattle, Washington.

Typical space calculation based on 2000 originating passengers/hour

Number of passengers per hour at kerbside for cars and taxis: 1000.
Number of passengers per car or taxi: say 1.7.
Number of cars and taxis: 1000/1.7 = 588 per hour.
Number of cars and taxis at one time: 588/40 = 16.
Length of kerb per vehicle: 6 m + 10%.
Length of kerbside for cars and taxis: 105.6 m.
Overall rule of thumb: 1.0 m of total kerbside (including public transport) per 10 passengers per hour.

IATA Airport Development Reference Manual references

Project data: Part 1.6.5.1.
Passenger Terminal functional areas: Part 3.6.

19.2 *Function*: waiting in landside public concourse

Context factors

International or domestic or both: not relevant.
Single-level or multi-level: not relevant.
Centralized or decentralized: a continuous public space is essential for decentralized processing.
Percentage of transfer passengers: if high, the concourse can reasonably be at ground level because relatively few passengers will need to climb up to the elevated airside concourse.

See Figures 19.2 area 2, 19.7 and 19.8.
Policy decisions to be applied

19.7 London Heathrow Terminal 4 landside concourse. Architects: Scott Brownrigg & Turner, Guildford.

19.8 London Gatwick North Terminal landside concourse. Architects: YRM Architects and Planners, London. Photographer: Richard Bryant.

Security: entry to the public concourse can be controlled by a security comb, but this is the least common option depending as it does on searching of passengers and visitors alike.
Commercial: shopping and catering facilities will be appropriate here, together with bureau de change (international terminal only), flight insurance sales office and post office. Provision for spectators may be made. Car park pay station for the benefit of car drivers seeing passengers off.
Baggage: All circulation areas should make allowance for baggage trolleys.
Government controls: access to airside to be provided for staff.
Airline: airlines will require ticket sales desks and offices.
Information systems: public display of information on departing flights. Information desk for public.
Predicted changes: provision may be made for exceptional conditions occasioned by delayed flights. Additional seating or even extra catering space, which may also be usable from the airside, may be provided.

Quantity factors to be assessed

Hourly passenger flows: two-way flow will be relevant where there is to be a combined departures and arrivals area.
Visitor ratio: a common ratio in the West would be 0.5 to 0.2 visitors per passenger (with even lower ratios for certain domestic traffic) and in the East or Africa 2.5 to 6 or even higher.
Processing rate: not relevant.
Estimated dwell time: a common time would be 20 minutes.

Typical space calculation based on 2000 originating passengers per hour

Number of people per hour: 5000 (1.5 visitors per passenger).
Number at one time (peaking factor, say 50% in 20 min): 2500.
Space per person (level of service A): 2.7 m^2.
Area required: 6750 m^2.
Some area may be in shops and catering spaces.

IATA Airport Development Reference Manual references

Project data: Part 1.6.5.2.
Passenger terminal functional areas: Part 3.5.2.

19.3 *Function*: Checking-in, with or without baggage

Here passengers show their tickets, have seats allocated and if necessary have large items of baggage weighed (and possibly security screened) for registration and loading into the aircraft hold.

Context factors

International or domestic or both: can be mixed.
Single-level or multi-level: system of baggage belts can exploit the change of level in the case of multi-level solutions.
Centralized or decentralized: The advantages of relieving the passenger of his heavy baggage as soon as he enters the terminal building at a central position can readily be seen. Conversely, the advantages of asking passengers to take heavy baggage to the point of boarding the aircraft, in some cases many hundreds of metres, lie in the avoidance of complex baggage sorting mechanisms: if baggage is checked-in at the gate it is ready-sorted. In the latter case problems arise if there are any difficulties over ticketing for passengers who have already bought their duty-free goods, etc. Thus it is that airport authorities provide for choice: a percentage of passengers, those without baggage, will wish to check-in at the last possible moment at the gate. Therefore a dual provision can be made, but the central location will be seen as the primary check-in (see Figure 18.1).
Percentage of transfer passengers: airside transfer passengers (those transferring from one international flight to another) will not use the check-in facility: their baggage will already be in the system and their onward fight details will have been checked at the transfer desk (see Section 19.12).

See Figures 19.2 area 3, 19.9 and 19.10.

Policy decisions to be applied

Security: all baggage may be searched by the airline's security staff at entry to their check-in area, or by the check-in and security staff at or near the desk by means of X-ray units.
Commercial: not applicable.
Baggage: one or more delivery points may be required for out-of-guage baggage.
Government controls: a customs check facility for certain heavy items of baggage may be provided in the check-in area.
Airline: offices for airlines and handling agents will be needed with close relationship with the check-in desks and preferably with a visual link.
Information systems: common-user terminal equipment will make it possible to allocate desks to any airline at any time, thereby reducing the number of desks needed. Otherwise the number of desks required is the sum total of those required by each handling agent, see below.
Predicted changes: the biggest single change will arise from the predicted advent of automated ticketing and issuing of boarding passes. Information technology which links the manual (conventional check-in system with baggage registration) and automated system (where the passenger simply communicates with a small machine) will make it possible to reduce the number of check-in desks while retaining the necessary central control which check-in clerks have always had. See also Section 23.3.

Quantity factors to be assessed

Hourly passenger flows: If CUTE is in use the total hourly flow to all desks can be used to compute the number: landside transfer passengers to be included.
Visitor ratio: not applicable.
Processing rate: a common rate would be 1.5 mins per passenger, with faster rates for domestic passengers.
Estimated dwell time: this is dependant upon the number of staffed check-in desks for a particular flight, but all check-in layouts have to make provision for queuing and a reasonable assumption is that a wait of 20 minutes is acceptable to passengers.
Percentage of passengers using gate check-in: this is a new facility and trends have yet to be established. Ten per cent usage of gate-check-in would be a reasonable assumption where the facility is provided at all, although even there it may only be made available by the airlines and their handling agents for certain flights.

Typical space calculation based on 2000 originating passengers per hour: central check-in

This will be irrespective of the configuration of desks (see Section 18.2).

Number of passengers per hour: 2000 minus 10% plus 10%.
Equiv number per hour (peaking factor, say 50% in 20 min): 3000.
Number of desks: 3000/40 = 76.

Queue depth might be 20 passengers at 0.8 m per person with check-in desks at approximately 2.0 m centres (max).

Space per person (level of service A): 1.6 m^2.
Total queuing area: 76 × 2.0 × 16 = 2432 m^2. Note that a discrete area is only applicable if there is a security-based separation between the landside public concourse and the check-in area.

IATA Airport Development Reference Manual references

Project data: Part 1.6.5.4.
Passenger terminal functional areas: Part 3.7.

19.9 *London Heathrow Terminal 4 check-in. Architects: Scott Brownrigg & Turner, Guildford.*

19.10 *Chicago O'Hare, United Airlines Terminal check-in hall. Architects: Murphy & Jahn, New York.*

19.4 *Function*: Pre-departure security check

Context factors

International or domestic or both: can be combined, pre-immigration.
Single-level or multi-level: not relevant.
Centralized or decentralized: economies of staffing and equipment can be made by locating one bank of security control equipment centrally, but the corollary of such a solution is that the whole airside area must be thus controlled, with every entry monitored by staff and security equipment. This militates in favour of segregated arrivals and departures routes, so the arriving passengers do not pass through the departures concourse and transfer passengers enter only at one or two points.
Percentage of transfer passengers: landside transfer passengers merge with the flow at this point, whereas airside (international to international) transfer passengers will have their own separate entry or entries to the airside concourse.

Policy decisions to be applied

Security: see *centralized or decentralized, above.*
Commercial: not applicable.
Baggage: in the case of central security, baggage belonging to passengers using the gate check-in facility needs to be taken into account.
Government controls: security control will either be the responsibility of the government/army/police force or of the airport authority.
Airline: airlines may also wish to conduct security checks.
Information systems: not applicable.
Predicted changes: as the demand for and perception of airline and airport security builds up changes can be expected.

Quantity factors to be assessed

Hourly passenger flows: for central security allow 10% transfer passengers, and for gate security allow 20% transfer passengers.
Visitor ratio: not applicable.
Processing rate: X-ray units handle 600 items per hour, with two X-ray units per metal detector archway.
Estimated dwell time: this is not calculable, since a problem item or passenger can very rapidly cause a queue to build up. The airport's objective must be for the security check to be carried out without interrupting the flow of passengers, but in reality staffing levels cannot totally eliminate queuing and a long queue area must be available without interrupting access to other functions.

Typical space calculation based on 2000 originating passengers per hour: central security check

For configurations see Section 18.3.
With two items of baggage or hand baggage per passenger.
One set (1 personnel metal detector plus 2 X-ray units) handles 600 passengers per hour.
2200 passengers per hour require 4 sets.

IATA Airport Development Reference Manual references

Project data: Parts 1.6.5.6 and 1.6.5.8.
Passenger terminal functional areas: Part 3.9.

19.5 *Function*: Outbound immigration check

Context factors

International or domestic or both: international only.
Single-level or multi-level: not relevant.
Centralized or decentralized: usually centralized.
Percentage of transfer passengers: landside transfer passengers will use this facility.

See Figures 19.2 area 4 and 19.11.

Policy decisions to be applied

Security: a central security control brings this area under security surveillance.
Commercial: not applicable.
Baggage: not applicable.
Government controls: Government policy will determine the designation of separate channels for different types of passport holders. Customs checks can also be carried out at this point, and offices and detention rooms will be required.
Airline: not applicable.
Information systems: private computer systems.
Predicted changes: the projected changes to border controls within the European Community post-1992 are an example of the effect of international policy-making. However, it is understood that border controls may still need to be exercised at times of emergency and therefore facilities should be retained.

Quantity factors to be assessed

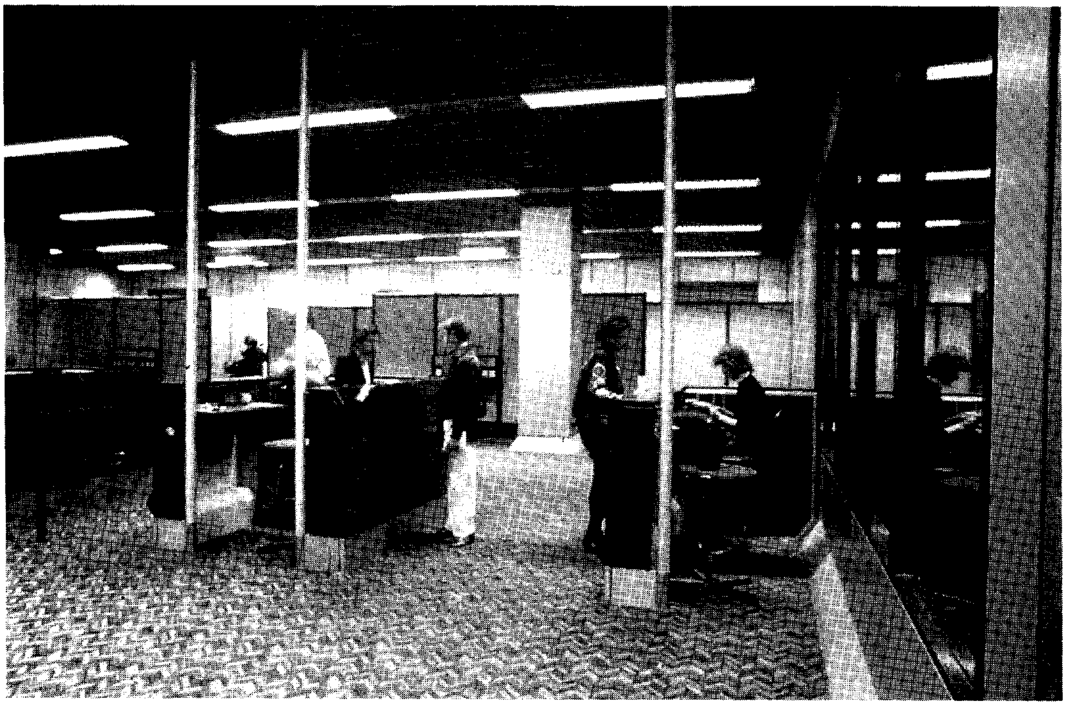
Hourly passenger flows: include landside transfers.
Visitor ratio: not applicable.
Processing rate: a common rate would be 10 sec per passenger.
Estimated dwell time: not applicable.

Typical space calculation based on 2000 originating passengers per hour

Number of passengers per hour: 2200.
Number of desks required: 6 (6.1 actually).
Area required (25 m^2 per desk): 150 m^2.

IATA Airport Development Reference Manual references

Project data: Part 1.6.5.5.
Passenger terminal functional areas: Part 3.10.



19.11 London Heathrow Terminal 4 outbound controls area. Architects: Scott Brownrigg & Turner, Guildford. For plan see Figure 19.2.

19.6 Function: Waiting in airside public concourse

Here passengers wait, shop, eat and drink and move sooner or later to the departure gate of their flight. In some cases this point may be the people-mover leading to a satellite or the coach station serving remote stands.

Context factors

International or domestic or both: not mixed.
Single-level or multi-level: a single-level airside concourse without segregation of arrivals and departures suggests a single-level entry to the bridgehead. Otherwise, in the case of two-level concourses, passengers will use stairs or ramps to the bridgehead.
Centralized or decentralized: many variations are possible dependant upon the forms of terminal analysed in Part II. However, the main distinction is between airside concourses with and without gate holding areas. Where provided these are intended to corral the passengers for each flight immediately before boarding to speed the process of boarding.
Percentage of transfer passengers: if high, a compact airside layout is essential.

See Figures 19.2 area 5 and 19.12.

Policy decisions to be applied

Security: see Section 4.1 above.
Commercial: shopping and catering facilities will be appropriate here, including duty-free shopping.
Baggage: not relevant, except that access must be provided for baggage trolleys throughout the concourse and shopping areas and amenities .
Government controls: not relevant.
Airline: airlines will have specific requirements at the gate positions. See Section 19.14 for CIP facilities.
Information systems: full information must be provided thoughout the concourse, and especially at the entries, on flight numbers, departure times, delays and gate numbers.
Predicted changes: none.

Quantity factors to be assessed

Hourly passenger flows: include landside and airside transfers.
Visitor ratio: not applicable.
Processing rate: not applicable to the concourse as such.
Estimated dwell time: a common standard would be 30 min.

Typical space calculation based on 2000 originating passengers per hour

Number of passengers per hour: 2400.
Number of passengers at one time: 1200.
Space per person (level of service A): 2.7 m^2.
Area required: 3240 m^2. Some area may be in shops and catering spaces. Gate holding areas should be sized to hold 80% of the maximum number of passengers boarding the largest aircraft which can dock at the stand in question.
Space per person (level of service A): 1.4 m^2.
Area for 400-seater aircraft: $320 \times 1.4 = 448\,m^2$.

IATA Airport Development Reference Manual references

Project data: Parts 1.6.5.7 and 1.6.5.9.
Passenger terminal functional areas: Part 3.5.4.

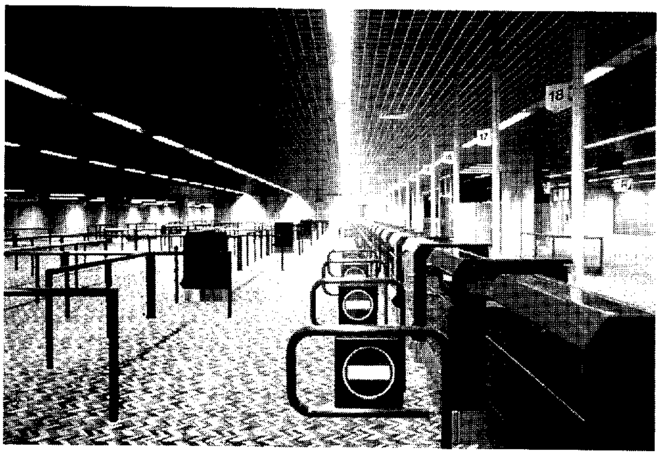
19.12 London Heathrow Terminal 4 airside concourse. Architects: Scott Brownrigg & Turner, Guildford.

19.7 *Function*: Inbound immigration check

Context factors

International or domestic or both: international only.
Single-level or multi-level: not relevant.
Centralized or decentralized: usually centralized.
Percentage of transfer passengers: landside transfer passenger will use this facility.

See Figures 19.3 area 6, 19.13 and 19.14.



19.13 London Heathrow Terminal 4 immigration control area. Architects: Scott Brownrigg & Turner, Guildford. For plan see Figure 19.3.

19.14 London Gatwick North Terminal immigration control area. Architects: YRM Architects and Planners, London. Photographer: Richard Bryant.

Policy decisions to be applied

Security: not applicable.
Commercial: not applicable.
Baggage: not applicable.
Government controls: Government policy will determine the designation of separate channels for different types of passport holders. Offices and detention rooms will be required.
Airline: not applicable.
Information systems: private computer systems.
Predicted changes: the projected changes to border controls within the European Community post-1992 are an example of the effect of international policy-making. However, it is understood that border controls may still need to be exercised at times of emergency and therefore facilities should be retained.

Quantity factors to be assessed

Hourly passenger flows: include landside transfers.
Visitor ratio: not applicable.
Processing rate: a common rate would be 30 sec per passenger for international passengers and 6 sec for domestic.
Estimated dwell time: not applicable.

Typical space calculation based on 2000 terminating passengers per hour

Number of passengers per hour: 2200.
If 50% international and 50% domestic passports, average processing rate is 18 sec per passenger.
Number of desks (without allowance for channelling): 11.
Area required ($25\,m^2$ per desk): $150\,m^2$.

IATA Airport Development Reference Manual references

Project data: Parts 1.6.5.11 and 1.6.5.12.
Passenger terminal functional areas: Part 3.10.

19.8 *Function*: Reclaiming baggage

Here passengers wait for and reclaim their baggage which has been unloaded from the aircraft while they have been travelling through the terminal building and passing through the immigration control.

Context factors

International or domestic or both: cannot be mixed, but requirements not affected.
Single-level or multi-level: the mechanism for delivering the baggage on to the reclaim devices can exploit the changes of level in a multi-level solution.
Centralized or decentralized: normally centralized.
Percentage of transfer passengers: not relevant.

See Figures 19.4 area 8, 19.15 and 19.16.

Policy decisions to be applied

Security: by definition all baggage in this area will have just been unloaded from aircraft.
Commercial: not applicable.
Baggage: there needs to be a means of delivering out-of-guage baggage to the passengers, and also a means for passengers to claim their baggage after they have passed through to the landside, either because they have forgotten it or because due to airline problems it has arrived on a different flight from them.

19.15 London Heathrow Terminal 4 baggage reclaim area. Architects: Scott Brownrigg & Turner, Guildford. For plan see Figure 19.4.

19.16 London Heathrow Terminal 1 baggage reclaim islands.

Government controls: not applicable.
Airline: none.
Information systems: numbers of reclaim units need to be displayed against the arriving flight numbers, particularly in areas where passengers are entering the reclaim area.
Predicted changes: none.

Quantity factors to be assessed

Hourly passenger flows: landside transfer passengers need to reclaim their baggage.
Visitor ratio: not applicable.
Processing rate: there are several ways of calculating throughput in baggage reclaim, but the one used here is based on the IATA Airport Terminals Reference Manual. A reclaim device for narrow-bodied aircraft should have a length of 30–40 m and one for a wide-bodied aircraft should have a length of 50–65 m. Average occupancy times for narrow- and wide-bodied aircraft would be 20 and 45 min respectively.
Estimated dwell time: a common standard would be 30 min.
Number of checked-in bags per passenger: possibly an average of 1.0 depending on whether the flight is long haul or short haul, although the flow calculation method used does not depend upon this factor.

Typical space calculation based on 2000 terminating passengers per hour

Number of passengers per hour: 2200.
Number of passengers at one time: 1100.
Space per person (level of service A): 1.6 m^2.
Area required (min. incl. waiting area): 1760 m^2.
However, the operative calculation is for the number of reclaim units and the space round each for a flight load of passengers waiting. Assume 50% of passengers arrive by wide-bodied and 50% by narrow-bodied aircraft.
Number of passengers per narrow-bodied aircraft at 80% load factor: 100.
Number of passengers per wide-bodied aircraft at 80% load factor: 320.
Number of narrow-bodied devices: $1100/3 \times 100 = 4$.
Number of wide-bodied devices: $1100/1.33 \times 320 = 3$.
Space per person (level of service A): 1.6 m^2.
Waiting area for narrow-bodied device: 160 m^2.
Waiting area for wide-bodied device: 512 m^2.
Total waiting area: $4 \times 160 + 3 \times 512 = 2176$ m^2 (excluding central waiting area at entry to baggage reclaim area).

IATA Airport Development Reference Manual references: amended

Project data: Parts 1.6.5.13 and 1.6.5.14.
Passenger terminal functional areas: Part 3.8.10.

19.9 *Function*: Inbound customs clearance

Passengers need an 'orientation' area as they approach the choice of entry to the customs area which will normally be designated as red and green channels.

Context factors

International or domestic or both: international only.
Single-level or multi-level: not relevant.
Centralized or decentralized: normally centralized.
Percentage of transfer passengers: landside transfer passengers will be included.

See Figure 19.4 areas 9 and 10.

Policy decisions to be applied

Security: customs officers are increasingly on the lookout for narcotics rather than contraband.
Commercial: not applicable.
Baggage: Provision for baggage trolleys.
Government controls: offices and search rooms will be required. Type of surveillance will need to be determined.
Airline: not applicable.
Information systems: not applicable.
Predicted changes: the changes to border controls within the European Community post-1992 are an example of the effect of international policy-making. However, it is understood that border controls may still need to be exercised at times of emergency and therefore facilities should be retained.

Quantity factors to be assessed

Hourly passenger flows: include landside transfers.
Visitor ratio: not applicable.
Processing rate: a rate for passengers being searched would be 2 min per passenger.
Estimated dwell time: not applicable.

Typical space calculation based on 2000 terminating passengers per hour

Number of passengers per hour: 2200.
Area required if 0.5 m^2 per passenger per hour: 1100 m^2.

IATA Airport Development Reference Manual references

Project data: Parts 1.6.5.15 and 1.6.5.16.
Passenger terminal functional areas: Part 3.10.

19.10 *Function*: Waiting in landside public space

Context factors

International or domestic or both: not relevant.
Single-level or multi-level: not relevant.
Centralized or decentralized: a continuous public space is essential in the case of decentralized processing.
Percentage of transfer passengers: not relevant.

See Figures 19.4 area 11, 19.17 and 19.18.

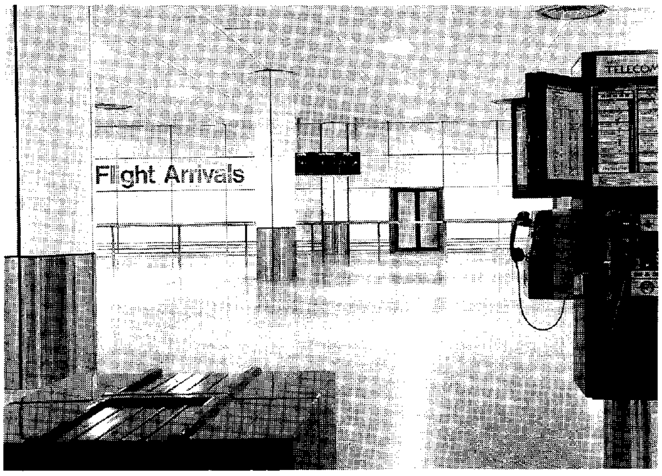
Policy decisions to be applied

Security: entry to the public concourse can be controlled by a security comb, but this is the least common option depending as it does on searching of passengers and visitors alike.
Commercial: shopping and catering facilities will be appropriate here, together with bureau de change (international terminal only), hotel bookings and car hire sales desks and offices and post office. Provision for spectators may be made.
A car park pay station for the benefit of car drivers meeting passengers may be necessary.
Baggage: all circulation areas should make allowance for baggage trolleys.
Government controls: access to airside to be provided for staff.
Airline: not applicable.
Information systems: public display of information on arriving flights. Information desk for public.
Predicted changes: provision may be made for exceptional conditions occasioned by delayed flights. Additional seating or even extra catering space for meeters and greeters may be provided.

Quantity factors to be assessed

Hourly passenger flows: two-way flow will be relevant where there is to be a combined departures and arrivals area.
Visitor ratio: a common ratio in the West would be 0.5 to 0.2 visitors per passenger (with even lower ratios for certain domestic traffic) and in the East or Africa 2.5 to 6 or even higher.
Processing rate: not relevant.
Estimated dwell time: a common time would be 10 min for passengers and 30 min for meeters and greeters.

19.17 London Heathrow Terminal 4 landside concourse. Architects: Scott Brownrigg & Turner, Guildford.



19.18 London Gatwick North Terminal landside concourse. Architects: YRM Architects and Planners, London. Photographer: Richard Bryant.

Typical space calculation based on 2000 terminating passengers per hour

Number of people per hour: 5000 (1.5 visitors per passenger).
Number at one time (2000/6 + 3000/2): 1833.
Space per person (level of service A): 2.7 m^2.
Area required: 4949 m^2. Some area may be in shops and catering spaces.

IATA Airport Development Reference Manual references

Project data: Part 1.6.5.17.

19.11 *Function*: Leaving the terminal by car or bus

Context factors

International or domestic or both: not relevant.
Single-level or multi-level: a single-level forecourt may mix arrivals and departures (see Section 19.1).
Centralized or decentralized: if processing is decentralized, the pick-up areas may be dispersed.
Percentage of transfer passengers: if high the forecourt is most likely to be single-level.

See Figures 19.19 and 19.20.

Policy decisions to be applied

Security: not relevant.
Commercial: for commercial reasons the whole forecourt or at least the private car section may be incorporated in the short-term or nearest car park. This will force motorists to pay for the privilege of parking close to the arrivals area.
Baggage: for high volumes of inclusive tour traffic, with coaches picking up large pre-sorted volumes of baggage, it may be appropriate to have a dedicated area and a route from the baggage areas.
Government controls: not relevant.
Airline: for large terminals shared by many airlines it may be appropriate to have signed sections of forecourt.
Information systems: as above.
Predicted changes: take account of any predictable changes in traffic mix which may affect the modal split (the percentages of passengers leaving by car or bus).

Quantity factors to be assessed

Hourly passenger flows: in the case of a combined departures and arrivals forecourt a planned two-way rate will be relevant.
Visitor ratio: not relevant. Numbers of people meeting passengers will not be a determinant of the forecourt.
Processing rate: not relevant.
Estimated dwell time: an average of 1.5 minutes may be allowed for cars and taxis.
Modal split: subject to local conditions, 50% of passengers may use private cars and taxis. Many types of bus and coach will call at the arrivals forecourt, and need dedicated waiting positions. In order to provide the shortest route for the greatest number of passengers, coach and bus bays should be located closest to the terminal doors.

Typical space calculation based on 2000 terminating passengers per hour

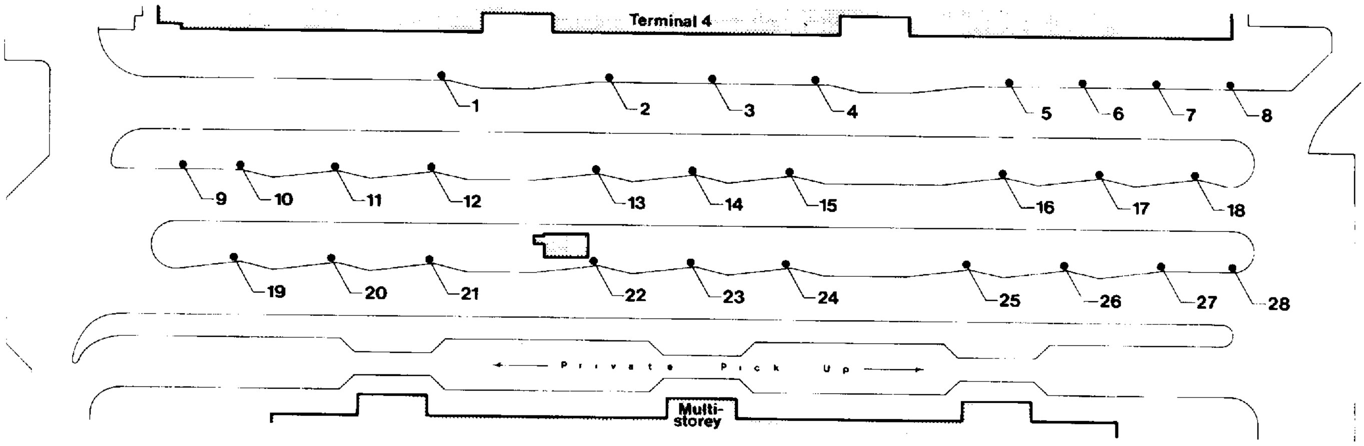
Number of passengers per hour at kerbside for cars and taxis: 1000.
Number of passengers per car or taxi: say 1.7.
Number of cars and taxis: 1000/1.7 = 588 per hour
Number of cars and taxis at one time: 588/40 = 16.
Length of kerb per vehicle: 6 m + 10%.
Length of kerbside for cars and taxis: 105.6 m.
Overall rule of thumb: 1.0 m of kerbside (including public transport) per 10 passengers per hour.

IATA Airport Development Reference Manual references

Project data: Part 1.6.5.18.
Passenger terminal functional areas: Part 3.6.

19.19 London Heathrow Terminal 4 arrivals forecourt. Architects: Scott Brownrigg & Turner, Guildford.

Key
1 Taxis
2 Railair/Rickards/Alder Valley
3 Long term car park
4 Car rental concession
5 Transfer to Terminal 1
6 Transfer to Terminals 2 and 3
7 Alder Valley/Careline
8 Staff car park
9–11 Jetlink/National Express/City of Oxford
12 Speed link
13–15 Flight line/Airbus
16 Flightlink
17 National Express
18 City of Oxford/Southend/Premier
19–24 Group travel
25–26 Green Line/London Country
27 Local hotels
28 Off airport car parking/rental



19.20 London Heathrow Terminal 4 arrivals forecourt plan.

19.12 *Function*: Transit and transfer facilities

Transit passengers simply reboard the same aircraft. Transfer passengers board another aircraft without leaving the airport. If transferring from international to domestic or vice versa they need to pass through the control systems and therefore reclaim their baggage unless it has been booked through. This latter is more likely in the case of transfer from domestic to international traffic. Passengers need information about their onward flights.

The facilities for transfer passengers are the very heart of a hub terminal. Section 6.5 referred to the characteristics of a hub terminal, and to the minimum connecting time being a major determinant of layout. An airline schedule built on offering passengers onward connections depends upon speedy travel through the terminal for those passengers. It may be appropriate to provide decentralized border controls where clearances are to take place for passengers transferring from international flights to domestic ones on the principle of port-of-entry rather than port-of-destination.

The achievement of minimum hub connecting times will set a standard for intra-terminal and inter-terminal people-mover systems.

Transfer facilities in the vicinity of the terminal may be required for express packages and express documents, generally each weighing 68 kg or less. A busy hub may handle thousands of such items, and their speedy and accurate transfer from flight to connecting flight is the essence of an efficient air courier service.

Context factors

International or domestic or both: according to traffic.
Single-level or multi-level: not relevant.
Centralized or decentralized: a continuous airside corridor is needed.
Percentage of transfer passengers: if high, the transfer facility will be the focus of the airside.

See Figures 19.3 area 7 and 19.21.

Policy decisions to be applied

Security: transfer facilities will be outside the secure airside zone. Airside transfer passengers will re-enter this through a separate security control.
Commercial: not applicable.
Baggage: not relevant.
Government controls: not relevant.
Airline: information desks will be needed.
Information systems: CUTE (see Section 17.5 and Section 19.3).
Predicted changes: note the effect of changes in airline scheduling. Co-ordination of arrivals and departures, which on a large scale can generate a genuine hub, will encourage transfer traffic.

Quantity factors to be assessed

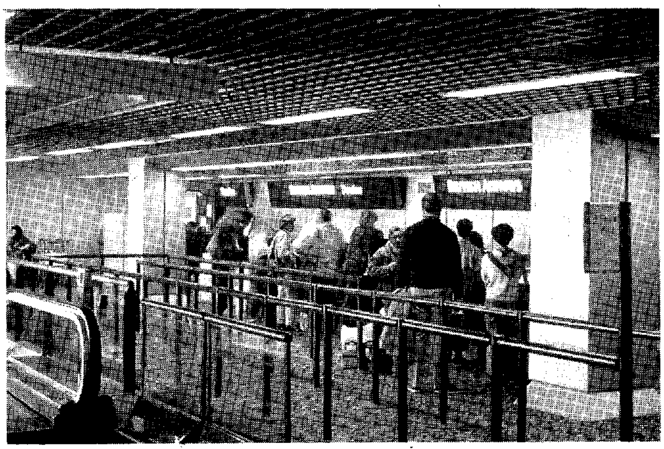
Hourly passenger flows: peaks will be caused by flight arrivals. Numbers of passengers will be relatively low except in the case of hub terminals.
Visitor ratio: not applicable.
Processing rate: a common rate would be 30 sec per passenger.
Estimated dwell time: a maximum of 5 min would be acceptable. The very essence of the processing of transfer passengers is speed.

Typical space calculation based on 2000 originating and terminating passengers per hour

Assume 20% transfer passengers.
Number of passengers per hour: 400.
Number of desks: 4.
Queue depth (0.8 m per passenger): 8.0 m

IATA Airport Development Reference Manual references

Passenger terminal functional areas: Parts 3.10.4–6.



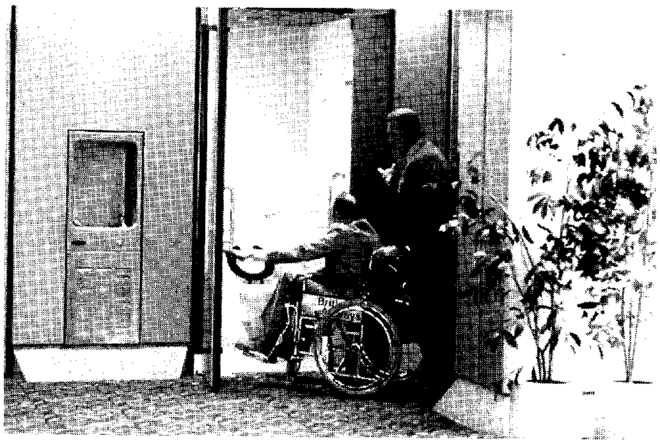
19.21 London Heathrow Terminal 4 transfer area. Architects: Scott Brownrigg & Turner, Guildford. For plan see Figure 19.3.

19.13 Facilities for the disabled

In making specific provision for disabled passengers and visitors, terminal design should be in accordance with the widest definition of 'disabled', beyond the immediately obvious needs of the wheelchair user to aspects of many ambulant disabilities. Hence detailed aspects for consideration will include, for example, the provision of braille lift-call buttons, signing which takes account of common colour-blindness traits, the inclusion of an induction loop for the hard of hearing and telephones, desks and other facilities at an accessible level. Unisex disabled toilets maximize flexibility for both users and helpers, in staff as well as public areas, Figure 9.22. Although most airports are equipped and prepared to assist disabled passengers through their journey, the option must exist for the passenger to cope alone if they wish. Almost inevitably, making a terminal easier to use for a disabled user will make it easier to use for the able bodied, Figure 9.23. Several airports now provide special information desks for disabled passengers. Vancouver International Airport was the first to provide an unattended, self-contained information centre accessible to all, including wheelchair users and those with speech, hearing or visual impairments. The booth, called Communicaid II, provides data on arrivals, departures and location of terminal services.

IATA Airport Development Reference Manual reference

Passenger terminal functional areas: Part 3.11.



19.22 London Heathrow Terminal 4 wheelchair users' WC.

19.23 London Heathrow Terminal 4 check-in.

19.14 CIP and VIP facilities

Waiting lounges for first class ticket holders are provided by airlines with significant passenger throughput within the area of the airside departures concourse. The facilities are at the choice and expense of the airline. Suites of rooms for very important passengers are generally provided by the airport authority, whose guests the VIPs are while on the ground. These rooms are accessible by car from both the landside and airside, while being inside the security cordon, and include facilities for customs and immigration officials to attend arrivals and departures.

References

International Air Transport Association (1995) *Airport Development Reference Manual* (8th edition). Montreal, IATA.

20 Baggage handling

Baggage handling as defined here refers to the conveying of baggage which has been checked in by passengers for transport in the hold of the aircraft. The activity of check-in itself and the delivery of baggage back to arriving passengers have already been described in preceding chapters.

Airlines are responsible for loading their passengers' baggage; handling agents (companies which exist to provide services for airlines in some cases operating one flight per week to a particular airport and therefore having limited staff presence), assemble flight loads. All wide-bodied jet aircraft have containerized baggage. See below for details of the containers used.

Airlines, by their ticketing and pricing systems, set limits on the amount of baggage that passengers take and check in. It is unusual for a flight load of 200 passengers to check in as many as 400 items of hold baggage. The norm also is for items to range in size between a small briefcase and a large suitcase. Items such as skis have to be classed as out-of-guage and handled separately from the rest because no system can be economically designed for the worst case. In practice, this means the provision of a route for porters to use to carry these items from the check-in desk to the point where the flight load is assembled or even directly to the aircraft.

In the case of arriving baggage, clearly there is no need to go through any sorting stage. A complete flight load needs to be taken from the aircraft to a collection point at the terminal, and the only complication is that baggage for direct transfer to other flights, identified by labelling, needs to be taken to a different point.

One step in baggage processing now found to be necessary in the handling of arriving baggage is the checking of a complete flight load for drugs. This is most conveniently carried out using dogs on a 'sniffer' belt before being discharged to the passenger reclaim belt.

20.1 Baggage handling systems

Checked-in baggage can either be routed direct from the single-flight check-in desk to the container or trolley en route to the aircraft or collected on multi-flight belts to be carried to a sorting area for assembly of flight loads. Baggage sorting can be of the three following types:

- manual, with staff reading labels and lifting items into place,
- semi-automatic, with staff reading labels and directing automatically to flight loading positions, or
- fully automatic, with electronic reading of labels and direction to flight loading positions.

Irrespective of the type of system, the following standards apply to baggage conveyor belts:

Width: 900 mm.
Gradient: 32% maximum.
Clearance above for obstacles: 1200 mm.
Inner radius for turns: 900 mm.
LD3 trailer size with container: 3.5 m long, 1.75 m wide, 2.4 m high with flap up.
LD4 trailer size with container: 4.5 m long, 1.75 m wide, 2.4 m high with flap up.

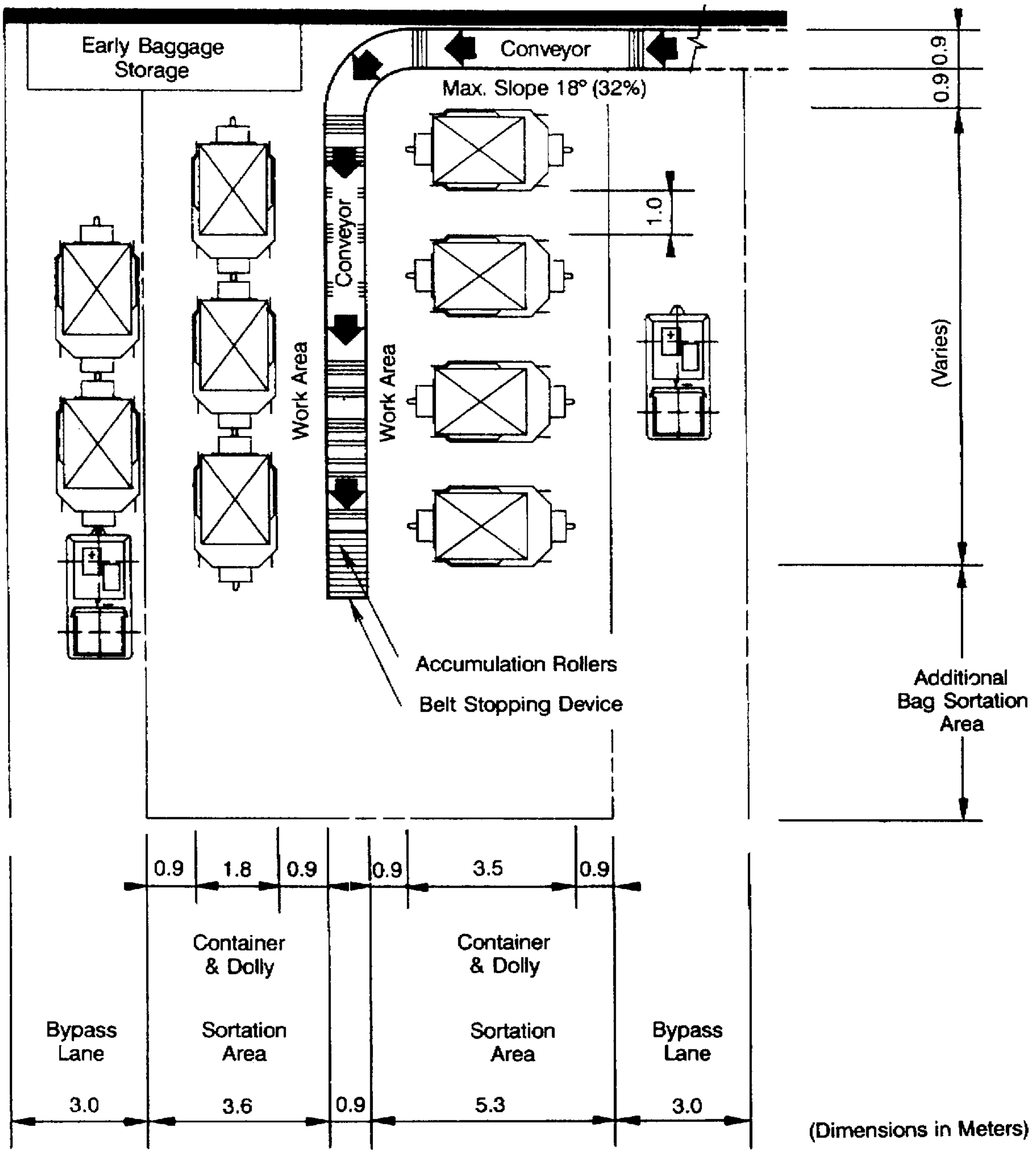
20.2 Manual sorting layouts

The optimum system is for the baggage to be conveyed from central banks of check-in desks to a circulating belt, alongside which are ranged the baggage trolleys and containers for the flights served. Baggage handling staff read baggage labels and off-load items at the appropriate points. Since staff are in attendance there is no need for reservoir areas for sorted but not loaded baggage.

Gate check-in creates the need for baggage chutes, but on arrival at apron level adjacent to the aircraft stand the baggage needs no further sorting, Figures 20.1–20.3.

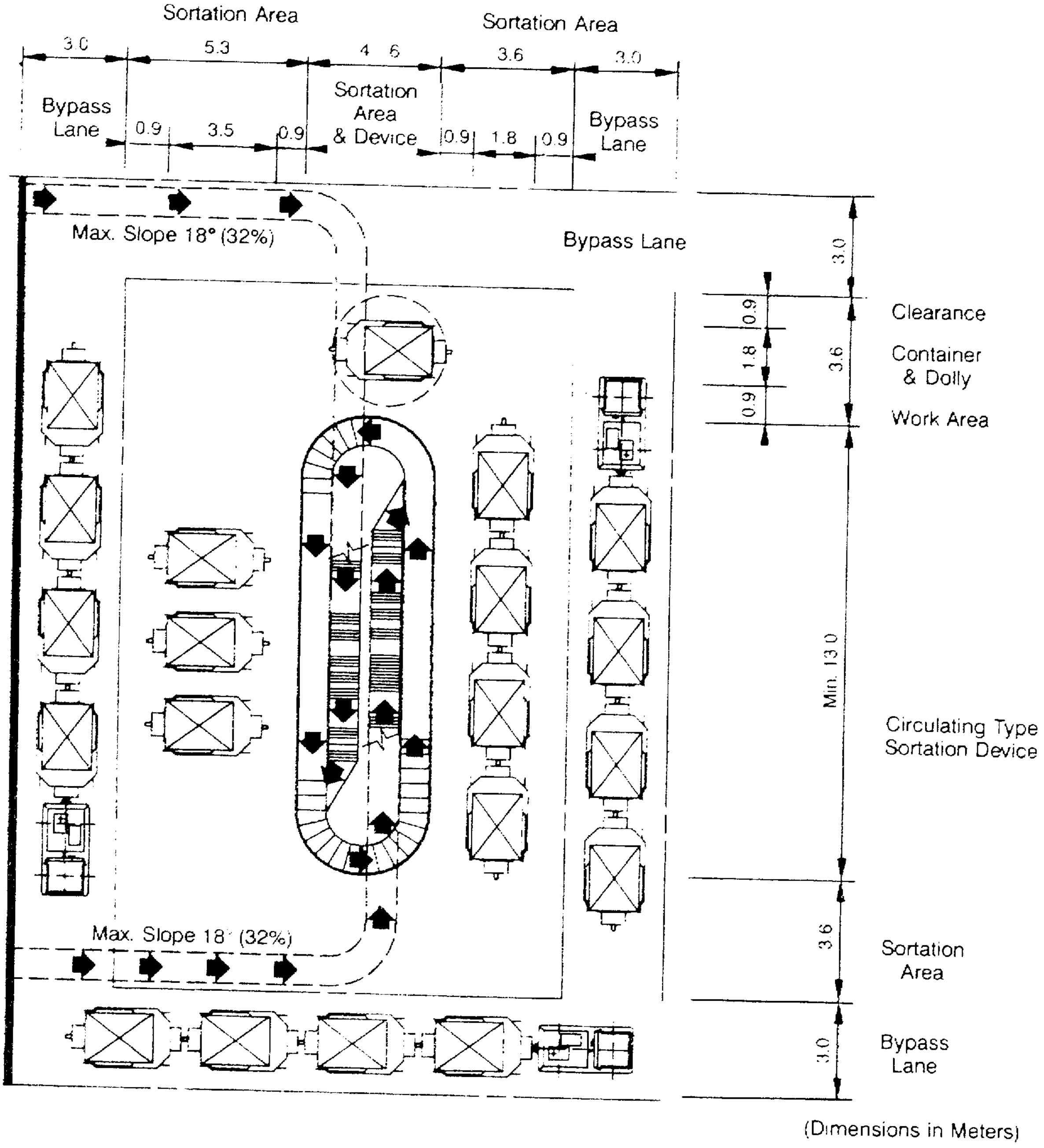
20.3 Semi-automatic and automatic sorting systems

The principle here is one of minimum staffing. It has to be borne in mind that a terminal with an hourly



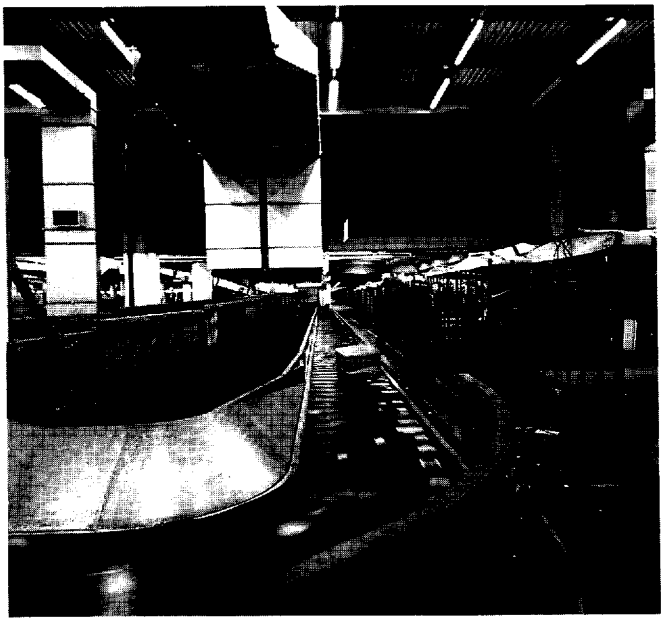
Note: *The preferable container parking configuration is that shown on the left side of the baggage belt which permits direct loading from the conveyor into the container. Container dolly dimensions may vary at specific locations; check with airlines locally.*

20.1 Single-feed departures baggage sorting system, from IATA Airport Development Reference Manual.



Note: *This should be inclined type of device; otherwise indexing feed system is required. The preferable container parking configuration is that shown on the right side of the sortation device (parallel) which permits direct loading from the device into the container. Container dolly dimensions may vary at specific locations; check with airlines locally.*

20.2 Multiple-feed departures baggage sorting system, from IATA Airport Development Reference Manual.



20.3 *Manual baggage make-up at London Gatwick.*

throughput of 2000 passengers and 20 flights departing in the check-in period of two hours, each with an average of two destinations, might need 40 baggage assembly or 'make-up' positions, each requiring staffing in the absence of an automatic system. Where automation takes over, baggage can be allowed to collect on a sorting spur or in a large tray ready for loading into containers or on to trolleys at the last moment.

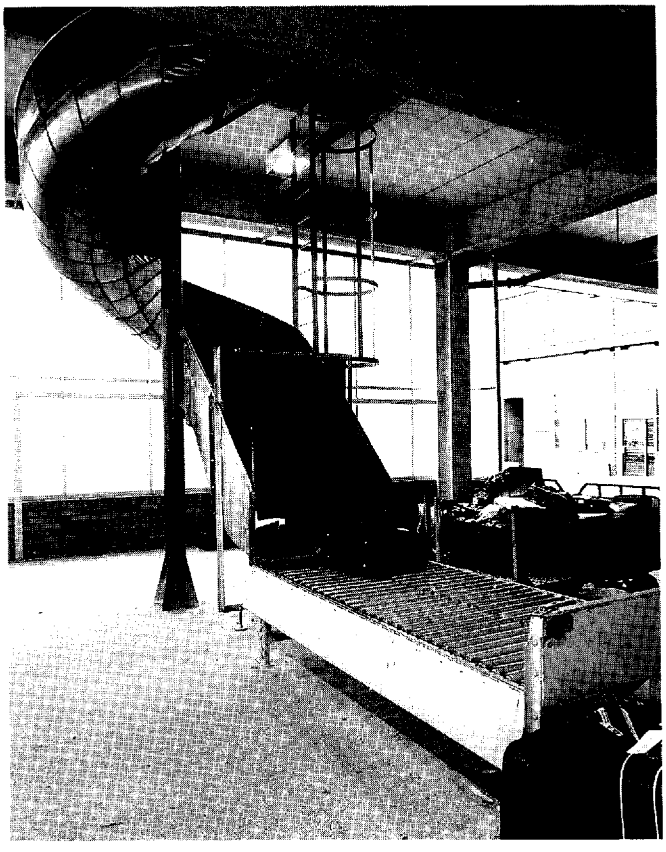
It is these baggage systems which pose the greatest constraint on the layout of large airport terminals. It is almost a case of designing the terminal around the baggage handling cathedral. The analogy of the cathedral is used because of the height and mystery of the required space. The priest is the operator who sits high up and directs the bags to their destinations. The height is necessary to provide all the crossovers of belts.

In addition to the sheer bulk of mechanical sorting systems and the difficulty and cost of reconfiguring them, there is the complexity of achieving flexible distribution of a bag from any check-in desk to any spur.

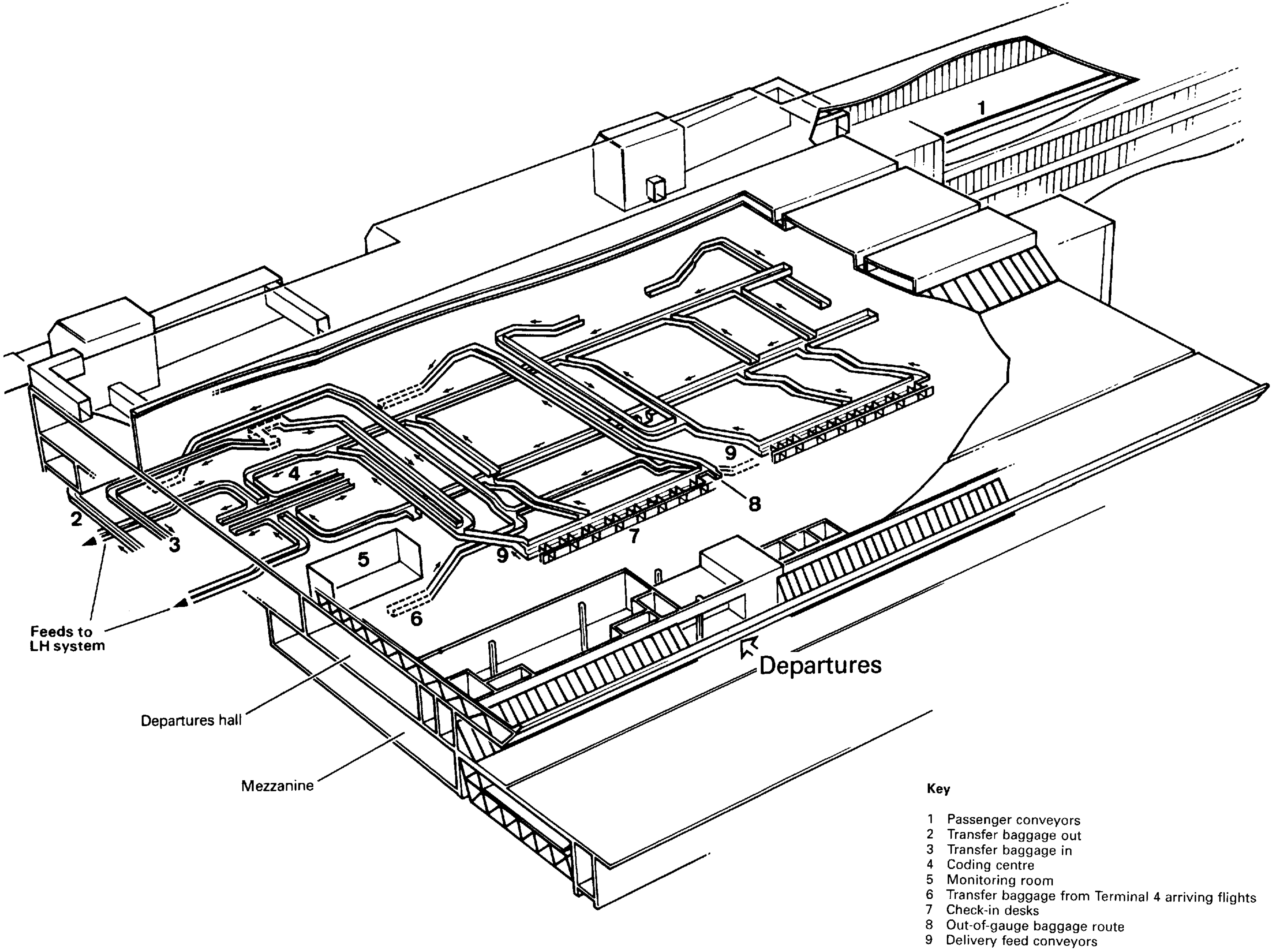
The pursuit of maximum reliability is paramount: mis-sorting of baggage is a cause of costly delay at the airport if the error is spotted in time or a cause of anguish to the passenger involved if not. Automation trials are being held in many places. Trials were carried out in 1987 at Heathrow Terminal 4 with a Marconi voice recognition system, in which the sorter (whose voice characteristics have already been recorded on the computer) merely speaks the destination, flight number or sorting spur of the bag coming past him. An increase of 50 per cent in sorting speed, from 20 to 30 bags per minute was achieved.

Fully automatic sorting will be possible with laser bar code reading of baggage tags or with optical character reading (OCR). Airport authorities are now satisfied that tags can be scanned successfully no matter in what position the bag is lying on the conveyor, but international operation of such a system depends upon international standardization and as yet no standards exist, even in the USA. The important advantage of OCR in the future will be that it can sort up to 60 bags per minute, matching the capability of the latest mechanical sorting system. Further in the future lies the possibility of baggage labels with

20.4 *Tilt tray mechanism at Zürich.*



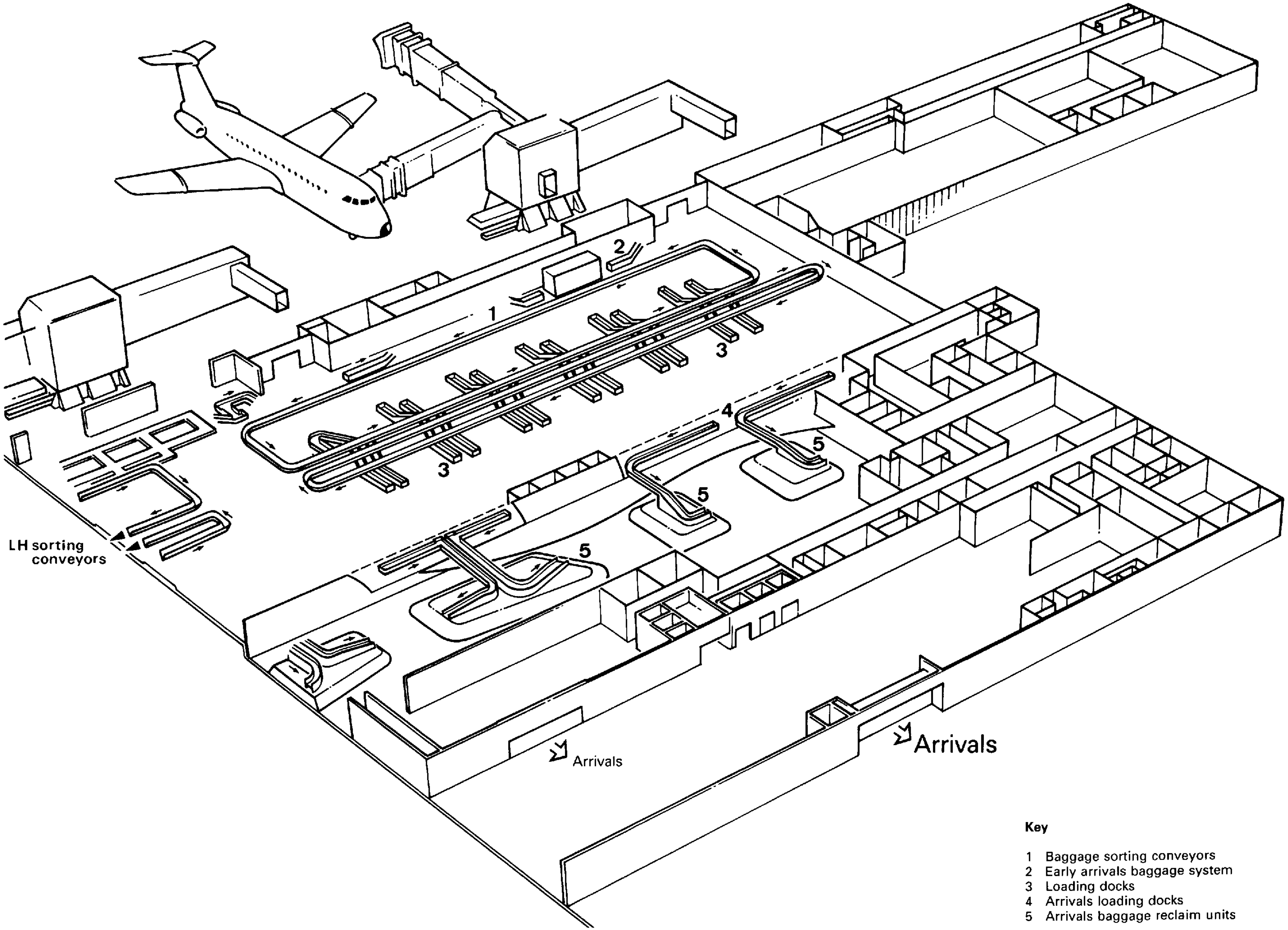
20.5 *Gate baggage drop at London Heathrow Terminal 1. Figures 20.3–20.5 courtesy of Messrs Logan Fenamec.*



Key

1 Passenger conveyors
2 Transfer baggage out
3 Transfer baggage in
4 Coding centre
5 Monitoring room
6 Transfer baggage from Terminal 4 arriving flights
7 Check-in desks
8 Out-of-gauge baggage route
9 Delivery feed conveyors

20.6 *London Heathrow Terminal 4 composite baggage handling, upper plan. Courtesy of Messrs Logan Fenamec.*



20.7 *London Heathrow Terminal 4 composite baggage handling, lower plan. Courtesy of Messrs Logan Fenamec.*

embedded microchips which could be used to record a much wider variety of information than just the flight number and destination.

Apart from the encoding and routeing technology, there are a range of mechanical devices to carry and divert items of baggage, Figure 20.4.

Provision also needs to be made for the transport to the apron of baggage checked in at the gate by late passengers. This an important aspect of passenger service in the eyes of the airlines, Figure 20.5.

Heathrow Terminal 4 composite diagrams in Figures 20.6 and 20.7 show half the terminal.

Reference

International Air Transport Association (1995) *Airport Development Reference Manual* (8th edition): Part 3.8. Montreal, IATA.

21 Flight information systems and signage

At the last count there were 17 different types of technology in use in the flight information display market. They fall into three main categories: electromechanical (for example, flap-boards), light-emitting electronic (television screens) and non light-emitting electronic (liquid crystal displays). Finding the most suitable technology for a particular terminal requirement is not as difficult as it might seem and the choice interacts with other factors of terminal design, Figures 21.1–21.3. The decision is based on:

- the amount of money the airport has to spend,
- the operating environment, lighting level, etc.,
- the density of traffic (frequency of update) and
- the distance between passengers and screen.

Static signs are important and need to be clear, consistent and well sited. The importance of these is shown by investment by airport authorities in standard systems and styles, recognized by frequent flyers and unfamiliar foreign travellers alike: see illustrations in Chapters 7–14 and in Chapter 19.

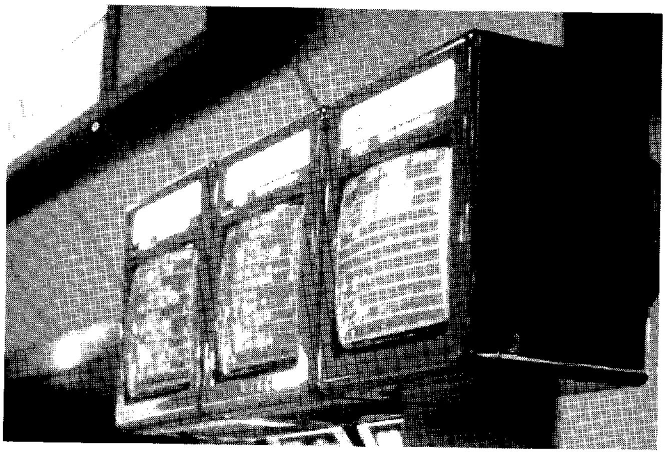
Public address systems are important too. In order to achieve flexibility of zoning of announcements Heathrow Terminal 4, for example, has 23 microphone positions and over 900 loudspeakers.

Figures 21.4 and 21.5 show the principal dynamic signs relating to departures and arrivals respectively. Others are as follows:

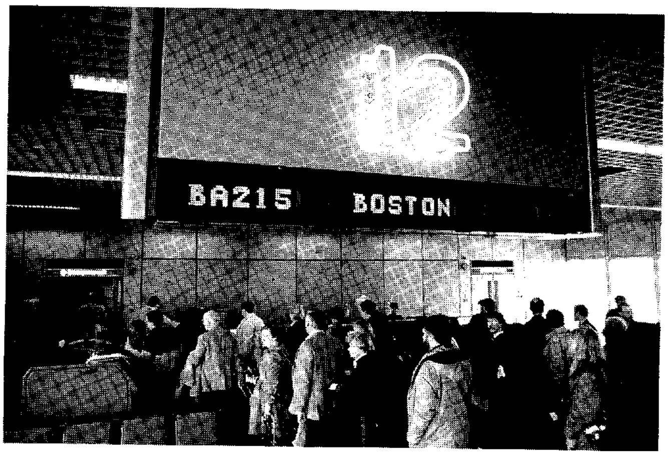
- airline name displays over check-in desks, activated from the desks,
- baggage loading directory for baggage handlers,
- ground transportation information displays,
- apron information displays related to gates and of value to all staff functions, and
- interactive information for passengers.

Chapter 24.3 addresses the integration of information technology.

21.1 Examples of display technology: Solari flap-board at London Heathrow Terminal 1.



21.2 *Ferranti TV screen at London Heathrow Terminal 4.*



21.3 *Racal LCD display at London Heathrow Terminal 4.*

Further reading

Blacklock, M. (1991) Visibly improving. *Airports International*, November.

Blacklock, M. (1992) Relaying the message. *Airports International*, September.

Bohush, L. S. (1989) VIDS for the future: Accuracy and flexibility. In *Airport Technology International 1989/90*, edited by M. G. Hudson.

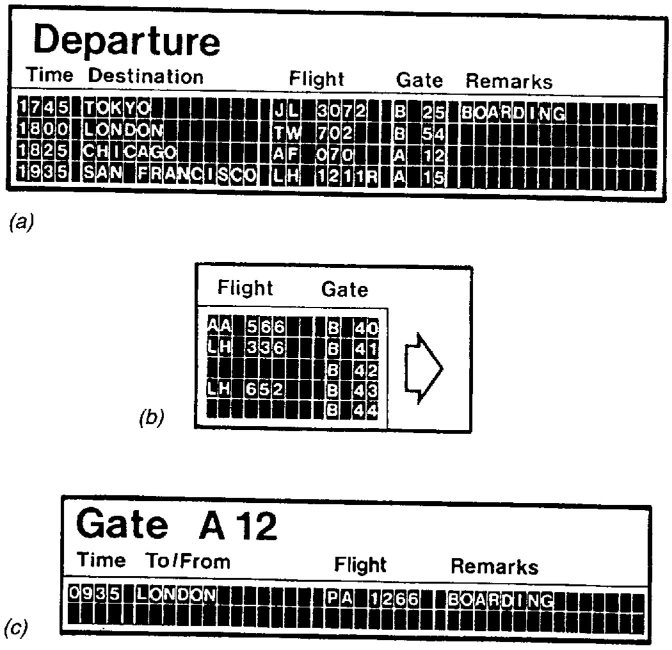
Butterworth-Hayes, P. (1985) Brighter types of screen characters. *Airports International*, July.

Butterworth-Hayes, P. (ed.) (1987) The search for life after CRT. *Airports International*, September.

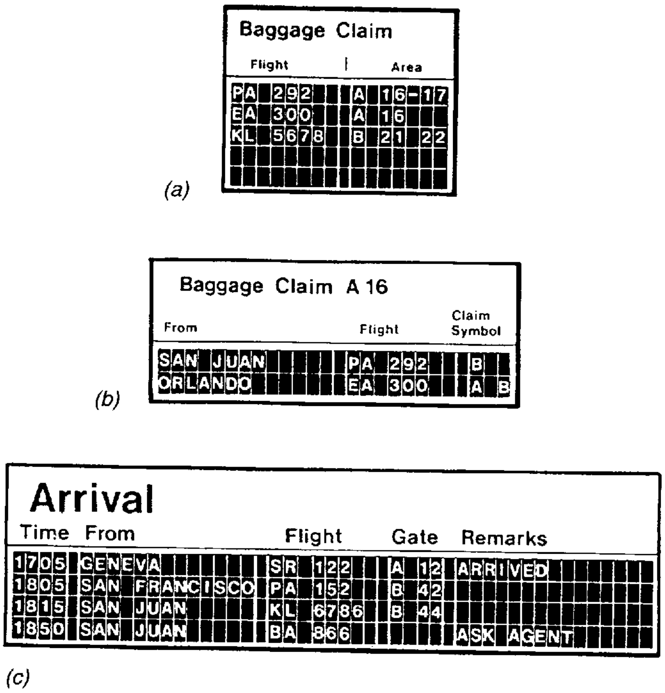
McCall, H. J. (1985) PA for T4. *Building Services*, December.

Momberger, K. and Momberger, M. (1988) Visual information displays can do more than just provide flight data. *Airport Forum*, **3**.

Walker, C. (1990) Intelligent displays. *Jane's Airport Review*, January/February.



21.4 *Departures signing: (a) main display, used in check-in/departures/transfer areas; (b) gate directory, used at entrance to satellites and concourses; (c) gate information, used at the gate itself (same format for arrivals).*



21.5 *Arrivals signing: (a) baggage claim directory, used where there are multiple claim areas and/or devices; (b) baggage claim unit information; (c) main arrivals display, used to inform people meeting passengers.*
Figures 21.4 and 21.5 from IATA Airport Development Reference Manual.

22 Conditions, finishes and fire criteria

22.1 Environmental standards and control

Acoustics

The main economic expedient for attenuating noise-generating activities is to site such sources at a distance from passenger terminals. Aircraft noise itself is perhaps more easily tolerated at airports where it is anticipated, than for example along the flight path. For many passengers the sound of aircraft enhances the expected thrill of air travel.

The opportunity to view arriving and departing aircraft from the airside of a terminal during the later stages of departure is a common requirement of a design brief, introducing extensive areas of glazing. Noise transfer through window walls is reduced to reasonable levels by double or triple glazing. A typical sound reduction requirement to BS 2750:1980 Part 3 would be to achieve indices of 22–62 for frequencies ranging from 63 Hz to 8 KHz, depending of course upon the particular location.

The higher levels of attenuation are necessary in highly staffed areas, where interviewing and security activities may also be taking place. Where staff are in occupation for 6 hours or more per day, it is desirable to reduce the perceived noise contour to attenuate to a minimum of, say, 40 dBA.

Whilst hard surfaces in concourses are generally acceptable in terms of the normal background noise of the terminal, the use of carpet in airside spaces provides a quieter starting and finishing mood for travel.

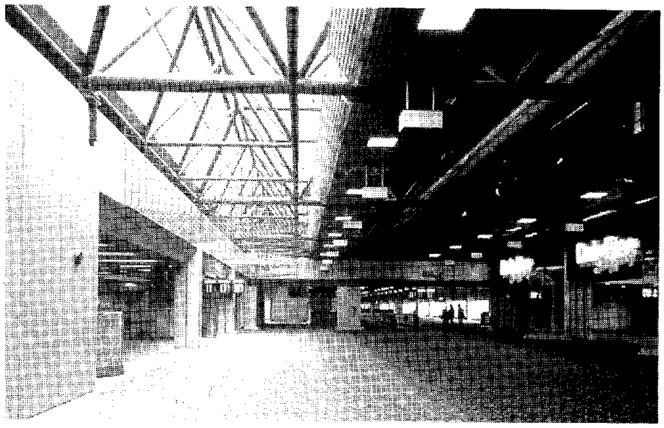
Lighting

Daylighting is always welcome inside passenger terminals, particularly when accompanied by a view of aircraft. However the control of artificial lighting is a significant element in determining comfort and ambience. The lighting designer will not wish to dazzle the arriving passenger who may be tired and looking for a subdued return to the world. Nevertheless good lighting will bring reflective surfaces to life in the concourses, and stimulate the input of the commercial enterprises contained therein.

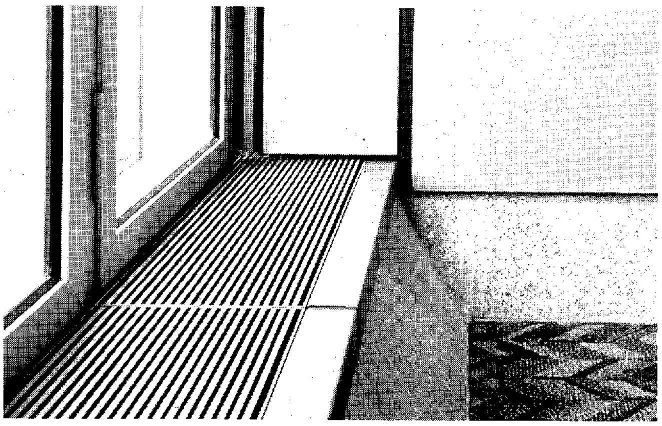
22.2 Finishes

Airport terminals are exacting test-beds for all materials; in particular floors and the lower levels of walls. The architect will, therefore, need to temper with practicality the interior image that he is striving to achieve. Primary considerations concern the nature of the activities taking place in each location, the length of time passengers spend there, and, of course, the level of usage.

22.1 Polished terrazzo flooring.



22.2 Carpeting of airside concourse edged by 45° splayed terrazzo skirting.



22.4 Window wall, perimeter heater casing, internal panelling and 45° skirting.

22.3 300mm square granite ceramic tiles in cafe area.

22.5 Trolley traffic tests durability of walls and floor.

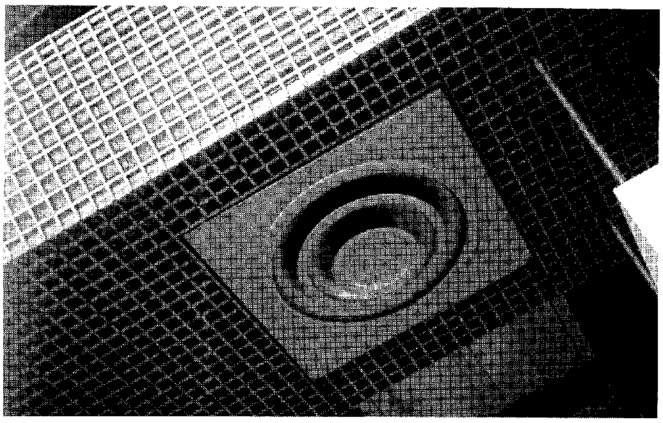
Floors

Close laid terrazzo or granite tiles form durable hard surfaces which can cope with the heavy usage inflicted on concourse floors. Many terminals have tried and tested alternatives: brick paving at Atlanta; studded rubber at Manchester Terminal 1; ceramic tiles in numerous locations.

As the passenger moves through the terminal away from the open air, and is parted from the potentially damage-inflicting baggage trolley, a softer, quieter ambience is preferred through the carpeting of airside spaces. Modern generation carpets are designed to withstand the traffic of a concourse. Geometric patterning reduces the effect of wear and staining, as well as contributing visually. Shops and cafes may reintroduce terrazzo type flooring, but usually create their own identity with ceramic tiles, Figures 22.1–22.3.

Walls

Baggage trolleys damage walls as well as floors. The use of a 45 degree splayed skirting is now a tried and tested way of defending walls against trolleys. Angled skirtings may be of the same materials as the adjacent floor, say terrazzo or carpet, or form a contrast in stainless steel. They are also effective in preventing damage to walls by cleaning machines, Figures 22.4 and 22.5.



22.6 Air diffuser integrates within eggcrate ceiling.

The selection of walling materials requires the designer to respond to criteria stretching beyond design function and aesthetic considerations. Future growth and change, pressures of particular construction method philosophies and ease of maintenance and replacement all play their part.

Many terminal buildings rationalize walling into a modular panel system. Dimensional co-ordination of different elements of the building's finishes, particularly where fast building predominates, is an essential control mechanism in the design and construction process, Figure 22.6.

Heathrow Terminal 4 was innovative in the use of aluminium skinned panels bonded to an expanded 'eggcrate' core, resulting in panels which are aircraft-like in appearance, easily formed, lightweight and non-combustible. In Terminal 4, escalators, lift enclosures and structural bulkheads are all wrapped in an aluminium skin to give an impressive uniformity to the public spaces, Figures 22.7 and 22.8.

Detailing

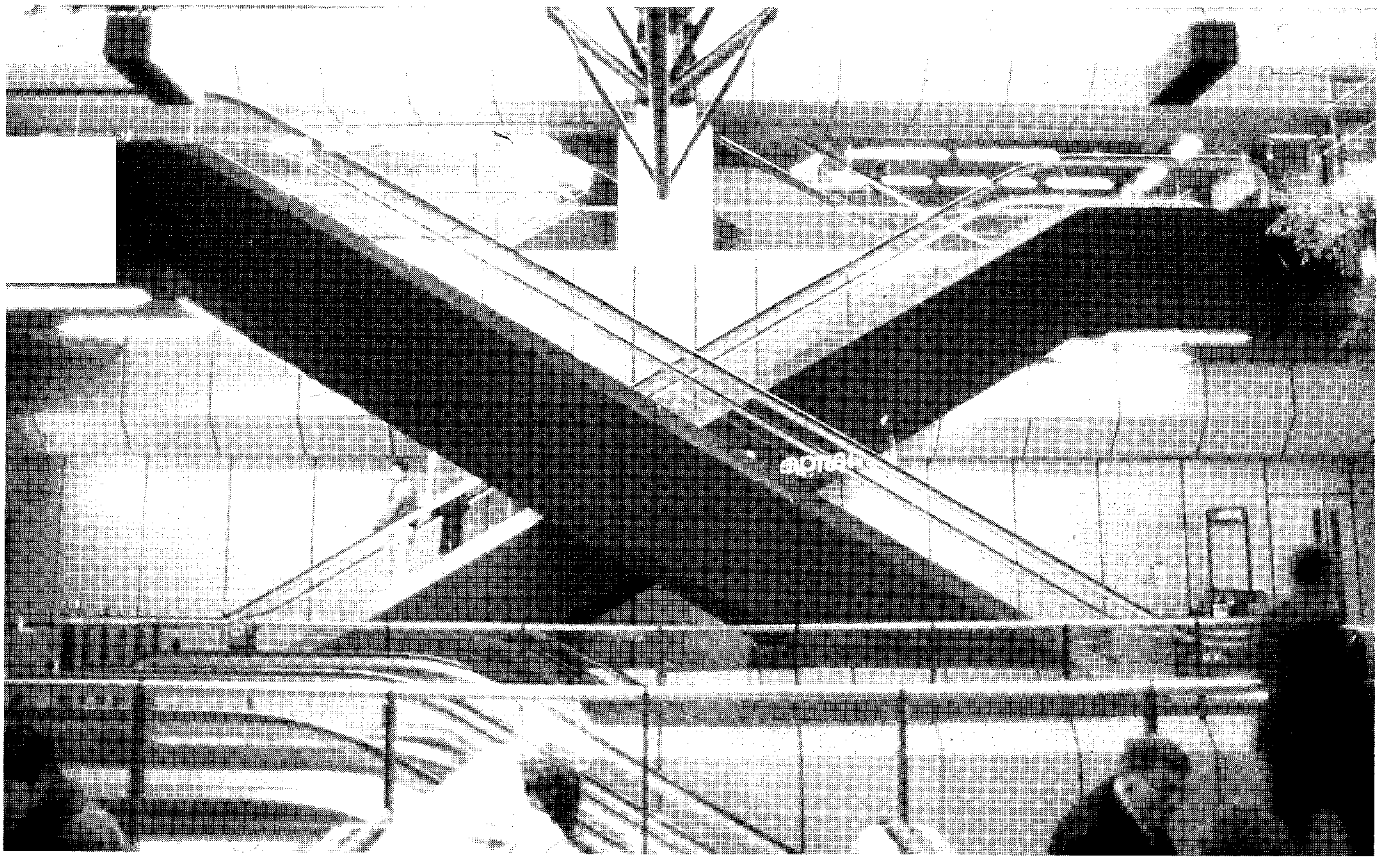
Ultimately, the quality of the interior is manifest in the detailing. Shown here are three details of parts of Heathrow Terminal 4 handled by passengers. The grit-blasted finish to the stainless steel handrails minimizes unsightly finger marks evident on polished metal, Figure 22.9. The push plate on the door is generous, as is the pull handle seen through the porthole glazing. Finally, the lift call buttons are easily seen, easily understood and easy to use, Figures 22.10 and 22.11.

22.3 Fire criteria

The excellent track record of airport authorities in fire fighting is due in no small part to the fast response time of the on-site fire brigades. Nevertheless, passenger safety in the event of fire is a major consideration in the fundamental planning process, with travel distances along defined escape routes a crucial consideration in deep plan buildings. Factors which will determine acceptable design in case of fire include:

- fire containment by compartmentation,
- the fire load in the compartment,
- determination of high/medium/low risk areas,
- establishment of smoke patterns and ventilation,
- alarm and detection systems,
- occupancy assumptions,

22.7 Bonded aluminium panels formed around spaces, with colour distinguishing lifts.



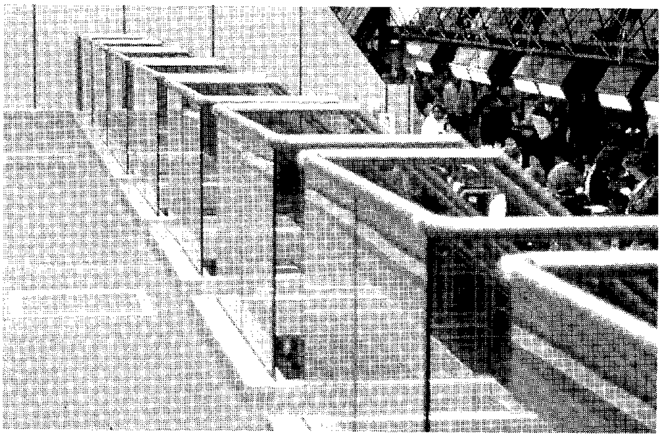
22.8 *Colour denotes vertical circulation escalator cladding.*

- compliance with statutory authorities and
- fire brigade response times.

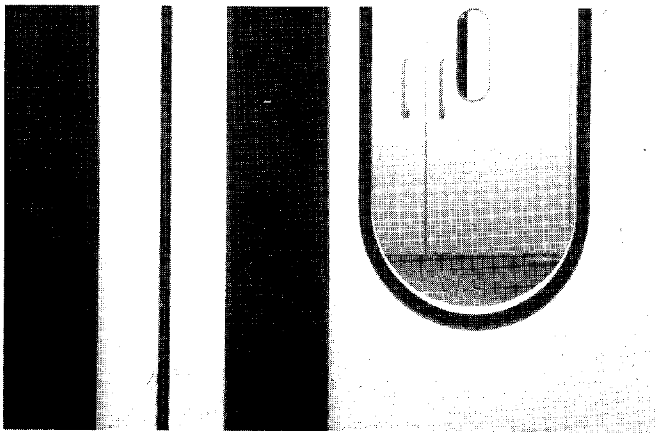
Terminal building designs with inevitably deep plans and long travel distances to the outside call for specific fire and smoke control simulations to justify critical decision making. Particular recent examples are the terminals at Manchester and Kansai, described in other terms in Sections 9.3 and 9.4 respectively.

22.4 Bomb blast

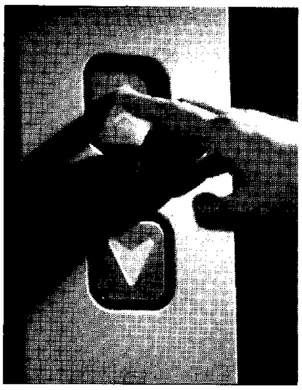
Measures can be taken to minimize the risk or effect of an explosion, either internally or external to a terminal building. At one level, interactive computer assessments can be applied to existing and proposed designs, and at another the reduction of concealment sites and choice of and treatment of materials so as to minimize casualties are prudent.



22.9 *Grit-blasted stainless steel handrails.*



22.10 *Full height push plates and deep pull handles.*



22.11 Lift buttons, easily seen, felt, understood and used. Figures 21.1–21.11 from Heathrow Terminal 4. Architects: Scott Brownrigg & Turner, Guildford.

Further reading

Architects' Journal Information Library (1988) Case study: Floor Finishes, North Terminal Gatwick Airport. *AJ Focus*, March.

Beever, P (1995). Burning questions. *Architecture Today*, No 56, March.

International Air Transport Association (1995) *Airport Development Reference Manual* (8th edition). Montreal, IATA.

Momberger, M. (1993) Computers help to design for security. *Airport Forum*, **6**.

Scott Brownrigg & Turner (1993). All fired up. *Architecture Today*, No 37, April.

23 Amenities

In addition to the facilities for specific types of passenger described in Chapter 19 are the general facilities appropriate wherever large numbers of people assemble, Figures 23.1 and 23.2.

23.1 Restaurants and bars

Wherever large numbers of people assemble there are opportunities for eating and drinking suited to people's pockets and degrees of pressure of time. Landside catering meets the needs of passengers probably hurrying to check-in or be relieved of their bulky baggage as well as of meeters and greeters who may have long waiting times. For these, three types of catering are appropriate:

- high volume, free flow, food courts,
- quality restaurants, and
- refreshment places, cafeterias and bars.

Airside facilities will duplicate landside ones but provide for fewer people and be distributed throughout the terminal. Where holiday charter passengers are to be catered for, long waiting times can be encountered, making special demands on airside catering facilities. In some circumstances it is possible to have restaurant areas which can be sometimes landside, sometimes airside, according to demand. However,

23.1 International departures lounge, Gatwick South Terminal, 1995. Architects: Chapman Taylor Partners. Courtesy of Gatwick Airport Ltd.

23.2 Impression of amenity area, Hong Kong's new airport. Architect: Sir Norman Foster & Partners. Courtesy of Provisional Airport Authority, Hong Kong.

catering kitchens and stores will not be interchangeable. An example is provided by Bahrain International Airport (Section 27.1).

Staff and employee catering facilities will be needed, located normally away from the public areas of the terminal.

Service and storage areas are an important facet of any catering complex and separate facilities are needed for landside and airside.

23.2 Shops and related amenities

The following list provides a guide as to the range of opportunites. Quantities will be determined by the volume of passenger traffic and visitors:

- airline booking and information,
- banking, including automatic teller machines,
- barber's shops and beauty salons,
- car rental,
- currency exchange,
- duty-free and tax-free shops,
- florists,
- gift shops,
- hotel reservations,
- insurance sales,
- news stands and bookshops,
- pharmacy,
- post office,
- shoeshine,
- specialist retail shops of many types,
- supermarkets, particularly suitable near staff areas,
- tourist information, travel agency and bookings, and
- vending areas.

The combination of available time, being already on a journey home in the case of up to half of passengers, being in a spending mood on holiday and the developing tradition of airport shopping combine to create record-breaking opportunities for retailers. Market research and careful physical planning in turn can combine to realize those opportunities, to the benefit of passengers, both in the range of value-for-money merchandise and in the cost of airport facilities passed on by airlines being mitigated by concession income to the airport operator.

Although the next section mentions opportunities for entertainment, and possibly revenue-earning facilities for which the airport authority may offer concessions, the principal entertainment centre in the airside terminal is often the duty-free shopping centre, with sales promotions and all the trappings of the retail industry to attract the captive passenger.

Service and storage areas are an important facet of high-volume airside trading. Access to duty-free shops may need to be provided for the cars which feature in their sales promotions.

23.3 Entertainment

As the popularity of air travel increases, so the novelty value decreases. For some people familiarity with airports breeds contempt, but for others the great interest stirred by flight and the supporting activities generates opportunity for learning. London Heathrow has an interesting past as well as an uncertain future, both opportunities for informing and educating the public. The belated advent of a visitors' centre at the airport came in 1995 on the northern perimeter of the airport, thereby depriving both originating and transferring passengers the opportunity to visit displays and exhibits.

This exemplifies the dilemma concerning spectators and visitors to the airport. Unless facilities are planned at the outset, there is a danger of conflict between the primary needs of passengers and the secondary needs of non-passengers. The closure of spectators' galleries at airports all over the world for reasons of security inevitably closed the door on a source of revenue for airports. Some rooftop restaurants survive, and in some places, possibly as a hangover from colonial times, airports are still a social meeting place with a long tradition of eating and watching. One such example is Zimbabwe.

Children's entertainment also has a place at the airport, particularly as a time-filler. Statistics show that 15 per cent of passengers at Denver Airport have children, generally in the age range 4–12, with them, and an appropriate 'kidsport' has been provided. A children's nursery will be welcomed by many harassed parents, and may come into the scope of services to be provided.

Video games centres and casinos, health and fitness centres, saunas and swimming pools are all possible additions to the list.

23.4 Business facilities

While many airlines are meeting the needs and expectations of their commercially important passengers by providing small business centres in their airside lounges, there are also opportunities in the landside areas of the terminal for conference and exhibition centres and, with them, business centres. Details of the standards and appropriate provisions are outside the scope of this book.

23.5 Hotels and accommodation

On the one hand, a hub airport offering the widest possible range of flights and scheduled transfer opportunities could be said to have failed its passengers if they need an overnight stay in or near the terminal. On the other hand, not all passengers' needs are met by perfect 45-minute transfers, and transit hotels as well as conventional full-service hotels have their place at the airport terminal. Experimental transit dayrooms are available for rental in some airside concourses.

Further reading

Beddington, N (1990) *Shopping Centres.* Oxford: Butterworth-Heinemann.

Lawson, F. (1981) *Conference, convention and exhibition facilities.* London: Architectural Press.

Lawson, F (1994) *Restaurants, Clubs and Bars.* Oxford: Butterworth-Heinemann.

Lawson, F. (1995) *Hotels and resorts.* Oxford: Butterworth-Heinemann.

Walsh, S. (1993) Opportunities blossom for airport shopping centres. *Airport Technology International 1994.* London: Sterling Publications.

24 Future technology in the terminal

There are three technologies apparent in today's terminal of the future: those for moving people and baggage and for giving information.

24.1 People movers

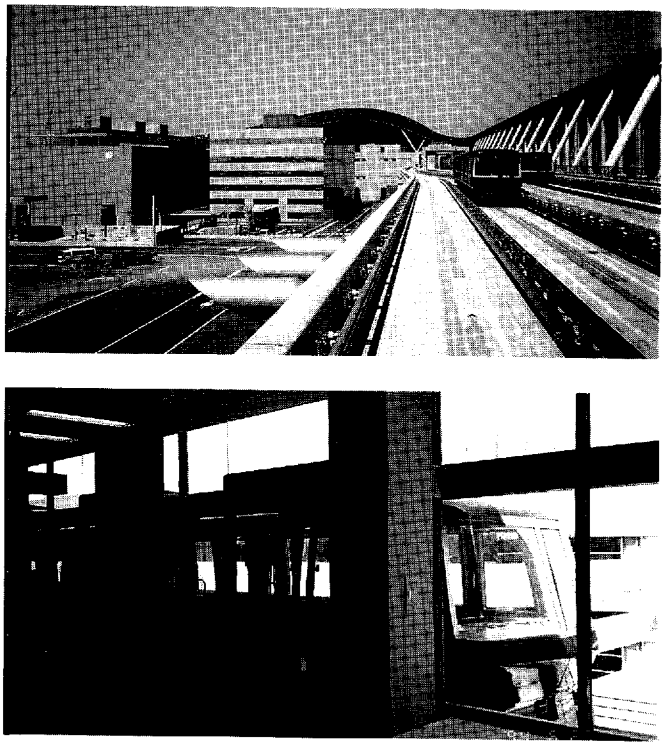
Although no fewer than twenty airports have sophisticated tracked railway systems internally linking central terminals and satellites, this is an area of development where much more is expected in the future. The systems in operation in 1995 are as follows: Tampa Florida, Seattle Tacoma, Houston Texas, Dallas Fort Worth, Miami Florida, Atlanta Georgia, Orlando Florida, Denver Colorado, J. F. Kennedy New York, Pittsburg Pennsylvania, Chicago O'Hare, Las Vegas Nevada, Newark New Jersey, Tokyo Narita, Singapore Changi, Honolulu, London Gatwick, London Stansted and Frankfurt/Main.

One of the latest to open is the people mover illustrated here (Figure 24.1) and located at Kansai International Airport in Japan. Two separate 'wing-shuttle' systems operate, one in each of the two wings illustrated in Section 9.4, with a total of six stations, four termini and two intermediate stations.

New systems are under construction or planned for Hong Kong, Kuala Lumpur, Paris, and many other airports.

The market is dominated by AEG-Westinghouse, with a total of fifteen installations, but many experimental and prototype systems are under trial, applying experience gained in moving large volumes of people in places other than airports.

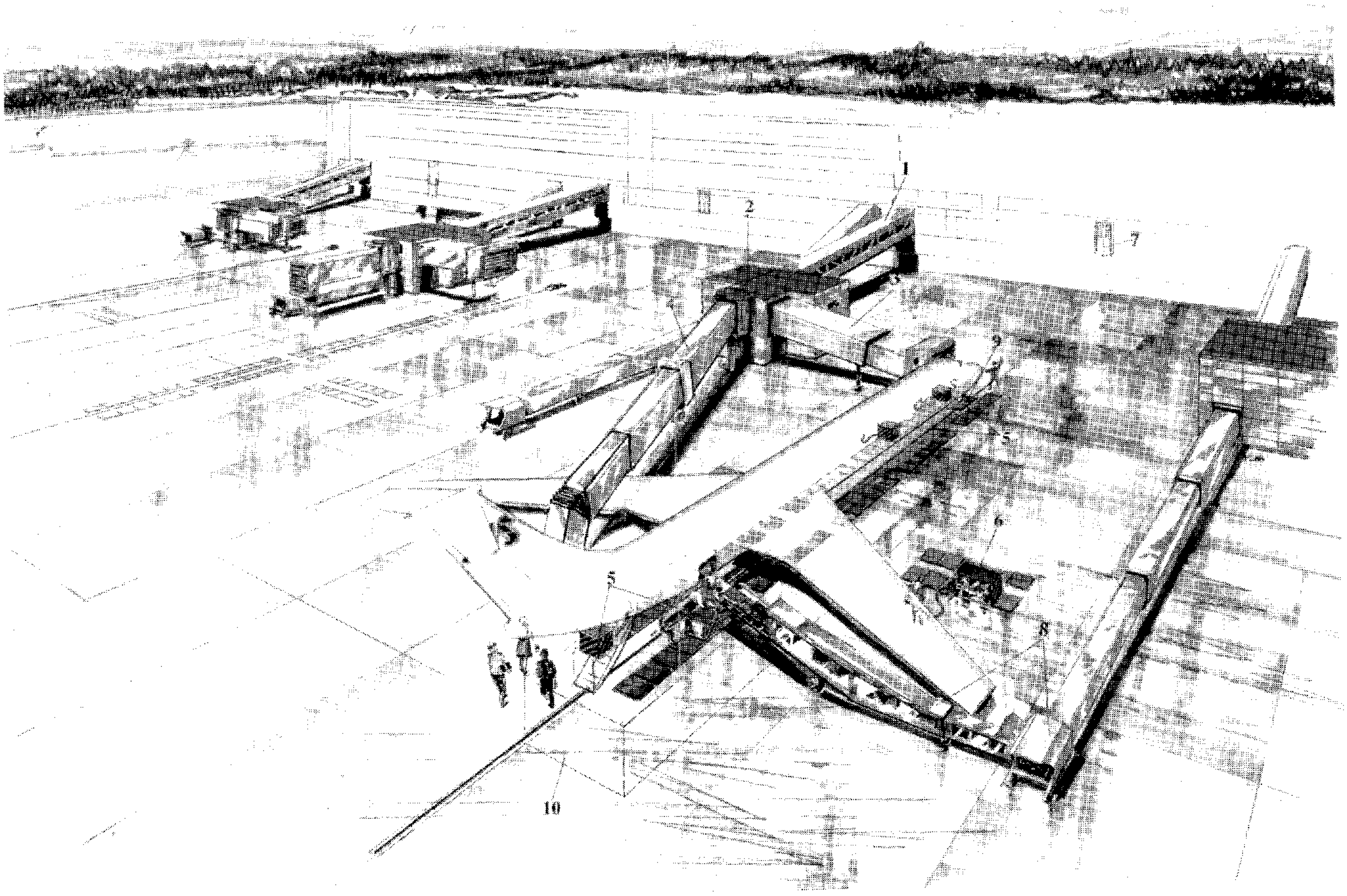
Previously, in the late 1970s, a concept was put forward by architect Hans Fischer known as the PIPE concept. The terminal building was to be connected to the parked aircraft, and many parts of the airport complex also, by an electronically controlled railway system running inside a glazed tube. Passengers, airport personnel and aircrew would be moved from place to place, and it was also thought possible that baggage could be conveyed in a similar way.



24.1 Kansai International Airport terminal people mover. Architects: Renzo Piano Building Workshop and Nikken Sekkei. Courtesy of Japan Airport Consultants.

24.2 Baggage

Recently the majority of effort in this area has been geared to the sorting of baggage, with technology being applied to automatic reading of labels and control systems for the items of baggage thus identified. Baggage conveyors continue straight from the gate to the hold of the aircraft at Arlanda Airport, Stockholm, Figure 24.2. Also under development, and now installation, for example between Terminals 1 and 4 at London Heathrow, are flexible destination-coded



Key

1 Fixed passenger bridge
2 Ramp building
3 Nose loader
4 OTW (over-the-wing) bridge
5 Underground elevator
6 Elevator for refuelling
7 Aircraft Parking and Information System, FMT APIS
8 Baggage conveyor system
9 Push Pilot
10 Supply culvert with blind cover

24.2 The vehicle-free ramp. Illustration based on the new Arlanda system, courtesy of Luftfartsverket, Stockholm Arlanda.

vehicle (DCV) systems, Figure 24.3. New attention is directed at automated detection of explosives or suspicious substances in baggage: see Section 17.1.

24.3 Information technology: passenger systems

Passenger data starts with the purchase of a ticket. With the advent of walk-on shuttle services, passengers are increasingly wanting to and able to buy their tickets immediately prior to departure. Apart from increasing airline ticket sales counters in the landside concourses of terminal buildings, this opportunity creates the one-stop process, ATB (automated ticketing and boarding) which comprises:

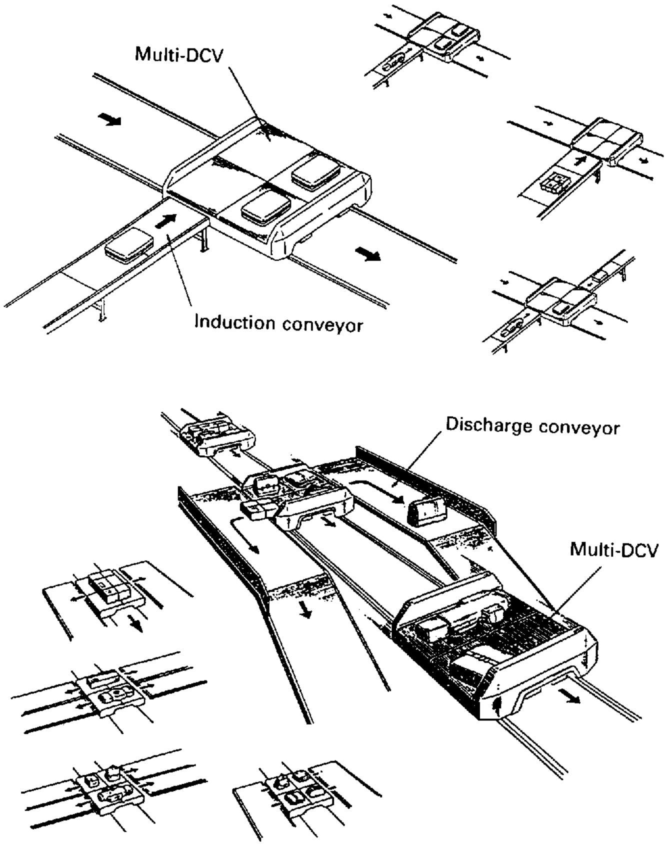
- ticket payment (by credit card, etc.),
- ticket issue,
- flight selection, and
- seat allocation.

When used in conjunction with short-haul business travel the following implications are clear:

- speed of passenger processing, especially where no baggage is to be checked in,
- reduction in personal contact between airline and customer, and
- 'seamless' continuous service to the passenger with additional facilities for car hire, hotel booking, etc.

Building layout implications

- *Security*: with the advent of centralized outbound security and segregation of arriving and departing passengers, access to airside spaces must be restricted to passengers. Ticket sales cannot be carried out at the gate or anywhere in the airside concourse. This pre-empts the trend towards gate check-in.



24.3 Destination-coded vehicle system. From IATA Airport Development Reference Manual.

- *Direct routes*: one-stop ticketing should take place on the shortest route from landside entry to the terminal to the outbound control area.
- *Baggage facilities*: this trend will relegate to a greater extent than presently the baggage check-in facility still offered by airlines. Note that at present some terminal designs give priority to passengers with baggage, or at least involve passengers without baggage traversing check-in halls.
- *Check-in queues*: will be shorter and take less space.

These passenger service and building layout implications are manifestations of an underlying management information system, made possible in the aviation industry, as in others, by the IT revolution. In turn, this system requires a new approach to cabling-up the terminal building, but that is beyond the scope of this book.

Further reading

Butterworth-Hayes, P. (1993) New ticket to faster handling. *Jane's Airport Review*, July/August.

Fabian, L. J. (1993) Downsizing landside traffic by the use of APMs. *Airport Forum*, **4**.

Glantz, H.-I. (1994) Ramp-handling achievements at Stockholm-Arlanda. *Airport Technology International 1994/95*.

Momberger, M. and others (1989) Rail/air interface – a documentation and survey. *Airport Forum*, **5**.

Petit, B. U. (1979) Airport plan based on the pipe concept. *Airport Forum*, **4**.

Rines, S. (1995) Terminals without check-in. *Jane's Airport Review*, April.

Shen, D. (1990) Airport passenger terminal design into the 21st century. In *Proceedings of the Conference Airports into the 21st Century (Hong Kong, 1990)*. Hong Kong: Hong Kong Institution of Engineers.

Walker, C. (1990) Where do bags go from here. *Jane's Airport Review*, March.

Walker, C. (1990) A passport to easing congestion. *Jane's Airport Review*, June.

Woolley, D. (1987) The terminal of the future – a view from BAA. *Airport Forum*, **5**.

Part V External airside factors

25 Aircraft taxiway and parking standards

25.1 Taxiways

The design of taxiways, the routes from and to runways and other facilities on the airfield, is a specialist skill. Information included here is sufficient to understand the critical clearances.

Taxiway clearances are specified by Chapter 3 of Vol. 1 of Annex 14 to the *Convention on International Civil Aviation* (published by ICAO), new edition, 1990. They are detailed in the *ICAO Aerodrome Design Manual* and the following standards in Table 25.1 relate to airports with code E, those suitable for aircraft with wingspans greater than 52 m and less than 65 m.

25.2 Aprons

Apron clearances are also specified in the *ICAO Aerodrome Design Manual* as in Table 25.2.

Table 25.1 *Taxiway clearances*

Taxiway pavement width	Minimum 23 m
Distance from centreline of instrument runway code 4 to centreline of parallel taxiway	Minimum 182.5 m
Distance from centreline of taxiway to centreline of parallel taxiway	Minimum 80 m
Distance from centreline of taxiway to a fixed obstruction, including a parked aircraft	Minimum 47.5 m
Distance from centreline of aircraft stand taxilane (a taxiway serving only aircraft stands and not a throughway)	Minimum 42.5 m

Table 25.2 *Apron clearances*

From aircraft of wingspan	*Distance to fixed or moving object*
36 m or greater	7.5 m
24 to 36 m	4.5 m
Less than 24 m	3.0 m

Stand sizes are suitably specified as in Tables 25.3 and 25.4, although many combinations are possible where specific aircraft are planned for, as in the case of airline hub terminals such as Birmingham. These examples are based on the categorization of aircraft given in the *ICAO Airport Planning Manual* and on codes used in Annex 14 mentioned in Section 25.1.

Apron circulation standards are important and vehicle clearances will be specified according to airline and airport handling agents' vehicles and equipment in use or likely to be in use in future. In practice, the

Table 25.3 *Stand sizes, groups LL, L,, M and S*

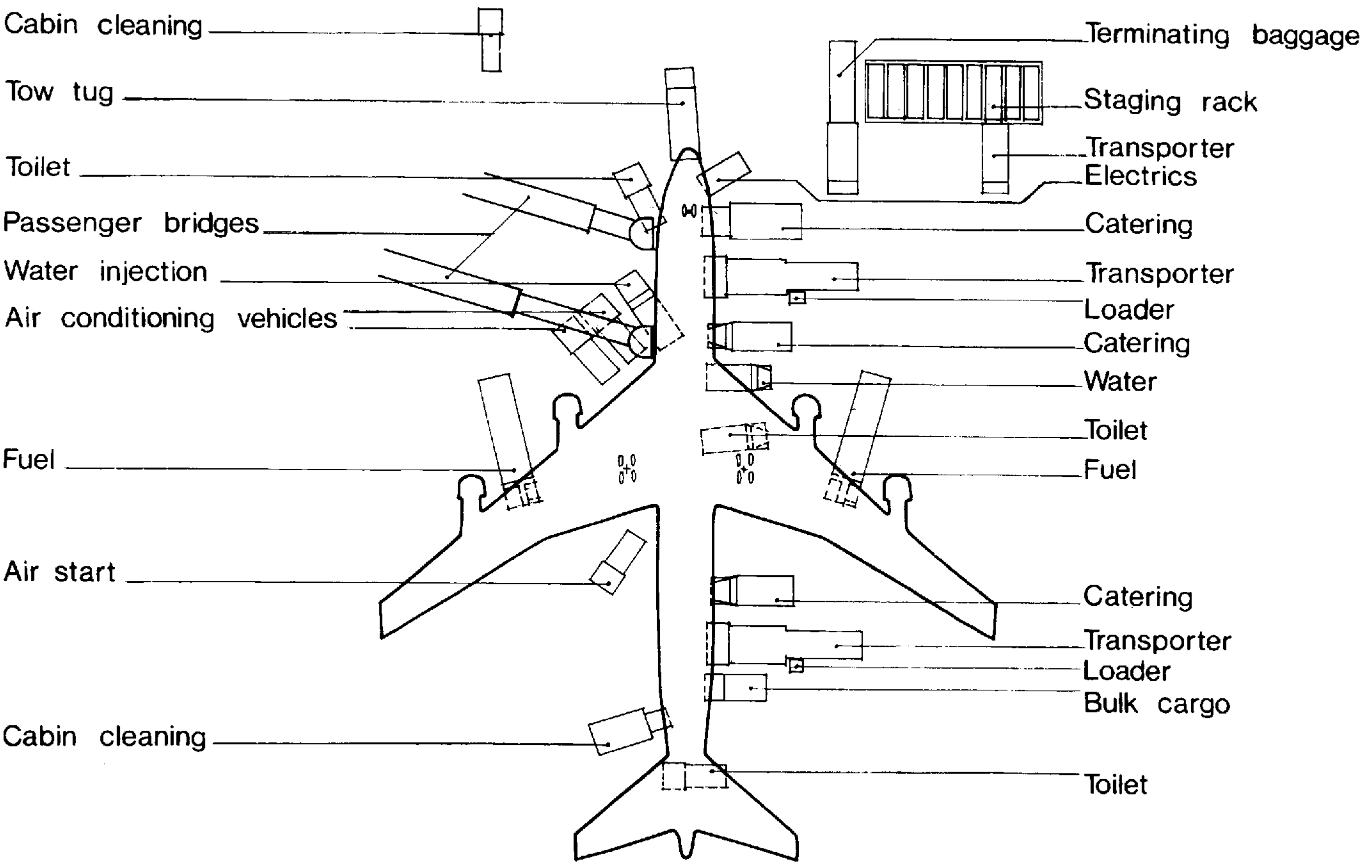
Group	*Aircraft*	*Stand depth**	*Stand width**
LL	B747–400	70.66 m	64.67 m
L	B747–others	70.66 m	59.64 m
M	Suitable for all sizes between B747 and B737-400	61.21 m	51.66 m
S	B737, BAe146, F28, BAC 1-11, DC 9-30, all turboprops	36.40 m	31.23 m

* Excluding positional tolerance.

Table 25.4 *Stand sizes, codes E, D, C and B*

Code	*Aircraft*	*Stand depth**	*Stand width**
E	B747 range, B777 and A3230/A340	70.66 m	65.00 m
D	Suitable for all sizes between MD11 and A310 inclusive (i.e. DC10/MD11, A300, B767, L1011, B757, A310)	61.21 m	52.00 m
C	B727, MD80/90, A320, B737, BAC1-11, Bae146, F28/100/27/50, ATR42/72, ATP, Dash 7 and 8	46.69 m	36.00 m
B	Suitable for smaller turboprops only	22.00 m	24.00 m

* Excluding positional tolerance.



25.1 Service vehicle cluster diagram.

most important clearance will be the height clearance under structures spanning airside roads. Typical clearance specified at Heathrow Terminal 4 was 4.33 m (14 ft 2 in), Figure 25.1.

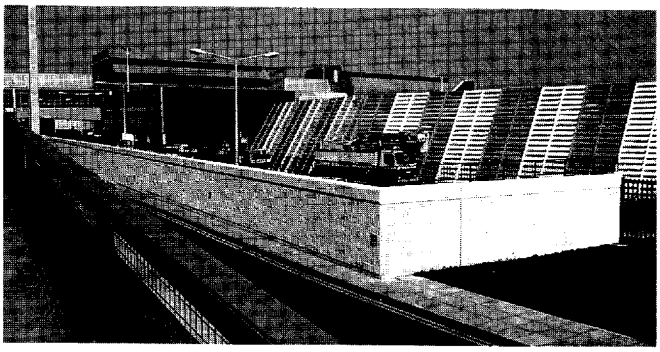
Apron layouts

The most important determinant of apron layout is the method of aircraft parking decided on. It is beyond the scope of this book to do any more than relate parking to terminal shape and form and to concentrate on the parking layouts which dock aircraft against terminal buildings.

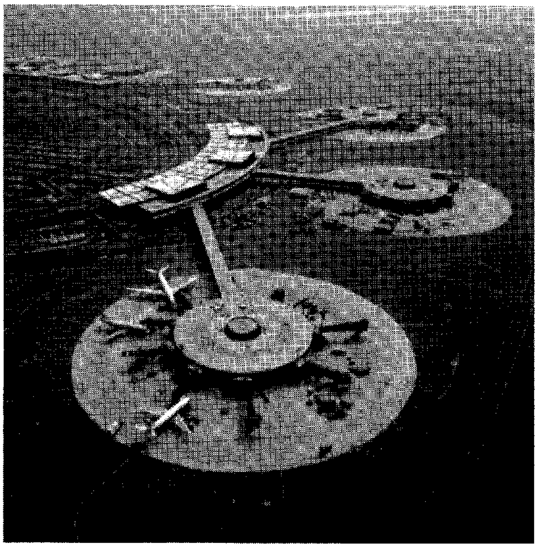
There is a vital relationship between terminal airside profile and aircraft parking positions and vice versa. From an aviation and management point of view, orthogonal apron layouts are preferable, particularly when standard for an airport in question.

Parking spaces for the many vehicles that service an aircraft on the apron can be better reserved. Non-orthogonal apron layouts lead to non-standard aircraft movements, particularly in order to avoid blast being directed at vehicles and personnel and even other aircraft on the apron when aircraft move away under their own power, Figure 25.2.

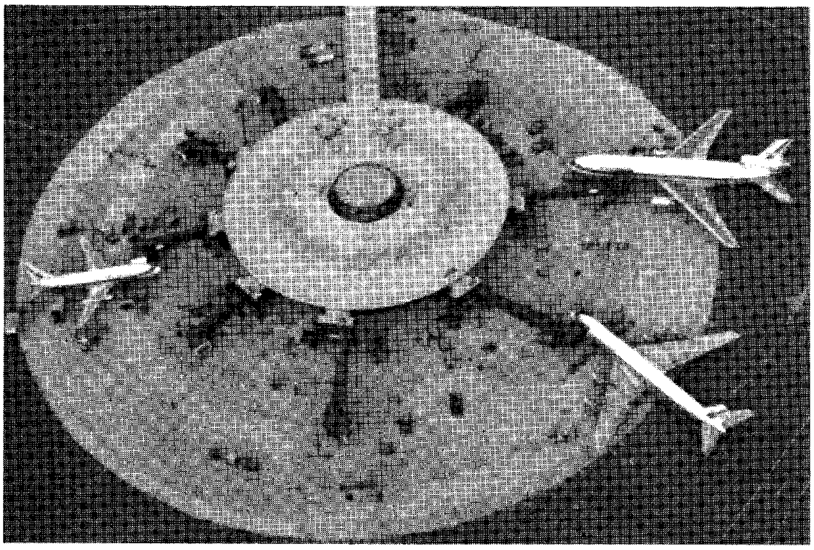
At this point it is appropriate to consider satellite terminal parking layouts. Many circular satellites with circumferential taxiways have been built and operate successfully. The apron radius determines the maximum size of aircraft which can be accommodated, just as does the apron depth in the case of a straight-line parking configuration. However, predetermined sectors of a circular satellite/apron are essentially uneconomic for small aircraft on larger stands: all the apron space is behind the wings where it is least useful. Apron service functions tend to cluster around the nose of the aircraft too, Figures 25.3 and 25.4. See Figure 24.2 for a new approach to the apron.



25.2 Blast screens, Heathrow Terminal 4. Courtesy of architects: Scott Brownrigg & Turner, Guildford.



25.3



25.4

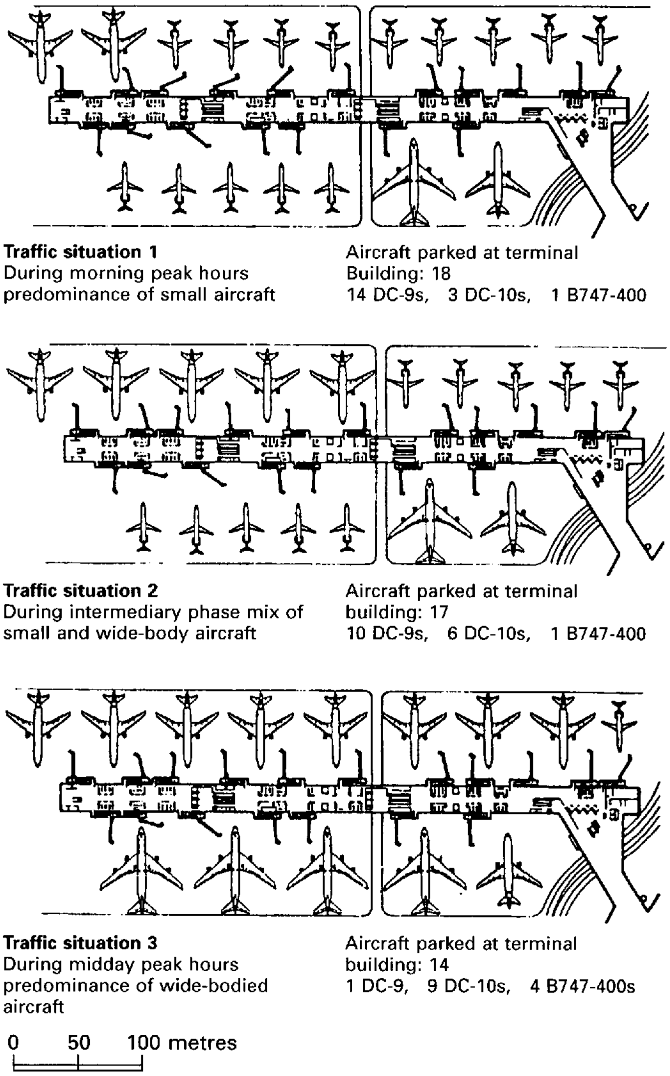
25.3, 25.4 *Satellite at Newark International Airport. Courtesy of Port Authority of New York and New Jersey.*

Two-on-one and three-on-two stand layout

Although it may be uneconomic in the use of apron surface area, it is certainly economic in terms of terminal airside frontage to park two smaller aircraft on a stand primarily laid out for one large aircraft. For example, a stand 62.5 m wide will accommodate the Boeing 747 (but not the Boeing 747-400) as well as two Boeing 737s subject to wingtip clearance of 4.5 m (62.5 = 2 × 29.0 + 4.5). A particular example of variable stand centrelines is illustrated at Zurich's new Pier A, opened in 1985. This example is also used to illustrate the variable use of loading bridges, Figure 25.5.

New large aircraft

First and foremost, opinions differ as to whether there will be an NLA in the foreseeable future at all, and doubts have been expressed as to the public acceptance of such a beast. Studies by British Airways have specified a 600-seater aircraft which must operate from 'current 747 airports', while having the same night-noise classification, wake turbulence separation and runway occupancy times as the existing 747, but others are considering another view of the future. For example, initial designs for Bangkok's second international airport safeguard for manoeuvring of a 90-metre wingspan 'design aircraft'. Hong Kong's new airport at Chek Lap Kok allows for 84-metre wingspan and 85-metre fuselage length. Correspondingly, Boeing understands that airport authorities are proposing recommended design criteria limiting wingspan to 80 metres and fuselage length to 80 metres, while its own reported NLA design has a 74.5 metre length, a 79.2 metre wingspan, and



25.5 *Example of flexible apron parking configuration. From* IATA Airport Development Reference Manual.

500–600 passenger capacity but a tail height of up to 24 metres. It is this feature which will limit parking positions against obstacle limitation surfaces, which in turn themselves may change as a result of the technology of navigational aids.

Aprons are already congested with fuelling, cargo and baggage loading, catering, cleaning, water supply, toilet servicing, ground power, pneumatics and air conditioning. What happens with the number of meals, carts and galley service trucks needed per NLA, which could amount to 1500, 180 and 7 respectively? What happens with the number of baggage containers needed per NLA, which could amount to 25? The prototype apron at Stockholm Arlanda gives another view: see Figure 24.2. Investment in existing facilities and those already in the planning or construction stage at Heathrow Terminal 5 and Hong Kong, for example, militates against a more radical solution.

While certain airport terminals will undoubtedly need to be bigger, the order of magnitude of change is greatest in respect of the apron. Six hundred passengers need 50 per cent more space than 400, but a 85 × 85-metre NLA needs nearly double the space for a Boeing 747 when parked on double-sided taxiways, for example. In such circumstances the only reducing factor is the number of taxiway movements per unit length of taxiway as between NLAs and Boeing 747s. There is already a lot of experience with multiple-stand centrelines, and two-on-one and three-on-two stand configurations. For example, the new apron at Manchester Airport Terminal 2 has 92- and 46-metre stand centrelines on the two-on-one principle. Thus, a little more than the minimum is provided in some circumstances in order to provide the optimum in other circumstances. To allow some opportunity for economy in combining facilities for NLAs and Boeing 747s, one solution could be multiple taxilane centrelines and double- and single-taxilane cul-de-sacs: see Chapter 6.5.

References

International Civil Aviation Organization (1987) *Aerodrome Planning Manual, Master Planning,* document 9184 pt 1 (2nd edition). Montreal: ICAO.

International Civil Aviation Organization (1990) *Aerodromes, Volume 1: Aerodrome design and Operations: International standards and recommended practices*: Annex 14 to the *Convention on International Civil Aviation* (1st edition). Montreal: ICAO.

International Civil Aviation Organization (1991) *Aerodrome Design Manual, Taxiways, Aprons and Holding Bays,* document 9157 pt 2 (3rd edition). Montreal: ICAO.

Further reading

Baldwin, R. (1994) Sizing up the superjumbo. *Airport Support*, December.

Harder, H. (1988) New-design passenger loading bridges for Pier A. *Airport Forum*, **6**.

Woolley, D. (1995) Is eighty-metre span the limit? *Airport Forum*, **2**.

26 Aircraft docking and loading

There are several ways for passengers to transfer from terminal to aircraft. They may:

- walk across the apron and up the steps,
- ride on a conventional bus and walk up the steps,
- ride on a low-floor, no-steps, high-comfort bus and walk up the steps,
- ride in a mobile lounge direct from the terminal floor level to the aircraft door, or
- walk through a loading bridge directly into the aircraft.

The last method, and the mechanical devices that go with it, has been an overwhelming success because of the short walks in the right direction in the warm and dry. Conversely, mobile lounges and buses-with-steps have not so far been a commercial success. High operating costs, slow transfers, sensitivity to adverse weather and reduced flexibility in terminal use have been cited as major drawbacks.

Procedures and mechanisms for the parking of aircraft are related to the precision needed as appropriate to the mechanisms of passenger loading and boarding. Unless aircraft park in predetermined positions adjacent to the terminal face in order to interface with loading bridges, parking precision is a very different matter. Different types of loading bridge demand different degrees of precision.

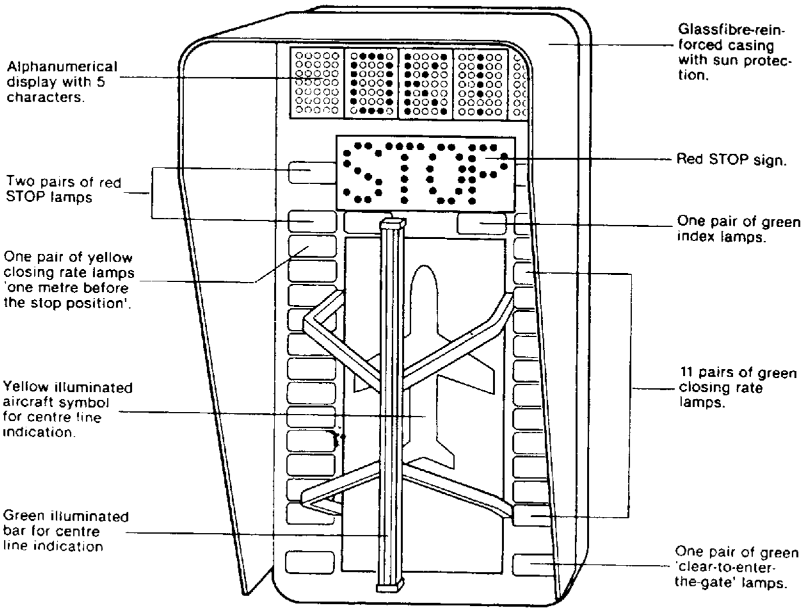
26.1 Aircraft docking

It is only within the scope of this book to consider aspects of aircraft docking which affect the building itself. Airside faces are conventionally used for fixing guidance marker boards of two types: AGNIS and PAPA.

AGNIS is the Azimuth Guidance for Nose-in Stands, and comprises a visual check for the pilot that the aircraft is accurately positioned on the stand centreline.

PAPA is the Parallax Aircraft Parking Aid, and comprises a visual check that the aircraft is stopping

26.1 PAPA board at Heathrow Terminal 4.



26.2 Safegate (Swedish) guidance system related to loading bridge operation.

at the correct point on the centreline, the correct distance from the terminal building or loading bridge, Figure 26.1.

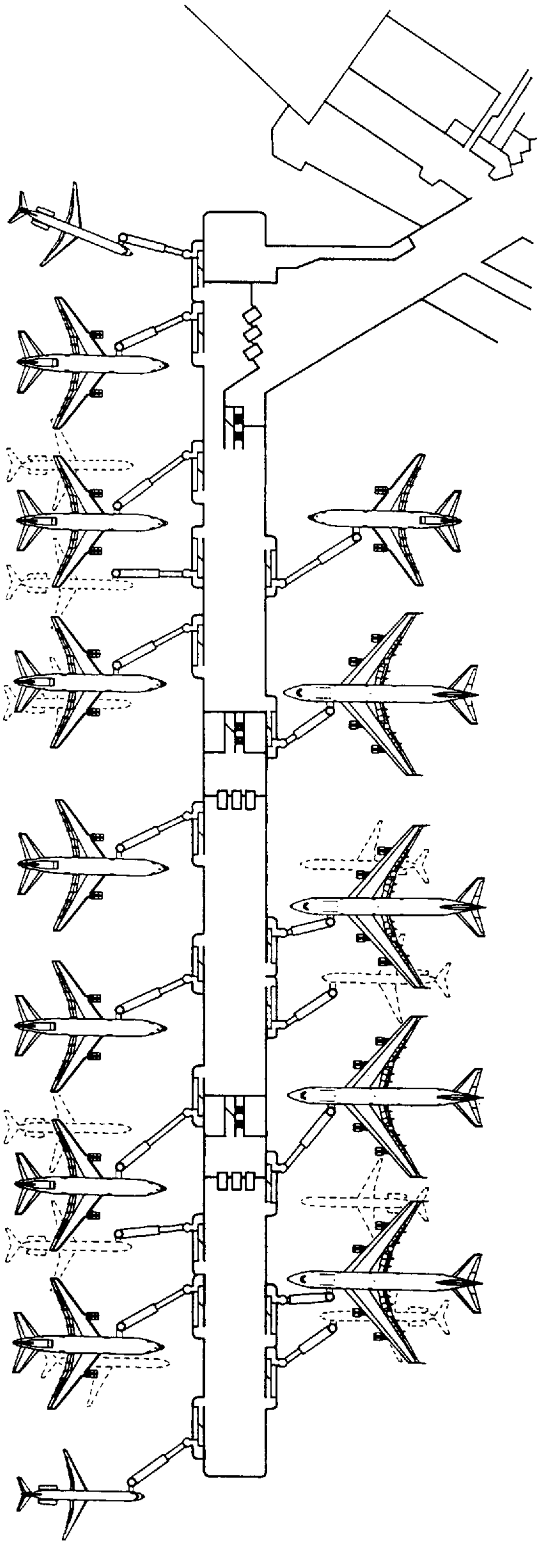
A number of integrated electronic taxiway and stand guidance systems have been developed and installed and proven of value particularly in adverse weather conditions. However, the important feature for the terminal designer is the integration of the docking system with the operation and therefore the type of loading bridge, Figures 26.2 and 26.3.

26.2 Aircraft loading by bridges

In view of the variable distances between ground and aircraft sill, between terminal floor level and door position, and between aircraft centrelines and door positions, there are many alternative devices available to bridge the gap between terminal and aircraft. Aircraft sill heights are listed in the Appendix.

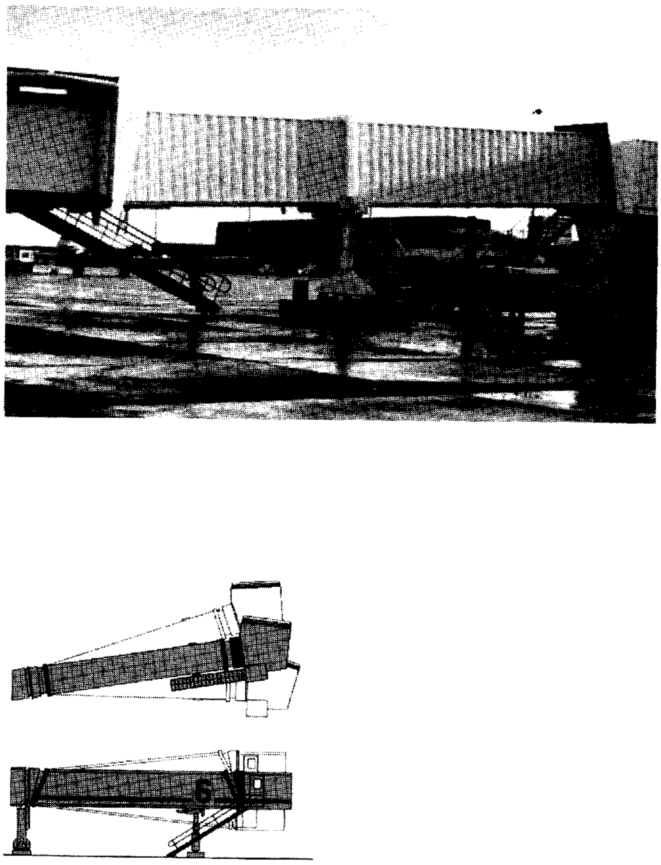
The following types are illustrated from one manufacturer's (Safegate) range of solutions:

1. Elevating sliding bridge
   Fixed type, non telescopic.
   Vertical movement: limited by gradient of single tunnel.
   Horizontal movement: limited.
   Figure 26.4.



26.3 Example of flexible loading bridge configuration, based on Zürich Airport Terminal A with 18 loading bridges (see Section 10.2) showing three sets of aircraft centrelines, as follows:

Case 1 (during midday peak hours) 14 aircraft; predominance of wide-bodied aircraft
Case 2 (during intermediate phase) 16 aircraft (dotted aircraft option, one side only); mix of small and wide-body aircraft
Case 3 (during morning peak hours) 18 aircraft (dotted aircraft option, both sides); predominance of small aircraft.

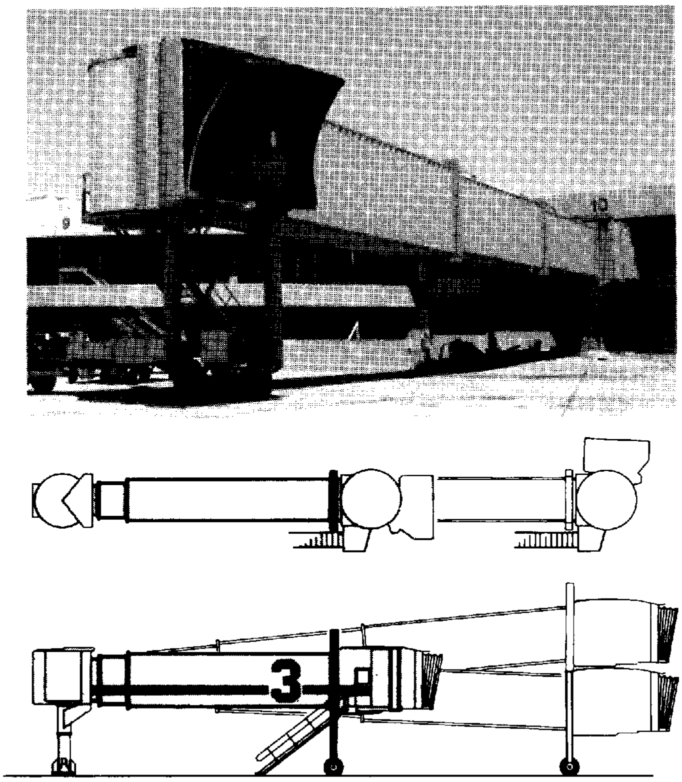


26.4 Elevating sliding bridge: Safegate.

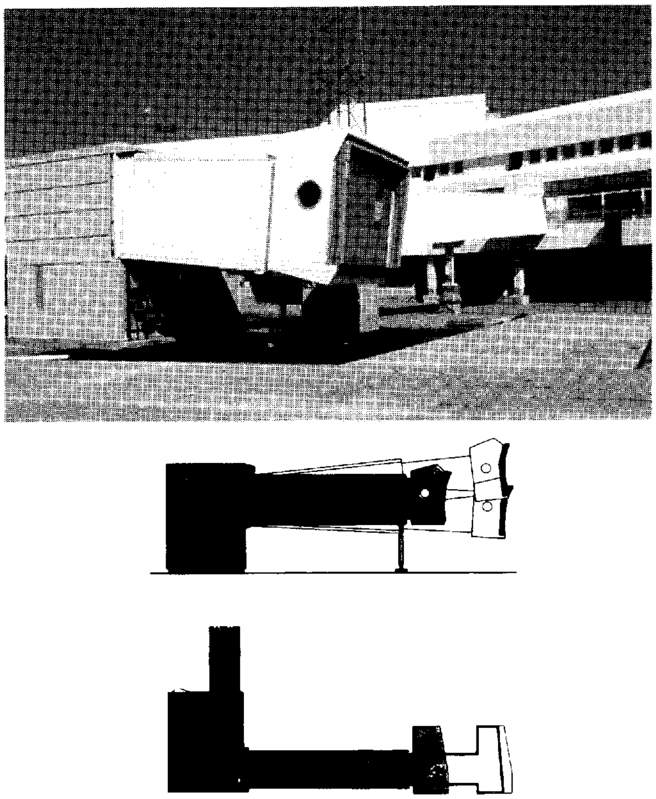
2. Apron Drive Bridge
   Telescopic with 2 or 3 tunnels.
   Vertical movement: this type offers the greatest choice.
   Horizontal movement: unlimited.
   Figure 26.5.
3. Nose loader bridge.
   Vertical movement: limited.
   Horizontal movement: forward and back only (3.6 m travel).
   Figure 26.6.
4. T-Bridge, single or double.
   Vertical movement: limited by gradient of single tunnel.
   Horizontal movement: limited.
   Figure 26.7.

The apron drive bridge offers many possibilities, including the sort of apron and stand flexibility illustrated by the Zürich Pier A example. This whole project utilizes a set of 18 two-tunnel apron drive bridges, the majority of which are designed as 19–20 metres retracted and 30–33 metres extended, but two of which are designed as 24 metres retracted and 40 metres extended.

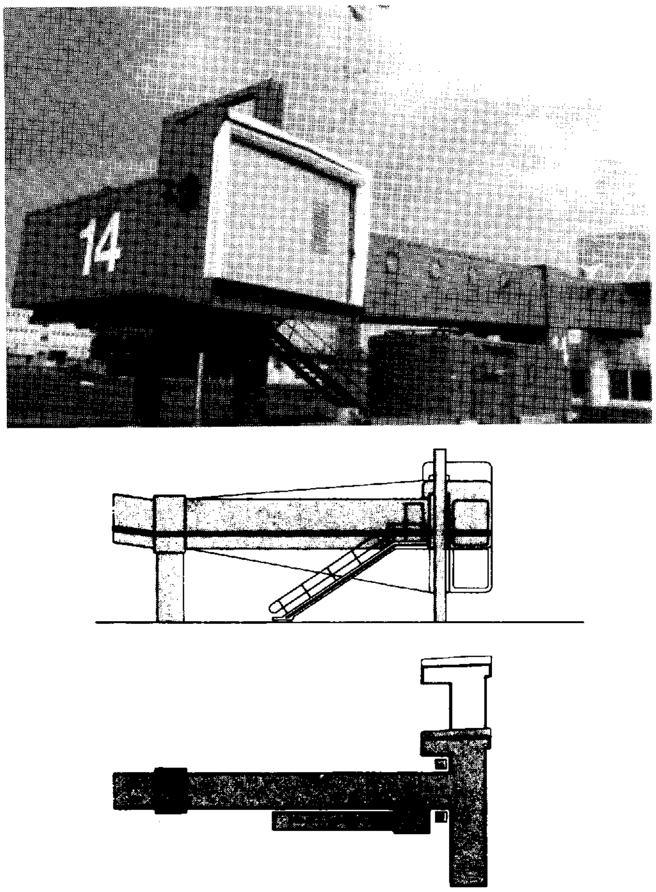
The introduction of segregated passenger routes on different levels in the airside areas of terminals (of which the British Airways terminal at J. F. Kennedy Airport New York illustrated in Chapter 27 is an early example) leads to the problem of passengers having to traverse ramps from and to each of these levels in order to enter the



26.5 *Apron loader bridge: Safegate.*



26.6 *Nose loader bridge: Safegate.*



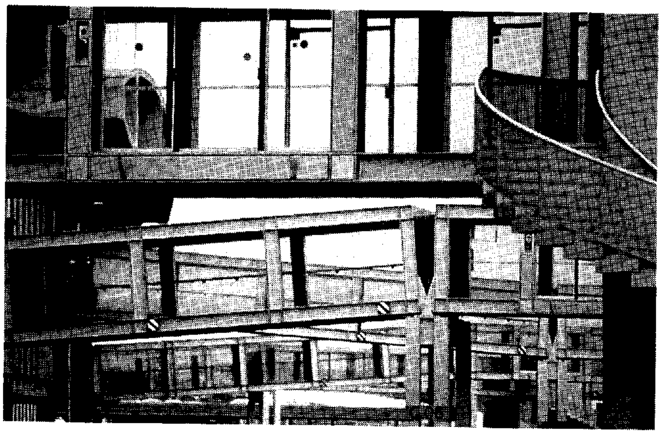
26.7 *T-bridge, single or double: Safegate.*

fixed end of the loading bridge. An economy measure is the use of a single ramp which pivots at the fixed end of the loading bridge, at a level approximately half way between the two passenger floor levels of the terminal, and moves on rails from one level to the other according to whether passengers are embarking or disembarking. Two examples are illustrated, at Terminal 2C at Charles de Gaulle Airport, Paris, and at Hong Kong Kai Tak Airport, Figures 26.8 and 26.9.

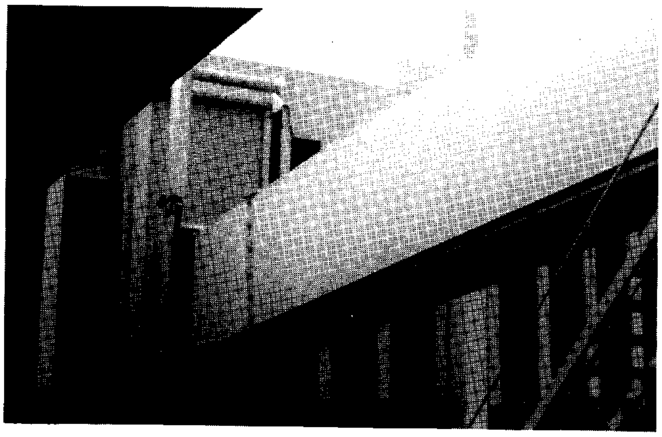
26.3 Superbuses and mobile lounges

There are several types available:

- The double-ended Aerobus-Uno built by Janus Bus SpA of Rome. This low-floor, no-steps bus is avalable as 150-passenger and 200-passenger models with roof mounted engines. It can move crabwise across the apron and is in use at Rome Fiumicino.
- The two-storey Galaxy Lounge built by Neoplan of Stuttgart, for 342 passengers and with an inbuilt covered stair unit.

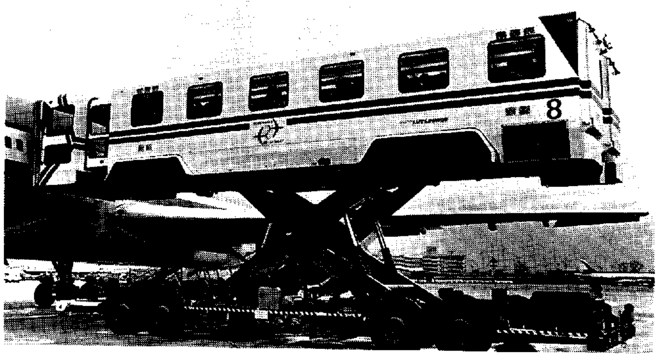


26.8 Luffing bridge at Charles de Gaulle Airport Terminal 2C. Architect: Paul Andreu. Courtesy of Aeroports de Paris.



26.9 Luffing bridge at Kai Tak Airport Hong Kong.

26.10 ÖAF-Gräf and Stift apron bus. Courtesy of ÖAF-Gräf and Stift AG, Vienna.



26.11 Trepel mobile lounge. Courtesy of Trepel GmbH, Wiesbaden, Germany.

- The ÖAF-Gräf & Stift apron bus, available typically as a low-floor, no-steps, driver-at-either-end 160-passenger vehicle. Figure 26.10.
- The Shuttlelift elevating lounge built by SOVAM Industries of France in use at Paris Charles de Gaulle Airport.
- The Trepel mobile lounge built by the German company Trepel and in use at Gothenburg Landvetter. Figure 26.11
- The American version, derived from the original design introduced at Washington Dulles in 1962, and now built by Airside Systems Inc.

Further reading

Alcock, C. (ed.) (1989) Docking Systems. *Airports International*, January.

Butterworth-Hayes, P. (1990) Flexibility costs more. *Jane's Airport Review*, January/February.

Harder, H. (1988) New-design passenger loading bridges for Pier A. *Airport Forum*, **6**.

Momberger, M. and Momberger, K. (1987) The interface: Passenger-handling systems and equipment. *Airport Forum*, **2**.

Part VI Redevelopment of existing airport terminals

A very important feature of any review of terminal buildings must be an analysis of growth and change achievements. As demonstrated earlier, airport terminals are living organisms. They need to adapt to changing conditions. The tents at Heathrow in the 1940s could not adapt and were thankfully totally replaced by permanent terminal buildings first on the north side adjacent to the Great West Road and now in the central area. Gatwick's original beehive terminal was wrongly sited and sized to meet the post-war situation. In relation to the investment being made in aircraft, the early terminals were essentially low-investment buildings. As traffic increased so the investment in terminal buildings increased to a point where it is not possible generally to scrap an undersized terminal and start again.

Problems encountered in airport terminal redevelopment will be transitional ones of matching, of continuous operation and continuous security. On 16 January 1956, in poor visibility, a BEA Viscount at Heathrow mistook an old runway for a new one, tried to take off and ploughed into a building site.

Difficulties more likely to present themselves are epitomized by the announcement 'alterations as usual during business'.

27 Examples

27.1 Bahrain International, redevelopment

Architects: Scott Brownrigg & Turner, Guildford.
Civil and structural engineers: Scott Wilson Kirkpatrick & Co. Ltd.
Mechanical engineers: Scott Houghton, now SWK (M&E) Ltd.
Electrical engineers: Buckle and Partners, now Pearce Buckle Partnership.
Quantity surveyors: D. G. Jones & Partners.
Client: State of Bahrain, Ministry of Works, Power and Water, Construction Projects Directorate.
User: Civil Aviation Affairs.
Contractor: AMA (Ahmed Mansoor Al-A'Ali).

This project, designed in 1985/6 and completed in 1994 as the third phase of a long-term plan, is typical of the situation which faces the airport terminals of the 1960s and 1970s. The client required an upgrade and extension to the terminal to meet the needs of the twenty-first century while still meeting the needs of the early 1990s for 24 hours a day. In turn, those needs were radically affected by the loss of 70 per cent of transit traffic between 1989 and 1991, and enhanced by the success of Gulf Air and rapid growth in Gulf region traffic such that 1994 traffic exceeded the pre-Boeing 747-400 and Gulf War era peak of 3.3 million passengers annually.

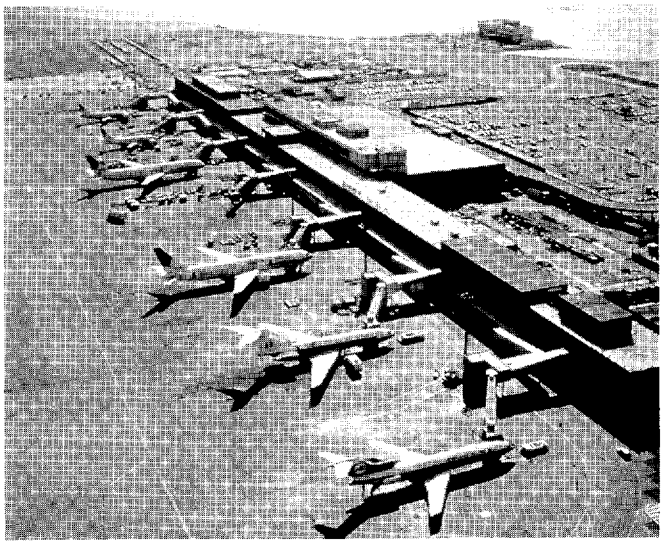
The two-storey original terminal, with a handling capacity of 400 passengers per hour in each direction, had a single-level landside concourse and an airside frontage of 300 m with five irregularly spaced loading bridges. After check-in, passengers had to go to the upper level where control formalities are carried out before entering the airside concourse. Arriving passengers have immigration check at the upper level before descending to baggage reclaim, customs formalities and the landside concourse. Baggage handling for both outbound and inbound traffic uses simple belts and manual sorting. The traffic pattern has always been a mix of transit and transfer for long-haul and local Gulf traffic and originating traffic for Bahrain itself.

The new requirement was for an hourly processing capacity of 1000 passengers in each direction, for airside segregation of arriving and departing/transitting passengers and for seven terminal-served Boeing 747 stands, Figure 27.1.

This has been achieved by doubling the gross building area of 20 000 m^2 and providing the following new or enhanced facilities:

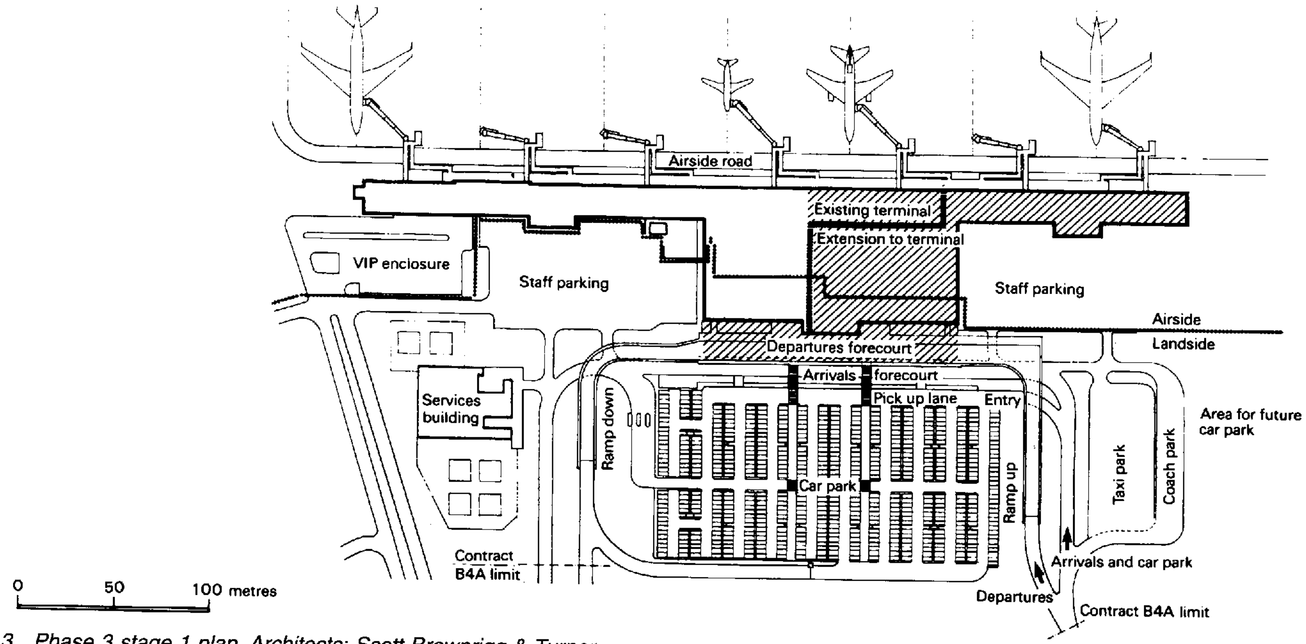
- two-level forecourt and concourse, Figure 27.2,
- extended departures airside concourse with seven loading bridges,
- a new mezzanine corridor for arriving passengers inserted at level +2.8 m between apron level and the departures level at +6 m, shown by Figure 1.2,
- ramps down from level +6 m to loading bridges and from loading bridges to level +2.8 m,
- a new three-storey section of terminal housing departures controls, arrivals security and immigration control, and baggage reclaim/customs facilities, and
- A new departures baggage handling facility.

The first stage of the work entailed closing the eastern leg of the airside concourse and constructing the whole new three-storey structure and elevated departures forecourt, Figure 27.3. The existing terminal was then refitted.



27.1 Bahrain International Airport. Airside photograph of completed Phase 3 project, 1994. Courtesy of Scott Wilson Kirkpatrick & Co. Ltd.

27.2 *Landside photograph of completed Phase 3 project, 1994. Courtesy of Scott Wilson Kirkpatrick & Co. Ltd.*



27.3 *Phase 3 stage 1 plan. Architects: Scott Brownrigg & Turner, Guildford, with Scott Wilson Kirkpatrick & Co. Ltd.*

Further reading

Butterworth-Hayes, P. (1994) Bahrain: A new hub for the Gulf. Special supplement, *Jane's Airport Review*, July/August.

Paylor, A. (1992) Transit drop sparks strategy rethink. *Jane's Airport Review*, January/February.

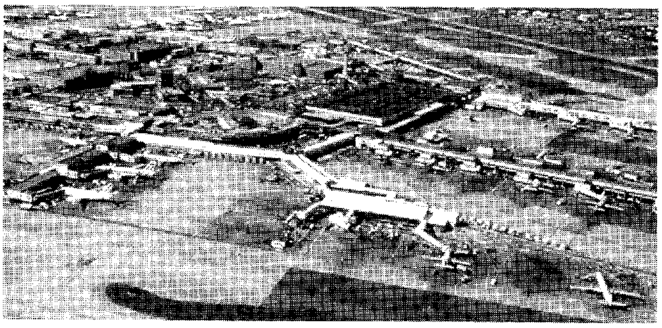
Pilling, M. (1995) Gulf gateways. *Airports International*, April.

27.2 London Heathrow Terminal 1 redevelopment 1981–93

Heathrow Terminal 1 has seen many phases of redevelopment since first opening in 1969, of which the those illustrated are just two, see Figure 27.4. Their common feature is the ingenuity required in their design.

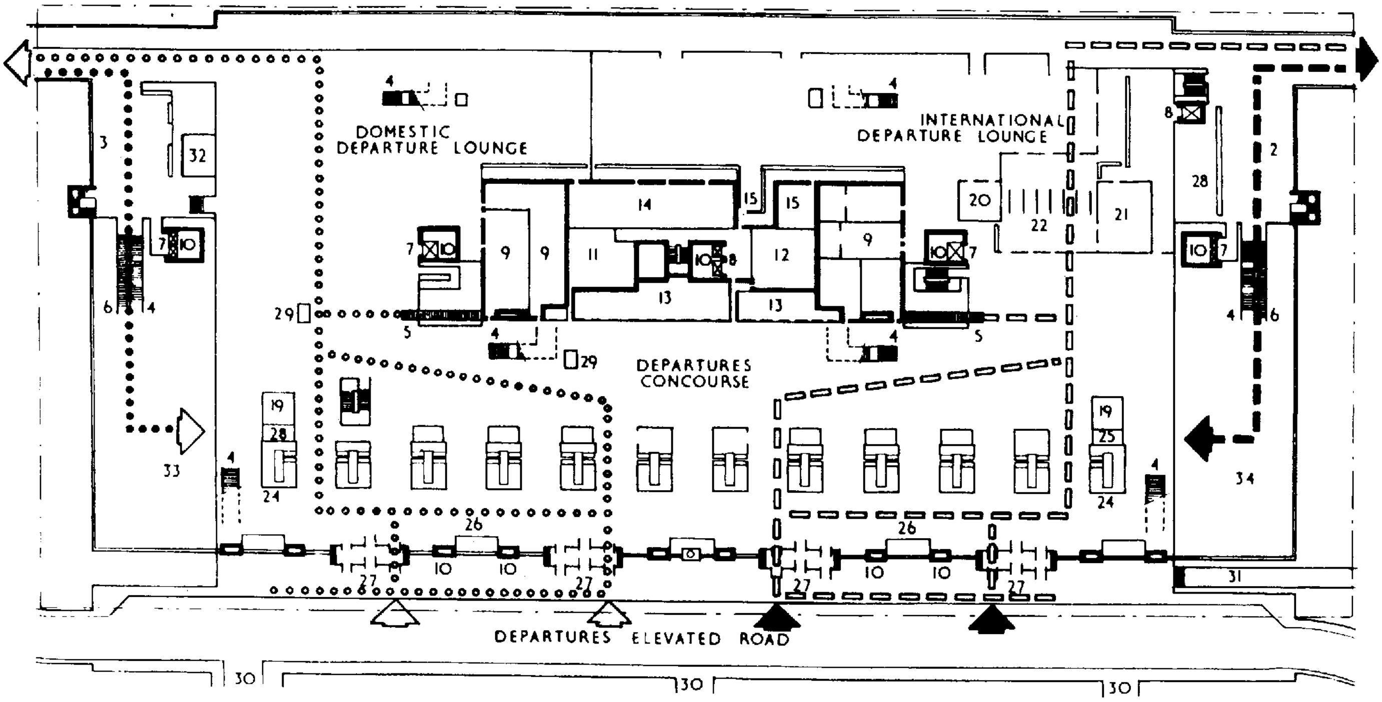
International Arrivals Building (1981)

Architect: Scott Brownrigg & Turner, Guildford.
Structural engineers: British Airports Authority.



27.4 Aerial view of Terminal 1, showing many new additions. Courtesy of Heathrow Airport Ltd.

Mechanical and electrical engineers: G. H. Buckle & Partners.
Mechanical handling engineers: British Airports Authority.
Interior designers: Juliet Glynn-Smith Partnership.
Quantity surveyors: Beard Dove & Partners.
Client: British Airports Authority.
Contractor: Fairclough Building Ltd.



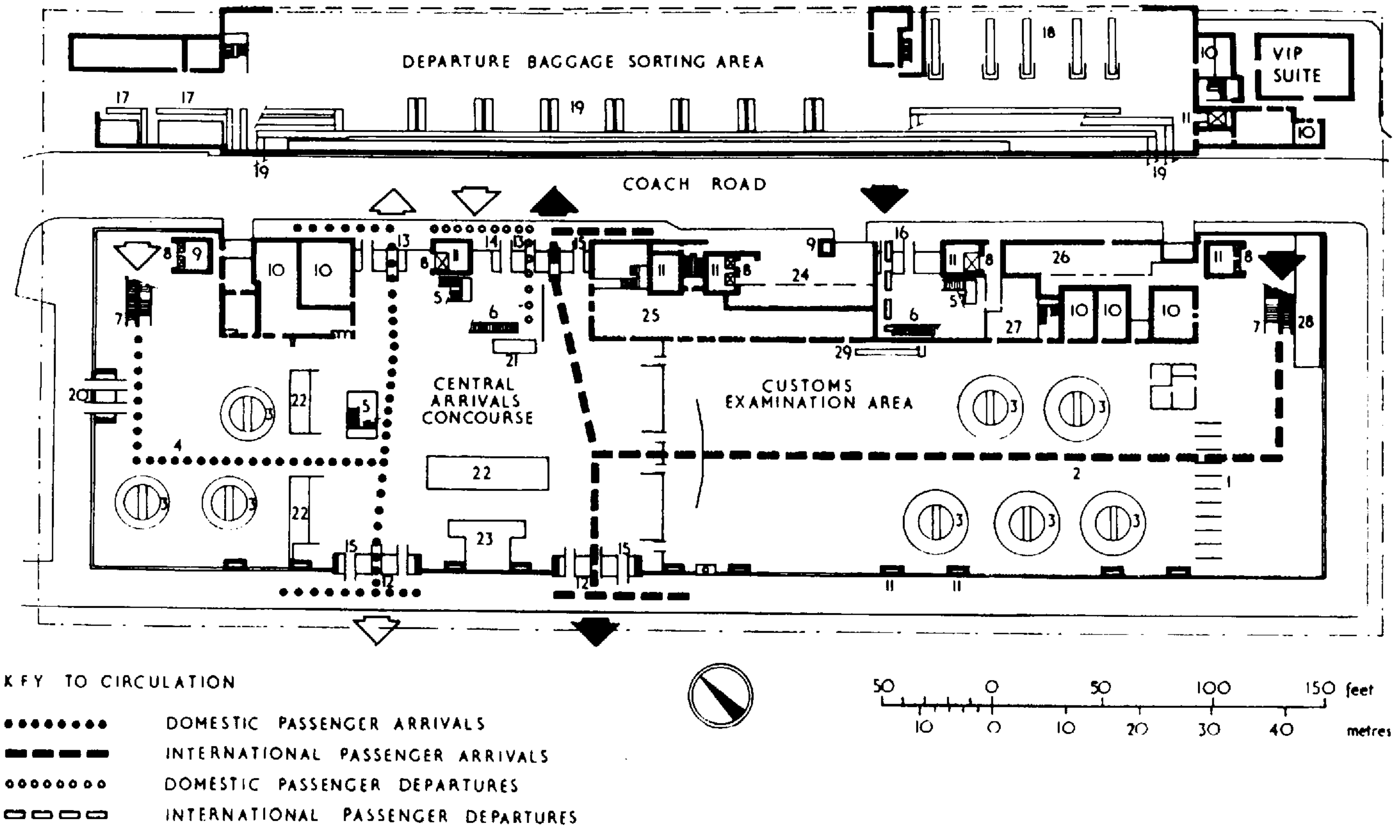
Key

1 Bridge to pier
2 International arrivals balcony
3 Domestic arrivals balcony
4 Staircase
5 Escalators up from coaches
6 Escalator down to arrivals hall
7 Passenger lifts
8 Goods and baggage lifts
9 Passenger lavatories
10 Service ducts
11 CIP lounge
12 Nursery
13 Shops
14 Bar
15 Duty free shop and store
19 Bookstall
20 Special Branch
21 Immigration and customs offices
22 Departure immigration and customs
24 Check-in desks
25 Airline offices
26 Airline counters
27 Entrances
28 Transfer desks
29 Telephones
30 Bridges to car park
31 Bridge to Queen's Building
32 Domestic VIP suite
33 Upper part of ground floor domestic arrivals area
34 Upper part of ground floor international arrivals area

27.5, 27.6, 27.7 Plans and section from Architects' Journal, *20 May 1970. Architects: Frederick Gibberd & Partners. Original terminal built 1969.*

Heathrow Terminal 1 was opened in 1969 as the London terminal for the then British European Airways, handling domestic and European traffic, Figures 27.5–27.7. The two-storey building has a two level forecourt and two long finger piers originally serving 20 stands. Over 25 years many changes and extensions have been planned and made to the building to accommodate changing traffic patterns such as the domestic shuttle services, but the most important deficiency in the mid-1970s was the capacity of the international arrivals facilities.

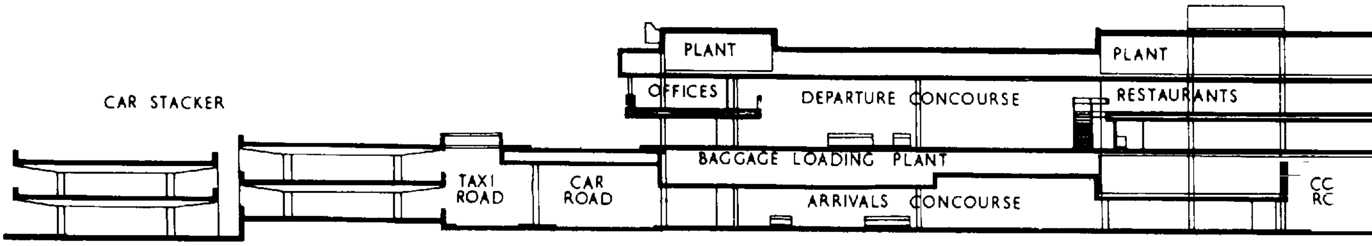
Prior to the project described here, arriving international passengers descended stairs and escalators from the transfer balcony at the south end



Key

1 Arrivals immigration
2 International baggage reclaim
3 Baggage carousel
4 Domestic baggage reclaim
5 Staircases
6 Escalator up to departure level
7 Escalator down from piers
8 Passenger lifts
9 Goods and baggage lifts
10 Passenger lavatories
11 Service ducts
12 Exit to road for cars and taxis
13 Exit to coach road
14 Domestic passengers' entrance from coaches
15 Porter's access doors
16 International passengers' entrance from coaches
17 Domestic arrivals baggage conveyors
18 International arrivals baggage conveyors
19 Departure baggage conveyors (down from depatures level)
20 Domestic passengers' entrance from apron coaches
21 Information desk
22 Airline counters
23 Bank
24 Catering service entrance
25 Baggage stores and offices
26 Port health
27 Porters' accommodation
28 Ramp from apron coach station
29 Transfer baggage conveyor

27.6



27.7

of the building immediately before immigration control and baggage reclaim: see location 7 on Figure 27.6 (ground floor). Queuing space was severely limited and the capacity of this critical element was assessed as 1450 passengers per hour. Both this and the baggage reclaim capacity of 1500 passengers per hour were well below the potential of the whole terminal and pier system and below forecast rates for the year 1980.

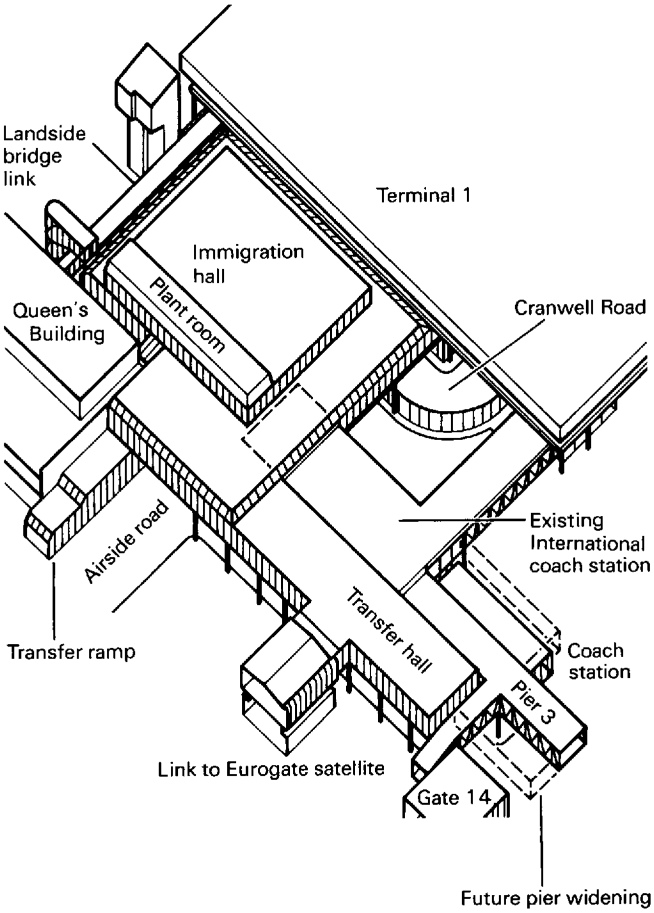
It was determined that the immigration and baggage reclaim facilities should be improved to a level where they could cope with at least 1850 international arrivals passengers per hour.

The British Airports Authority planners and architects Scott Brownrigg & Turner recommended the adoption of a scheme involving a new building straddling the roads south of the end of the terminal. The new building comprised a new immigration hall linked by ramps from the piers and by ramp and escalators to the baggage hall below, Figures 27.8 and 27.9.

Pier 4A (1993)

Architects: Nicholas Grimshaw & Partners Ltd.
Civil and structural engineers: BAA.
Mechanical and electrical engineers: BAA.
Quantity surveyors: W T Partnership.
Client: Heathrow Airport Ltd.
Construction manager: Amec Projects Ltd.

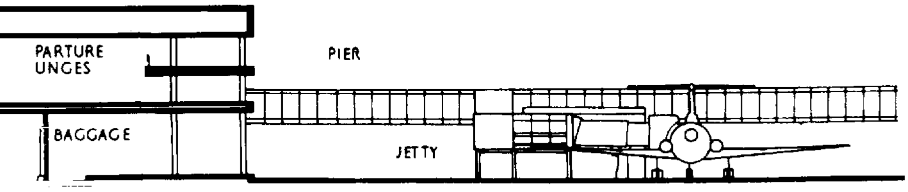
This ingenious addition to the terminal's multiple channels of passenger processing, designed to segregate and provide improved circulation and facilities for domestic, Irish and Channel Islands flights, has four components linked by tubes. The first is a 'nose-shaped' building at first floor level adjacent to location 3 on Figure 27.5, which divides domestic and Common Travel Area passengers, the latter having duty-free shopping facilities in the second component, the circular CTA lounge. This airside facility, segregating arriving and departing passengers, is balanced on a landside island. The nose-shaped building also contains baggage reclaim facilities for arriving passengers from the CTA. The third and fourth components are the two parts of Pier 4A itself, with a total of nine aircraft stands for domestic and CTA traffic. This facility is declaredly temporary: the space occupied by these stands will be needed in future for taxiways: see Figures 27.10 and 27.11.

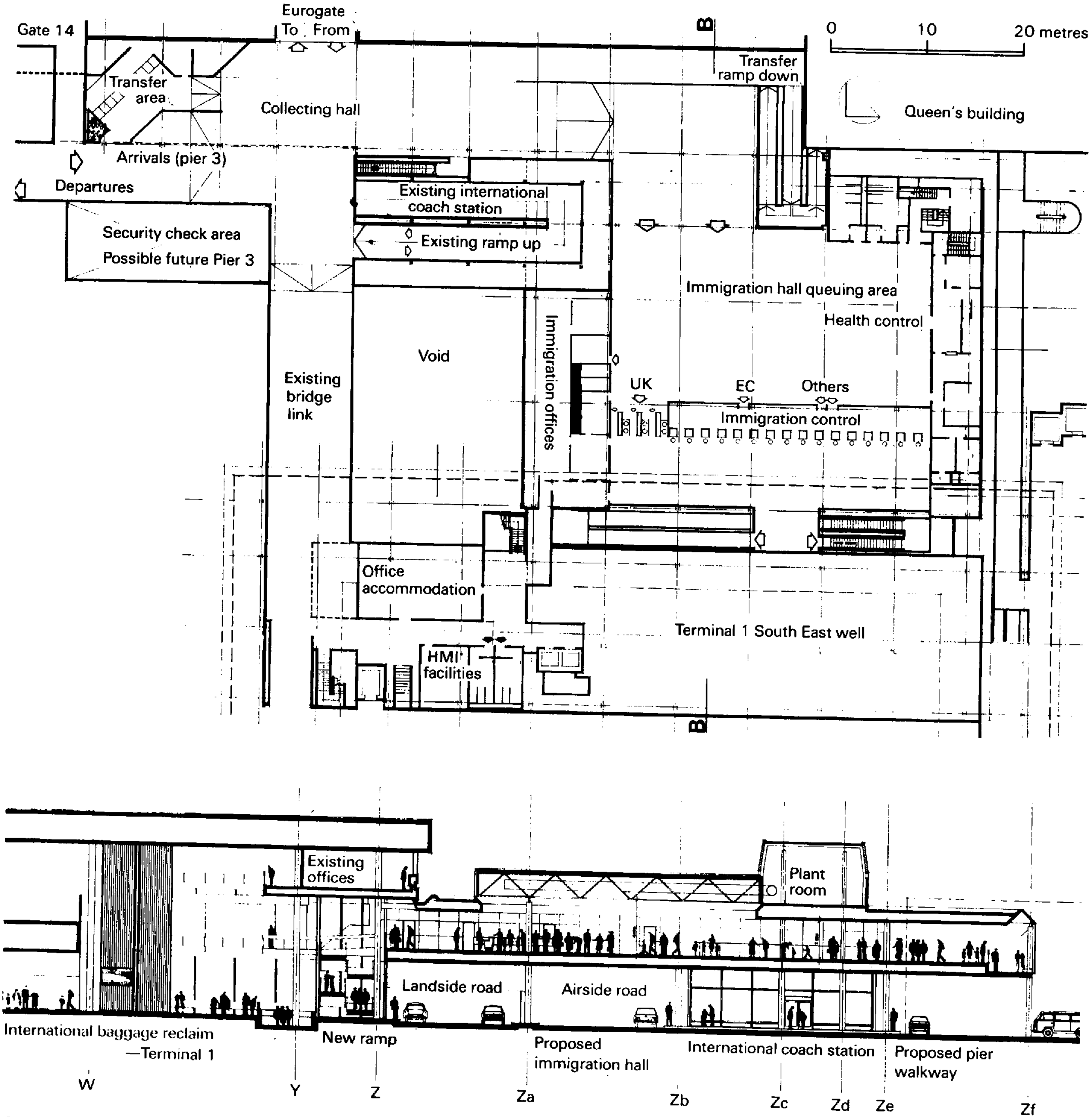


27.8 *International Arrivals Building axonometric. Architects: Scott Brownrigg & Turner, Guildford.*

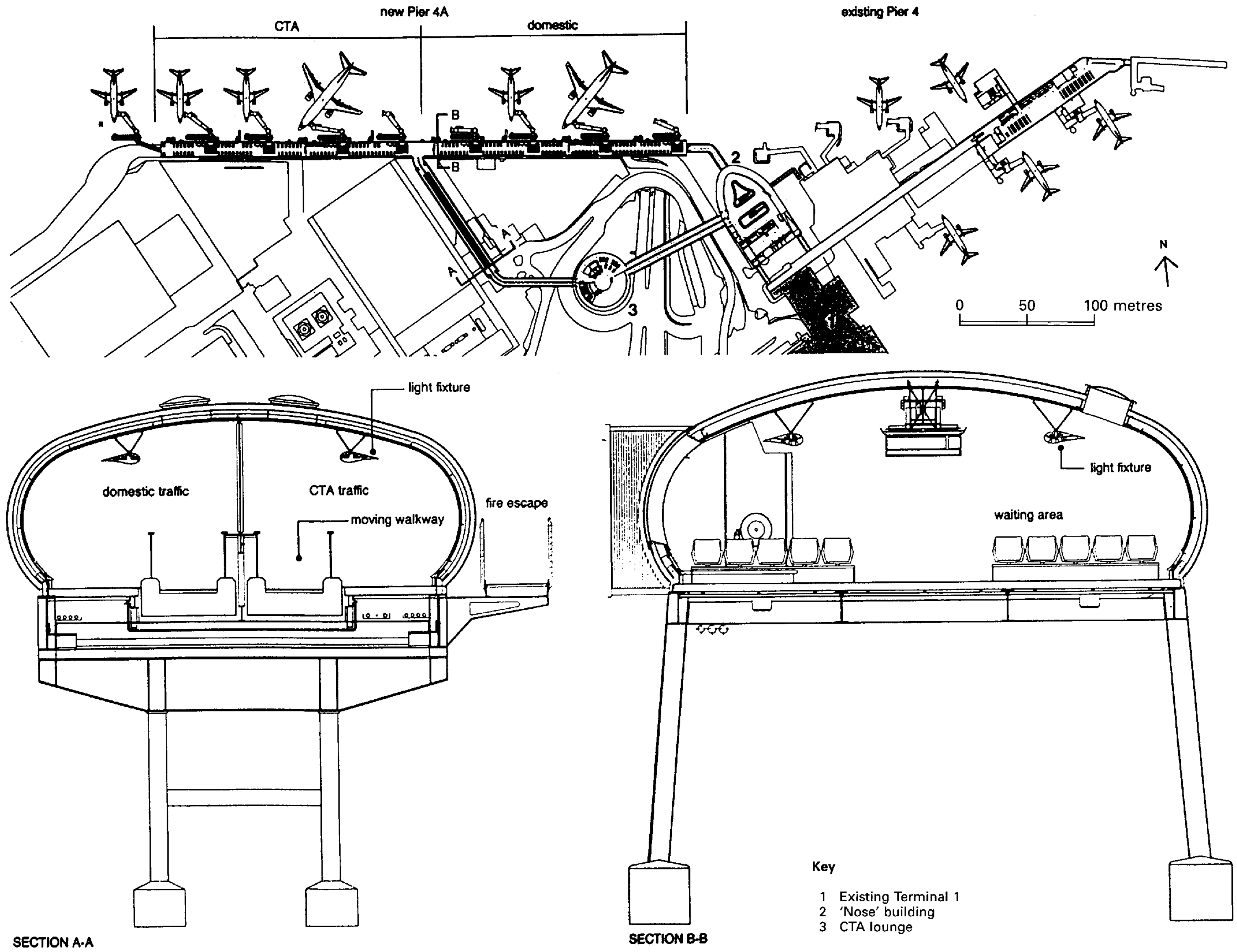
Further reading

Aldersey-Williams, H. (1993) Pier pressure. *Architectural Record*, June.

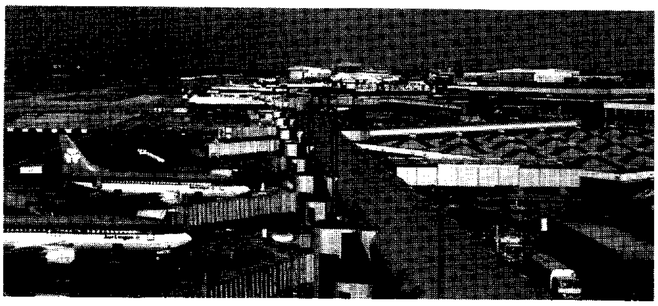




27.9 International Arrivals Building: (a) Plan 1978; (b) section B-B. Architects: Scott Brownrigg & Turner, Guildford.



27.10 Plan and sections of Heathrow Pier 4A development. Courtesy of Heathrow Airport Ltd.



27.11 Heathrow Pier 4A

27.3 Manchester Terminal A development (1986–89)

Architect: R. J. King, City Architect, Manchester City Council.
Structural Engineer: R. J. King, City Architect, Manchester City Council.
Civil engineer: S. J. McLeod, City Engineer and Surveyor, Manchester City Council.
Mechanical and electrical engineer: R. W. Gregory and Partners, Manchester.
Quantity surveyor: R. J. King, City Architect, Manchester City Council.
Client: Manchester Airport plc.
Contractor: A. Monk (Building and Civil Engineering) Ltd, Management Contracting Division, Warrington.

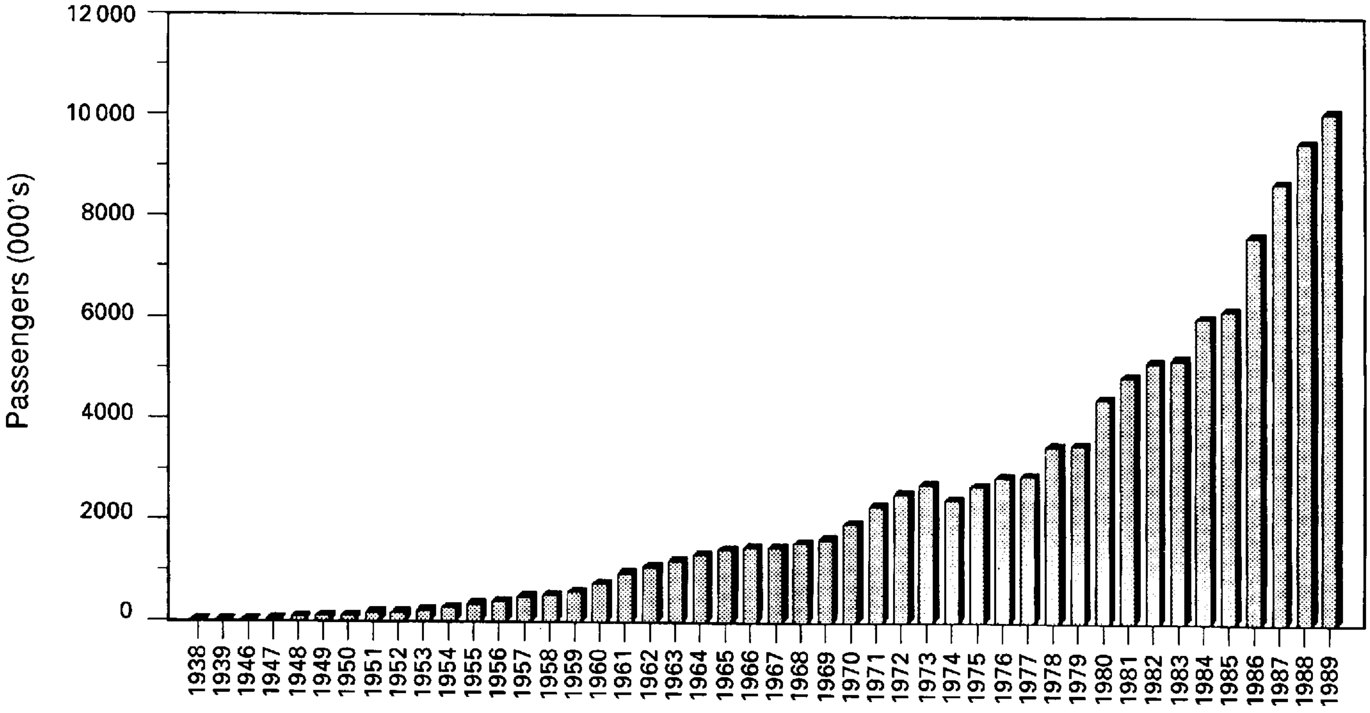
This project comprised the replacement of a domestic pier, originally constructed in 1962, by a completely new domestic terminal with its own forecourt. The demand for this new facility arose from the continued success and growth of both domestic and international traffic at Manchester. The success of the British Airways shuttle link to London Heathrow was a significant part of this growth, and provides 12 flights daily each way, generating approximately 5000 passengers per day for the domestic terminal.

Terminal A links at first floor level with international Terminal B for the convenience of transfer passengers. Otherwise domestic passengers do not impinge upon the international terminal, and passenger flows are thereby simplified. Inside the terminal on the first floor there is a public concourse with a direct, covered bridge link to a dedicated multi-storey car park. The check-in hall contains a total of 28 check-in desks, four of which are equipped with integrated X-ray facilities. Two airside lounges with catering facilities are also provided. Passengers board by way of one of the three loading bridges (four more may be installed at a later date) or, in the case of short-haul commuter flights, by stairs to the apron. Arriving passengers, upon issuing from the loading bridge, descend stairs to a segregated arrivals corridor at apron level and thence to the baggage reclaim area and the landside concourse.

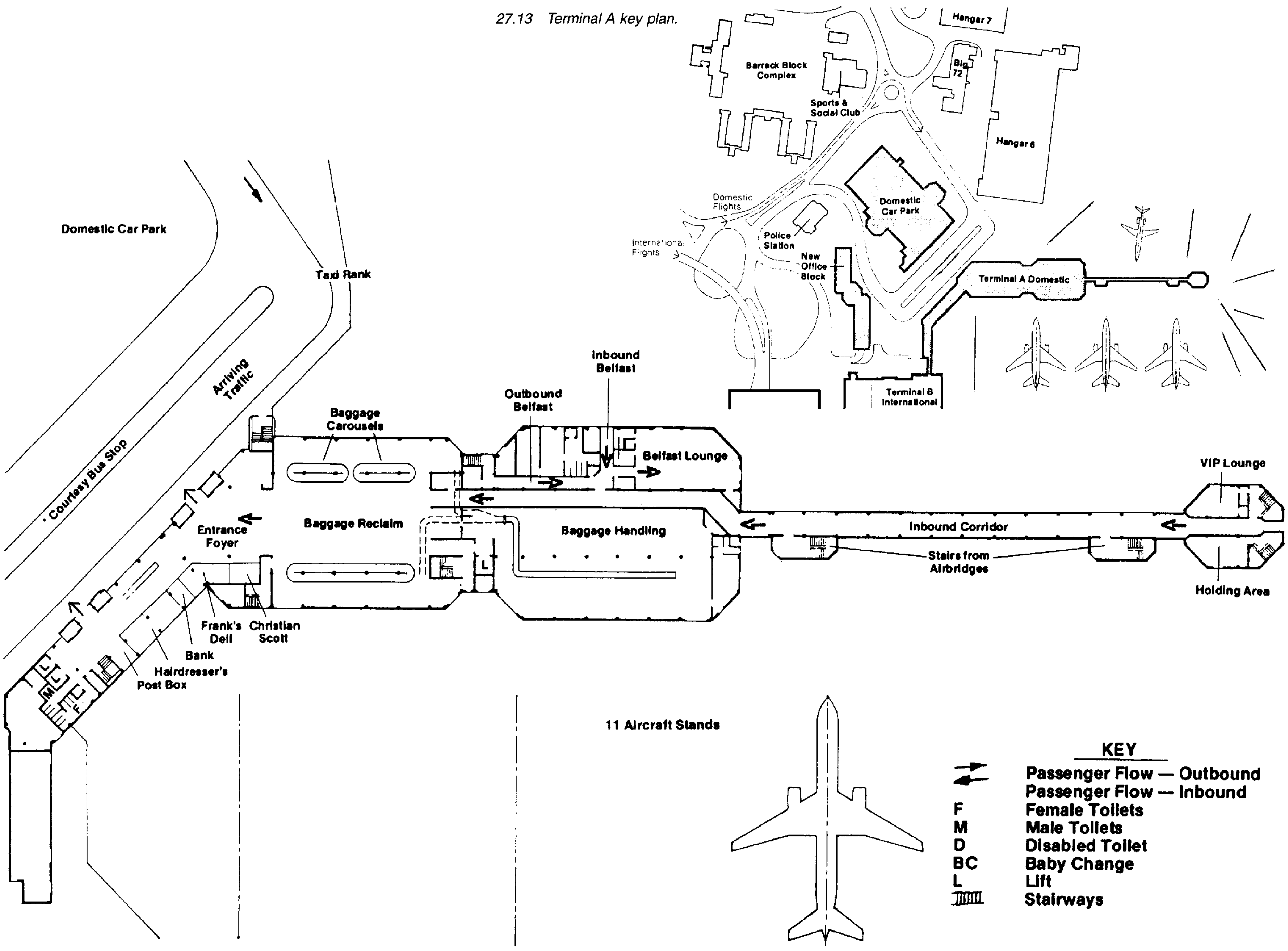
The new terminal was built parallel to and on the east side of the old pier, which was demolished when Terminal A opened in May 1989.

Further reading

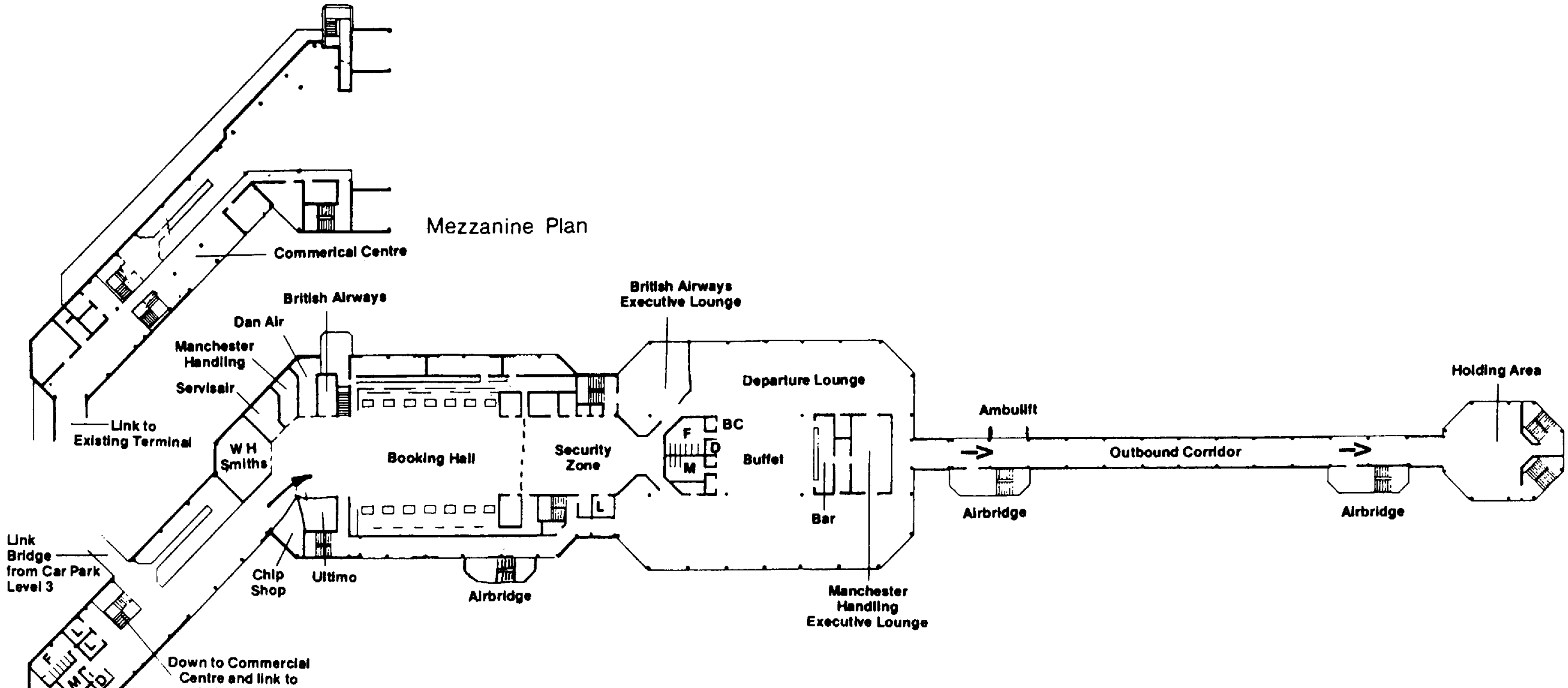
Woolley, D. (1988) Manchester aims at becoming a major hub. *Airport Forum*, **2**.



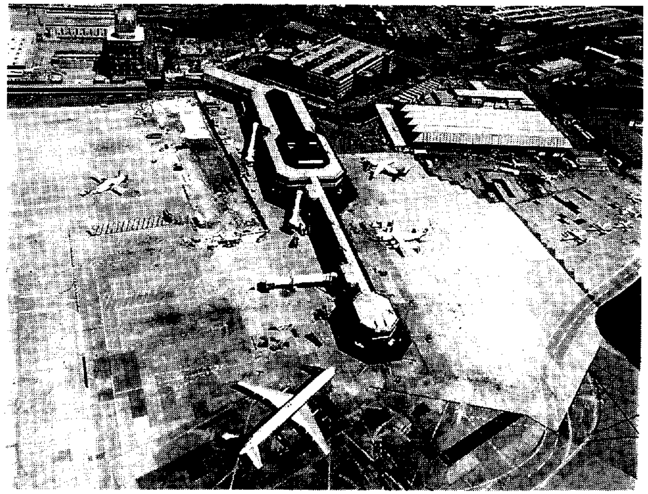
27.12 Manchester Terminal 1 growth pattern 1938–89.


27.13 Terminal A key plan.

27.14 Apron level plan.



27.15 Pier level plan.



27.16 Aerial photograph from the south, showing Terminal A, the remains of the old Pier A to its left and the 900-space car park joined by a bridge to the terminal. The existing terminal can be seen on the left. Courtesy of Manchester Airport plc.

27.4 New York J. F. Kennedy: British Airways Terminal redevelopment (1988–90)

Architect: William Nicholas Bodouva + Associates, New York.
Structural engineer: Alfred Selnick, New York.
Mechanical and electrical engineer: Joseph R. Loring, New York.
Client: British Airways.
Contractor: V. R. H. Corporation, Englewood, New Jersey.

This building was designed by British architects Gollins Melvin and Ward, opened in 1970 and handles about 2 million passengers per year. It is partly vertically segregated, with luffing ramps serving both and arrivals and departures levels.

This project is in fact the third phase of a process of redevelopment which commenced in 1984. Inbound and outbound baggage handling systems have already been replaced, customs clearance facilities have been improved and check-in facilities and shops have been relocated.

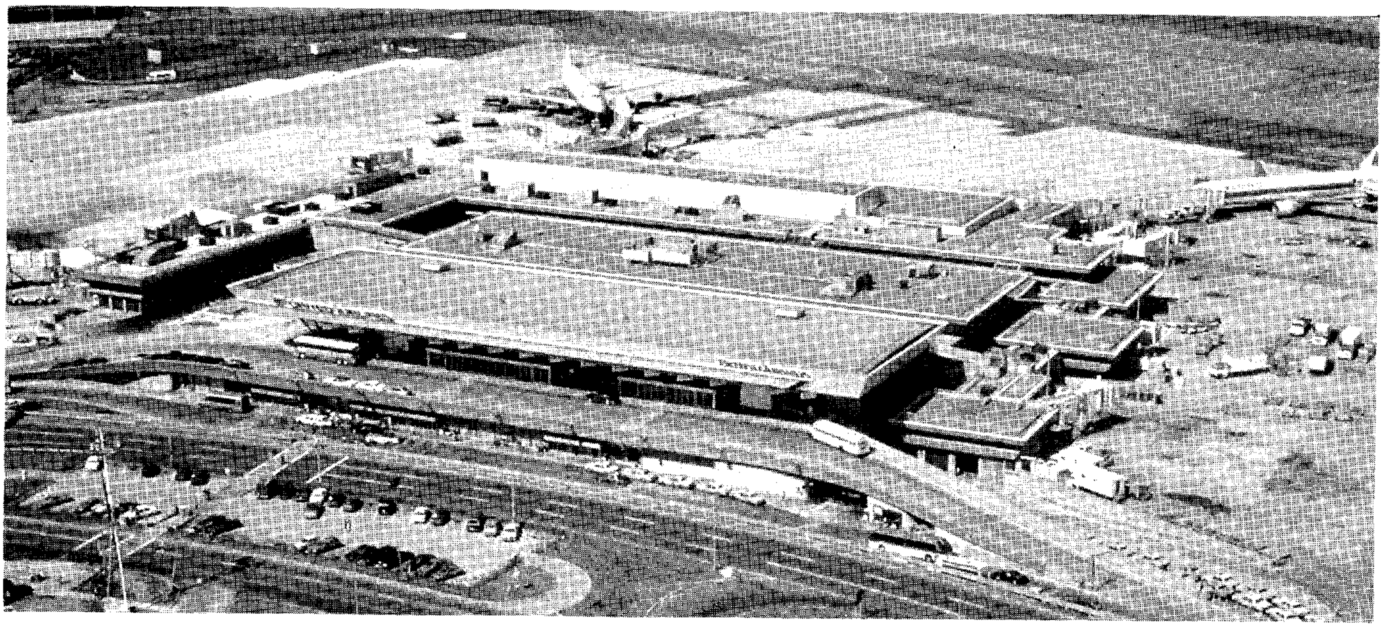
This 24-month project will enable United Airlines to share this terminal with the original owner/occupiers British Airways. Additional space and gate positions are being constructed in a phased programme, and the principal features are new check-in desks for United Airlines, a new open plan airside holdroom area, three new aircraft gates and relocation of existing gates to provide a total of 10 wide-body (six Boeing 747-400) and two narrow body positions and new domestic baggage reclaim devices. Passenger handling capacity goes up from 2200 to 3400 per hour, Figure 27.17.

The phasing of the redevelopment is shown in Figures 27.18–27.20.

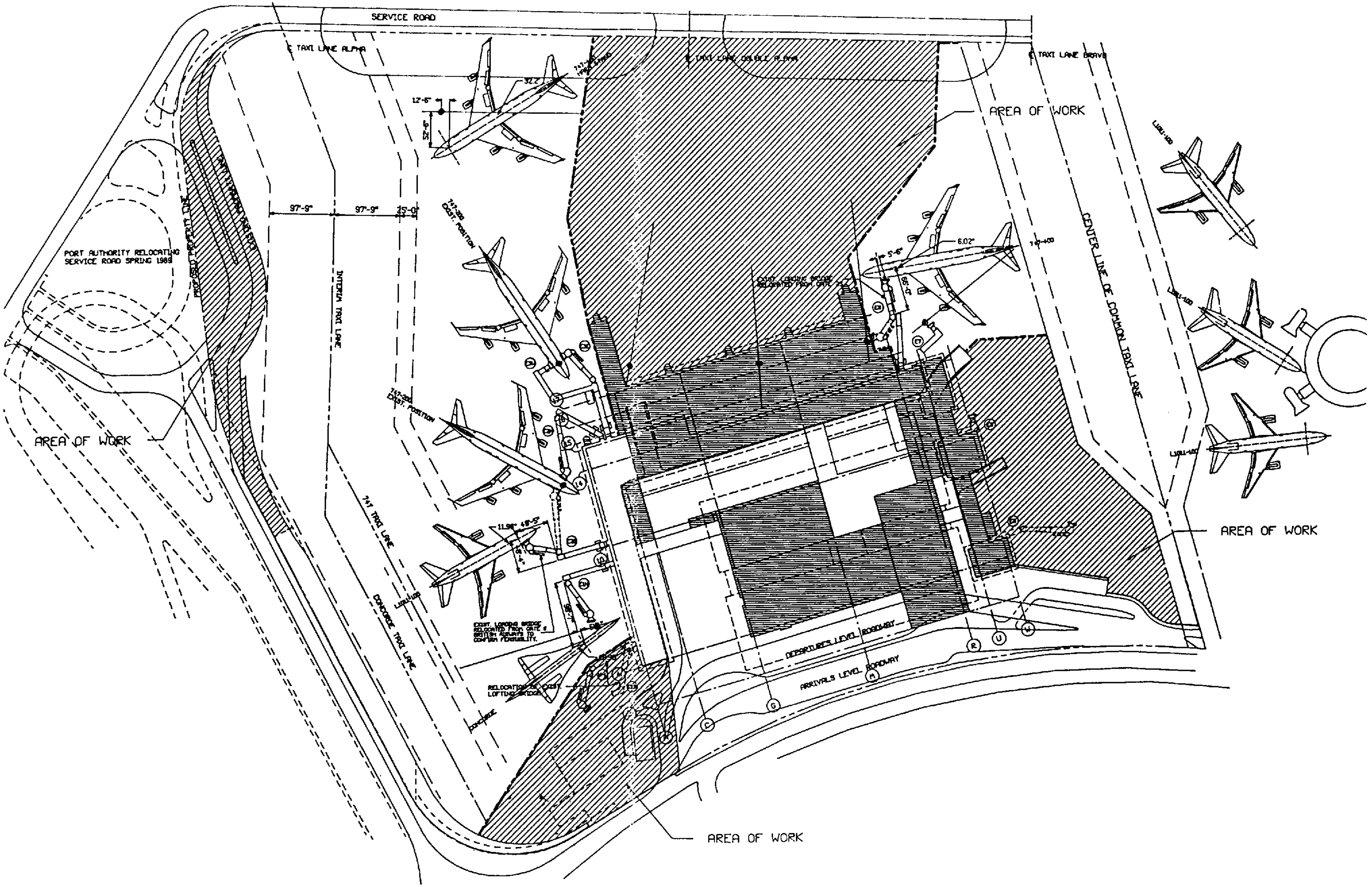
Figure 27.18 Phase 2A: February 1989 to June 1990.
Airside extension under way.
Internal fitting out under way.
Eastern apron works under way.
Only six parking positions available.
Figure 27.19 Phase 2B: June 1990 to July 1990.
Airside extension still under way.
Gate area fitting out under way.
Stand E3 out of commission.
Only five parking positions available.
Phase 3A: August 1990 to September 1990.
Airside extension still under way.
Stand E7 out of commission.
Only seven parking positions available.
Phase 3B: September 1990 to October 1990.
Airside extension still under way.
Stands N1, N5, N6, N10, N11 and N12 plus one open apron stand only available.
Figure 27.20 Completion.

Further reading

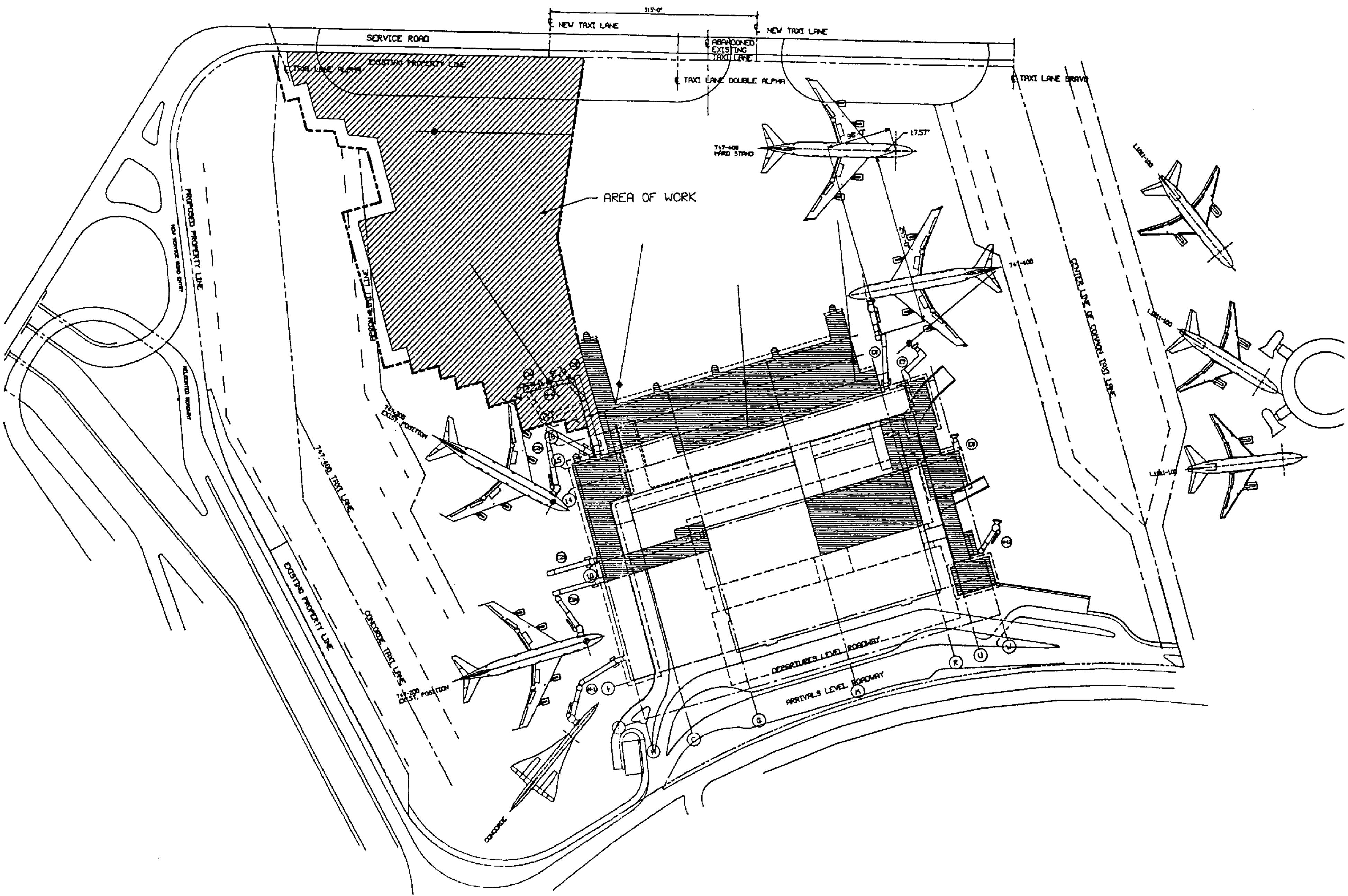
Schwartz, A. C. (1985) British Airways spending $US 30 million to upgrade JFK terminal. *Airport Forum*, **5**.



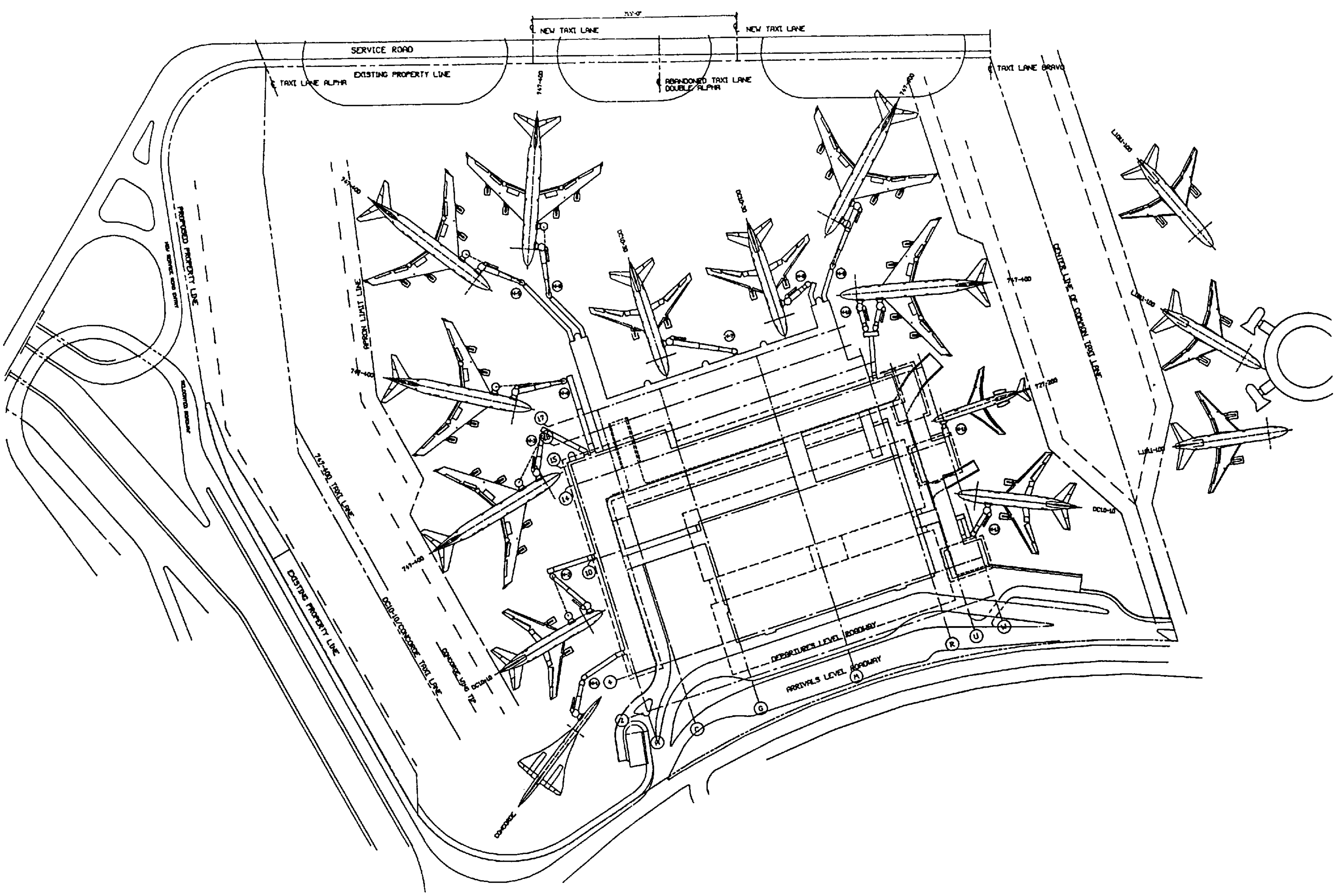
27.17 Aerial photograph of completed redevelopment, courtesy of British Airways.



27.18 New York J. F. Kennedy British Airways Terminal redevelopment: Phase 2A.
Figures 27.18–27.20 courtesy of William Nicholas Bodouva + Associates, New York.



27.19 Phase 2B.



27.20 Completion.

27.5 London Heathrow Terminal 3 redevelopment (1986–90)

Architect: D. Y. Davies Associates.
Structural engineers, Arrivals: Anthony Hunt Associates.
Structural engineers, Departures: British Airports Services.
Heating and ventilation, Arrivals: Donald Smith Seymour and Rooley.
Heating and ventilation, Departures: British Airports Authority.
Electrical engineers: British Airports Authority.
Interior designers: Fitch and Co., John Herbert & Partners.
Quantity surveyors: British Airports Authority.
Client: Heathrow Airport Ltd.
Construction management: Amec Projects.

Heathrow Airport's Oceanic Terminal opened fully in 1962 and experienced a relatively short first uninterrrupted phase of use. Between 1968 and 1970 a new intercontinental arrivals building was built adjacent and at right angles and the first terminal (built to handle arriving and departing passengers), was converted to handle only departing passengers.

Such has been the increase in world travel, especially trade and tourism between Europe and North America and the Far East, that between 1970 and 1980 the newly named Terminal 3 built up traffic and was consistently handling its design standard of 3000 passengers per hour in each direction. With the removal of British Airways' long-haul traffic to Terminal 4 in 1986, a programme of reconstruction and expansion at Terminal 3 was put in train.

This four-phase programme involves not only reconstructing the roof and external walls of the 1962 Departures Terminal to modern standards but also increasing the floor area of the Departures Terminal by about 25 per cent to a total of 35 000 m^2. The major item of work in the Arrivals building is the installation of new baggage handling equipment and the increase in the number of baggage reclaim devices from 7 to 11. The resultant capacity is increased from 3000 passengers per hour in each direction to 3500, the annual capacity increased from 7 million to 10 million passengers and the overall size increased by 33 per cent.

The new departures baggage sorting system is the first OCR (Optical Character Reading) operational system in the world: machine-readable tags are applied to each piece of baggage at the check-in desk.

Phasing was critical, especially in the Departures Terminal. The new sections of building were completed first (see site plan) and provided accommodation for decanting those displaced by subsequent phases of reconstruction. The Departures building was divided into three subsequent reconstruction phases, Figures 27.21–27.24.

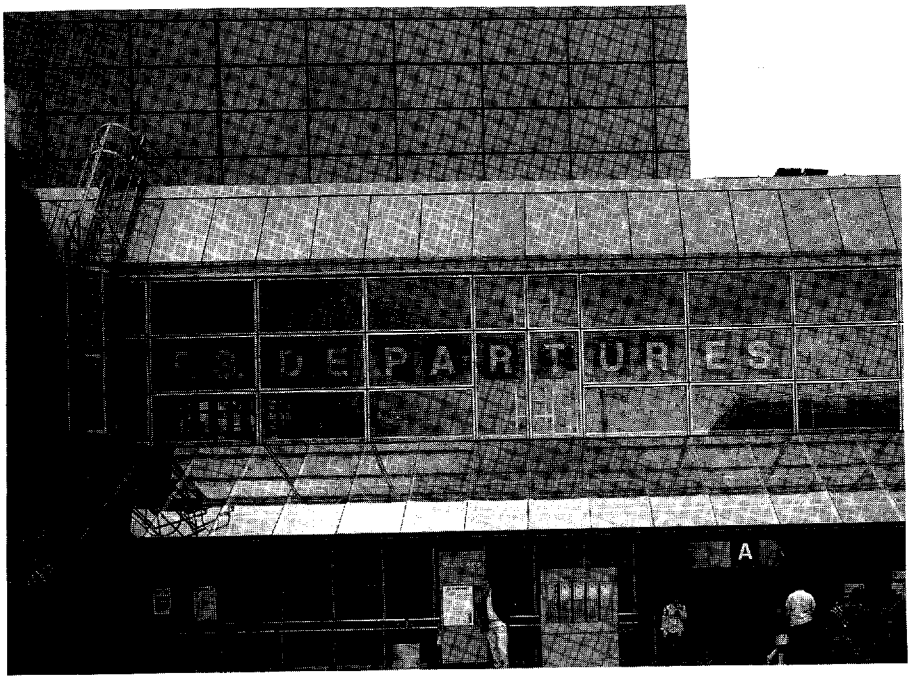
Further reading

Howell, G. D. (1988) Redeveloping the terminal buildings. In *Airport Technology International 1988*, edited by M. G. Hudson.

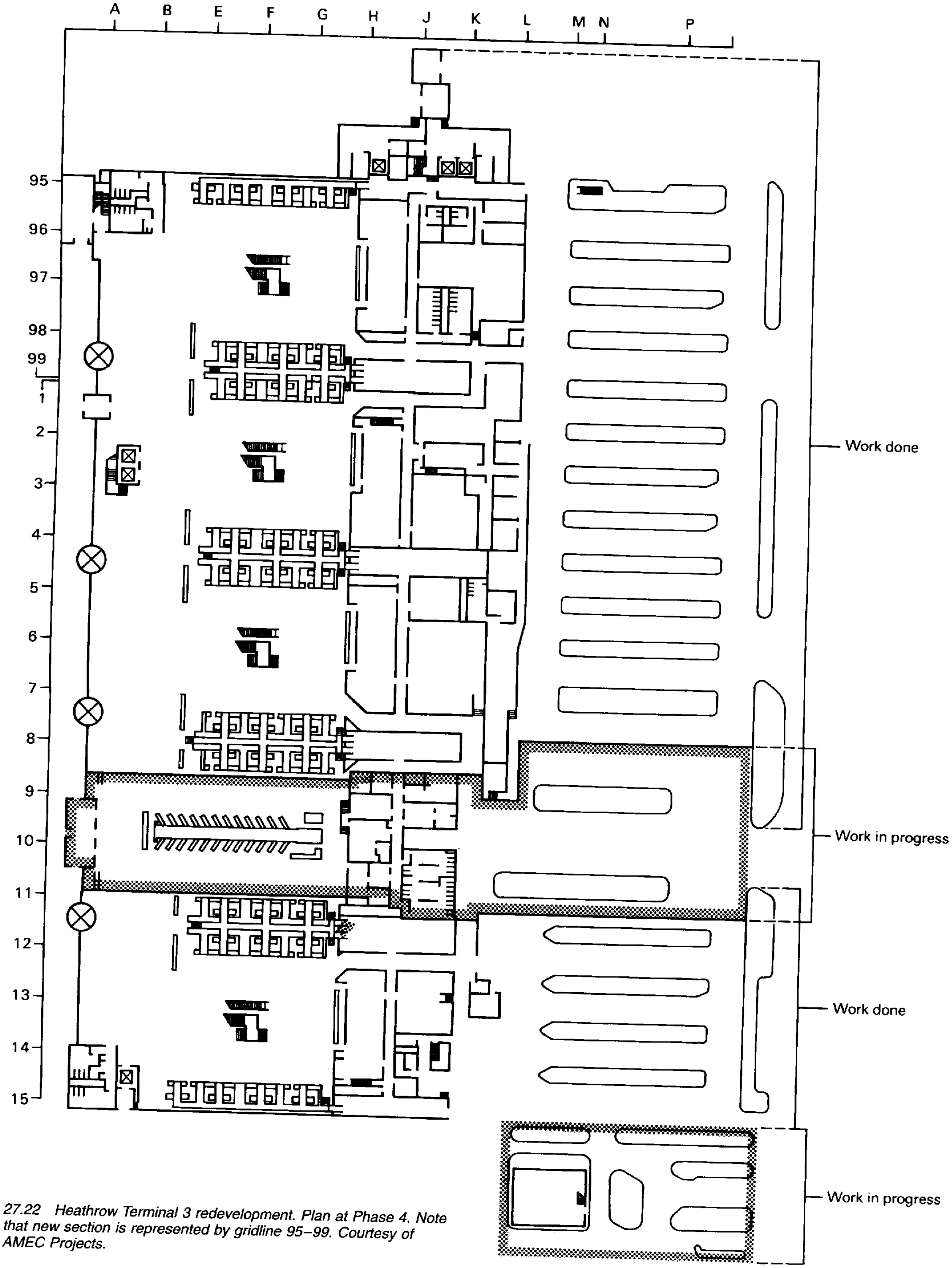
Melvin, J. (1989) Room to move. *Building Design* (Supplement on refurbishment), August 1989.

Ridout, G. (1988) Terminal 3 the remake. *Building*, 19 February.

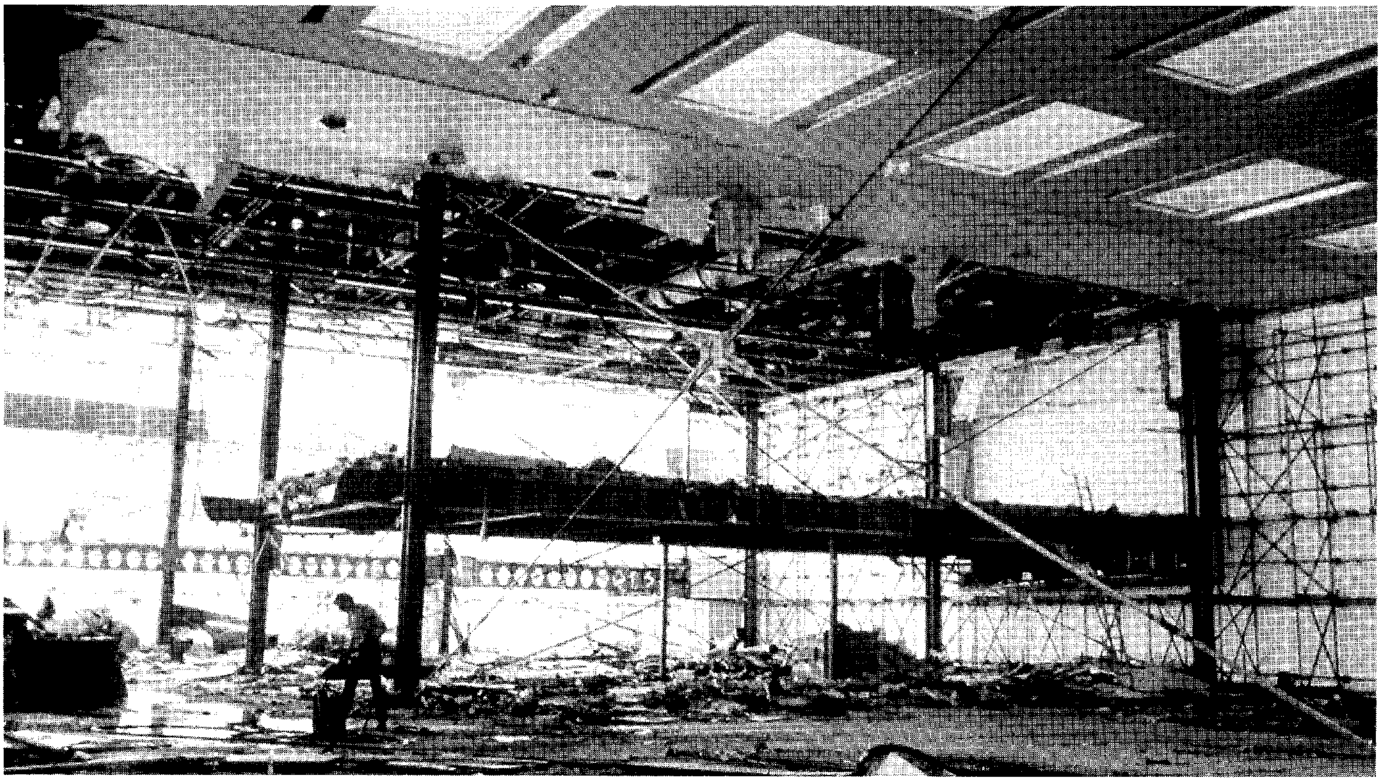
Weatherhead, P. (1990) New departures in arrivals. *Building* (Refurbishment supplement), 15 June.



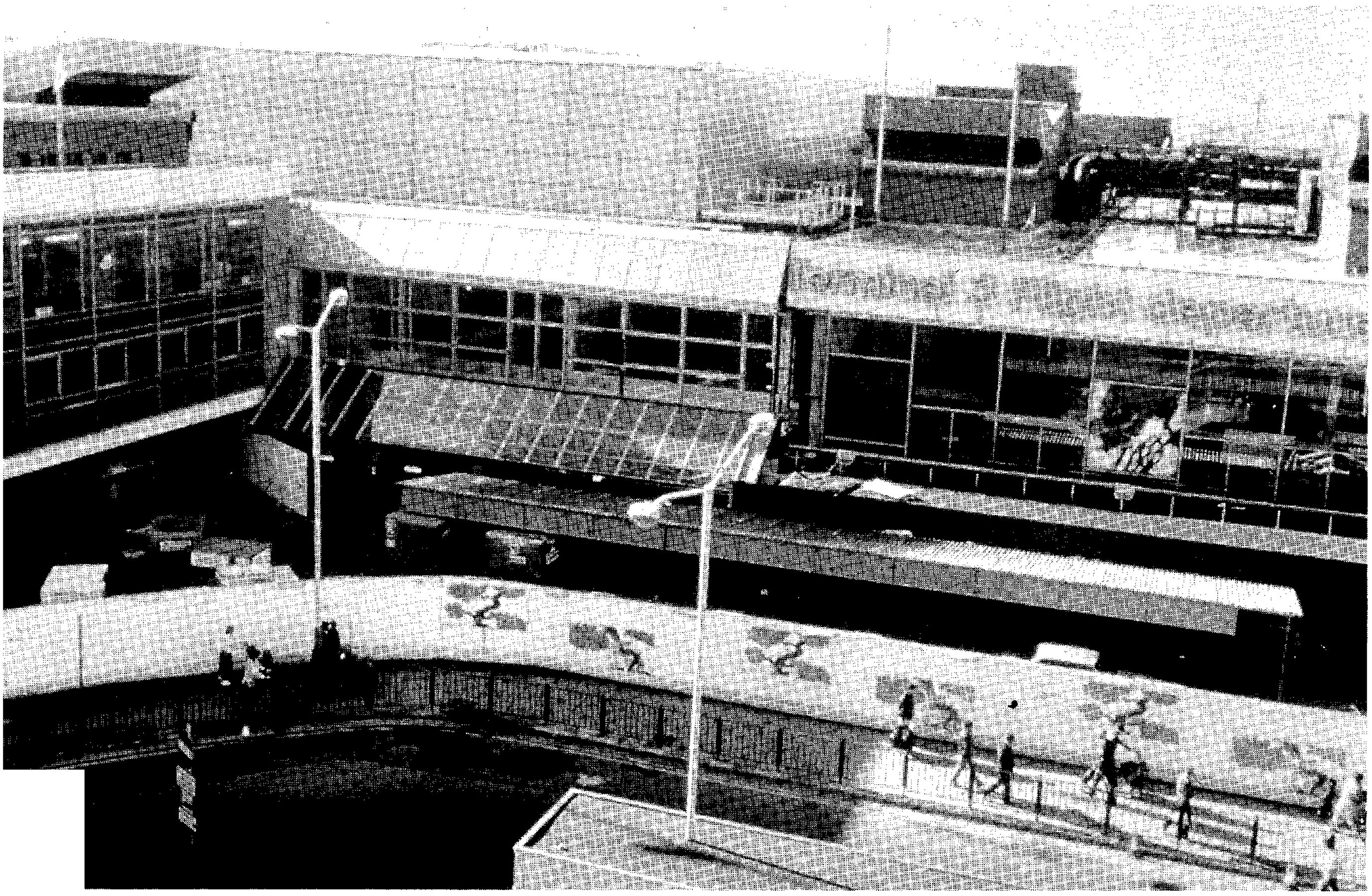
27.21 Exterior. Client: Heathrow Airport Ltd. Architects: D. Y. Davis Associates Ltd, Richmond, Surrey.



27.22 Heathrow Terminal 3 redevelopment. Plan at Phase 4. Note that new section is represented by gridline 95–99. Courtesy of AMEC Projects.



27.23 Interior demolition.



27.24 Exterior phasing.

27.25 Hamburg Fuhlsbuttel aerial photograph. Courtesy of architects: von Gerkan, Marg + Partner. Photographer: Reimer Wulf.

27.6 Hamburg Fuhlsbuttel Terminal redevelopment

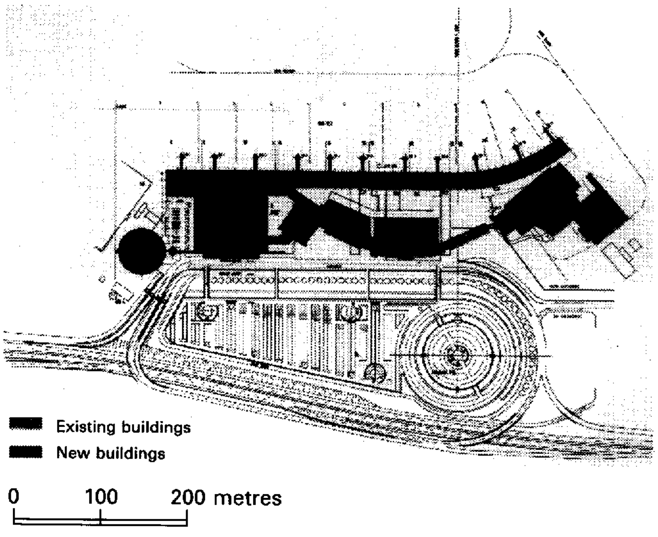
Architects: von Gerkan, Marg + Partner, Hamburg.
Project managers: Drees & Sommer AG, Stuttgart.
Technical consultants: HGR Ingenieurgesellschaft Ridder/Meyn, Schmidt Reuter Partner Ingenieurgesellschaft, Ingenieurgruppe HSP, Peter Andres.
Client: Flughafen Hamburg GmbH.
Contractor: Hochtief AG.

This building, the first phase of redevelopment of this important regional airport, comprises an elegant cylindrical car park, a new two-level terminal and a linear pier with 11 gates. The pier has a single passenger level, with gate control facilities. It curves at the end to permit short-term retention of the charter terminal and allow additional stands when the charter terminal is replaced. Completed in 1993, the terminal structure has much in common with the 1991 Stuttgart terminal building by the same architects (see Section 7.2). The terminal has a great curved roof, enclosing a 75 m × 100 m clear-spanned hall. The later aim is the replacement of all the earlier buildings, Figures 27.25 and 27.26.

Development of the old airport of Fuhlsbuttel, and the long-established terminal area within it, is a consequence of the abandonment in 1984 of 20 years of planning of a new airport at Kaltenkirchen on grounds of cost and opposition.

Further reading

Brauer, K. (1992) Hamburg Airport. *Public Transportation*, Summer.
Walters, B. (1990) Hamburg airport stretches its wings. *Building Design*, 19 January.

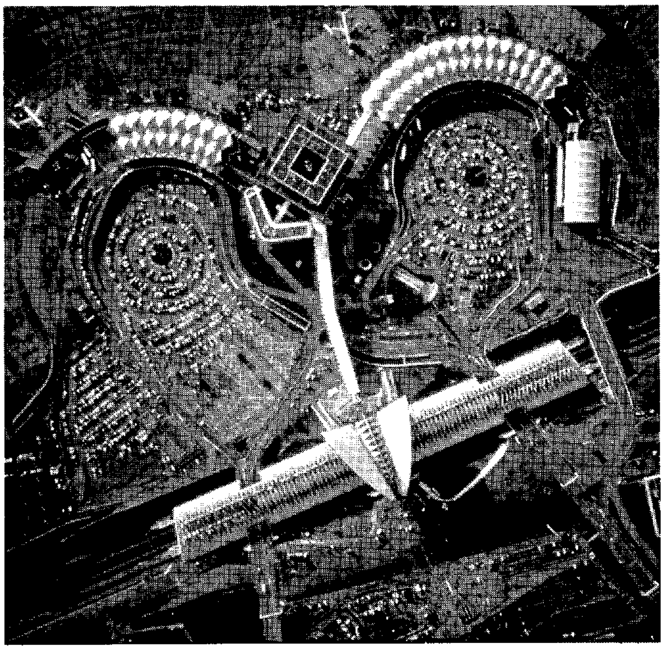


27.26 Key plan.

27.7 Lyon Satolas Terminal 2 redevelopment

Architects: Scott Brownrigg & Turner/Curtelin Ricard Bergeret.
Civil and structural engineers: Technip TPS Peyrard/Buro Happold.
Mechanical and electrical engineers: Technip TPS Peyrard.
Quantity surveyors: Cabinet Minangoy.
Client: Chambre de Commerce et D'Industrie de Lyon.

This project will double the capacity of the terminal (formerly known as the National Terminal and now known as Terminal 2) from 2 to 4 million passengers per year with a peak flow of 2000 passengers per hour in both directions. The design team has been commissioned to create a phased expansion programme, effectively turning the single-level domestic terminal into a vertically-segregated four-channel terminal. Previously, and prior to a decision to relocate all Air France traffic from the international terminal (now Terminal 1), the proposition

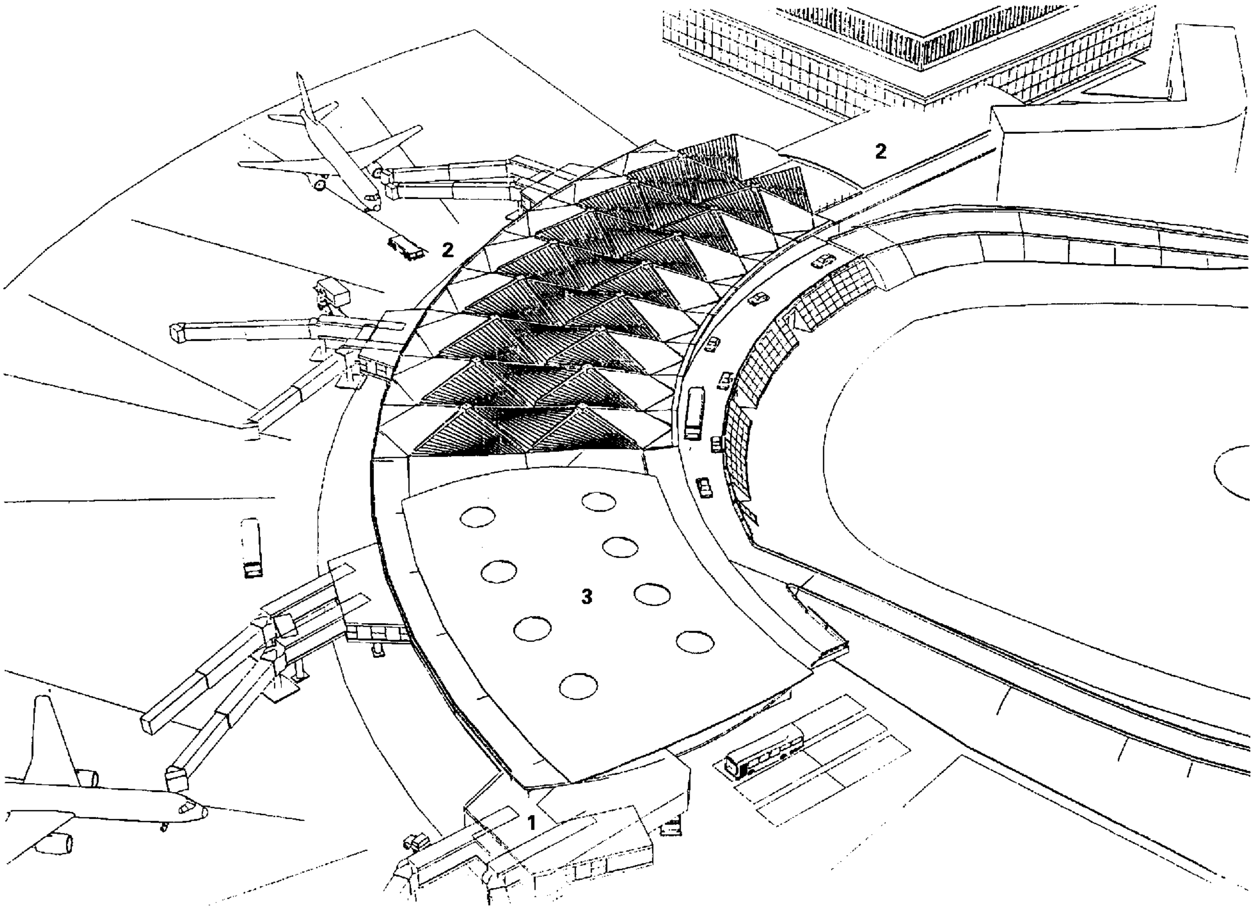


27.27 *Lyon Satolas areial photograph. Terminal 1 on right; Terminal 2 on left. Courtesy of Chambre de Commerce et d'Industrie de Lyon. Photographer: Mario Renzi.*

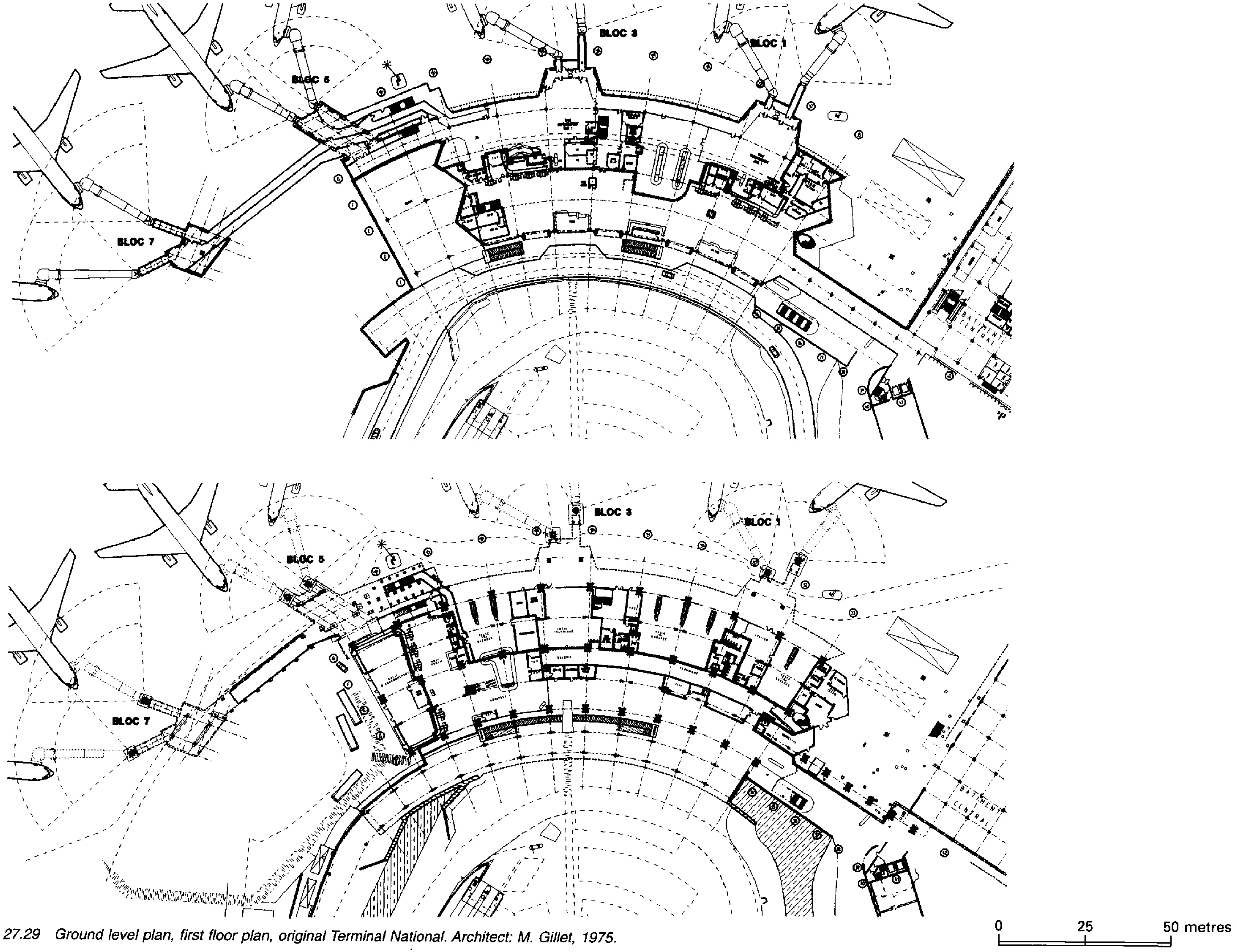
had simply been to develop domestic facilities. The new need to distinguish traffic between Schengen Agreement states from other intra-European Union traffic has built the demand for four channels. The existing structure has been discontinued and the necessity for intricate phasing is imposed by the need to maintain the maximum passenger service throughout. Phase 1 has already been achieved.

By virtue of its location, Lyon Satolas is a hub, and is served by a multiplicity of small airlines and aircraft as well as pan-European and international flights. The link between the two terminals improves transfer times between international and domestic flights, and the target is 20 minutes. The proximity of the TGV station not only improves surface links with the airport but makes possible the integtation of transport systems referred to in Chapter 15. Figure 27.27 shows the whole terminal complex, with Terminal 1 on the right, Terminal 2 on the left and the TGV station in the foreground.

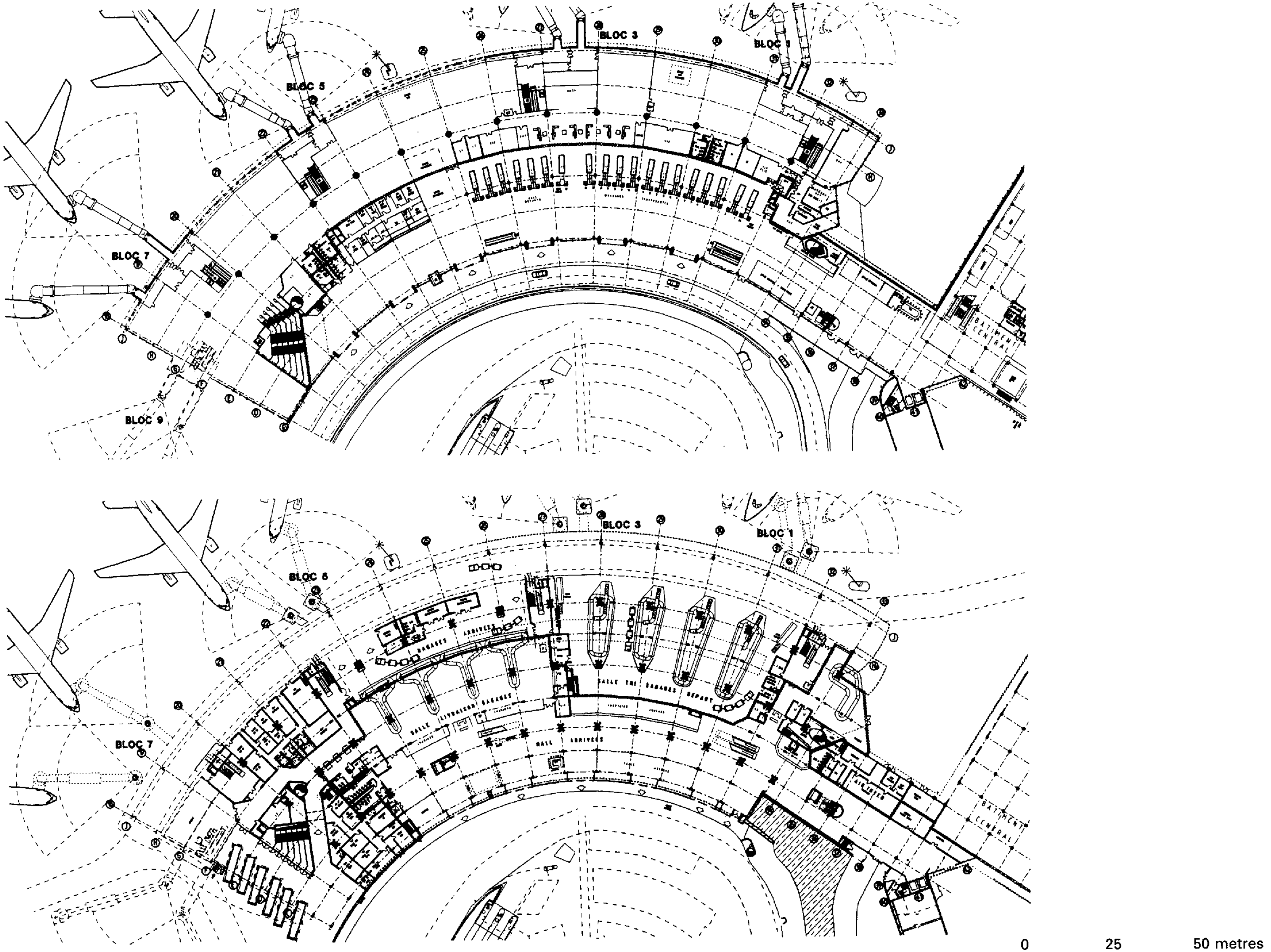
See Figure 27.28 for details of phasing. The planning of this transition has been particularly intricate. The original building, shown with Phase 1 added in Figure 27.29, is not easy to change. Plant originally located at ground level in the path of new



27.28 *Computer model indicating project phasing. Architects: Scott Brownrigg & Turner, Guildford.*



27.29 Ground level plan, first floor plan, original Terminal National. Architect: M. Gillet, 1975.



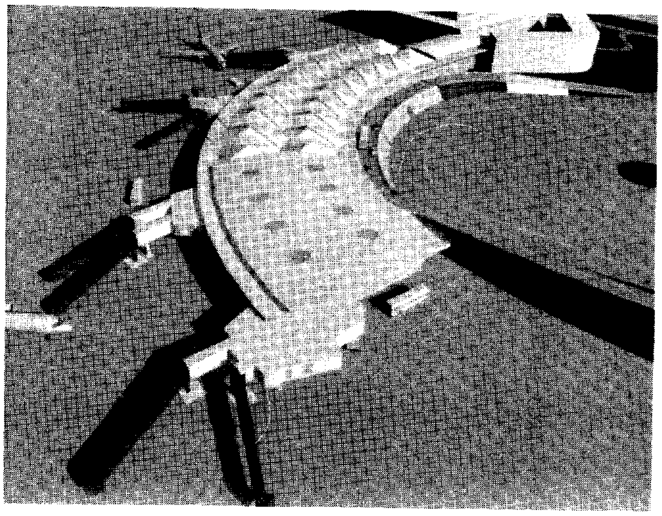
27.30 *Ground level plan, first floor plan, Terminal 2 complete redevelopment. Architects: Scott Brownrigg & Turner, Guildford.*


(a)

essential baggage facilities is relocated in a new basement constructed within the curtilage of the functioning terminal. The price of continuous operation is the long-term construction site. After addition of a new pair of fixed gates, the three principal phases are as follows, bearing in mind the client's wish to be able to stop the programme after any phase with a complete and viable unit:

Phase 2: A new link to the Central Facilities Building; Airside extension along existing frontage; Rearrangement of check-in and and baggage handling; Temporary baggage reclaim facility under link building. *Phase 3*: Principal extension on three levels (basement and two passenger levels); Temporary departures baggage make-up area. *Phase 4*: Completion of new check-in installation, all pass-through desks; Completion of related baggage make-up area.
See Figure 27.30. Figure 27.31 illustrates the complete transition.

(b)



27.31 (a) Original terminal, courtesy of Chambre de Commerce et d'Industrie de Lyon, and (b) three-dimensional visualization of complete redevelopment. Architects: Scott Brownrigg & Turner, Guildford.

Further reading

Yates, C. (1995) Lyon is fighting back. *Jane's Airport Review*, June.

Part VII Postscript

In the five years between preparation of the first and second editions of this book geographical and economic balances have shifted, as summarized in the new Preface, but the greatest local change in the terminal building lies in the use of information technology . . .

28 Reflections on the future of airport terminals

Continuous change there may have been over the life of airports described in this book, but it has not been such as to generate anything unrecognizable over two or more decades. Aircraft, ground vehicles (with the possible exception of mobile lounges) and ground facilities evolve slowly. It is the scale of the exercise which changes.

Prophecies may be self-fulfilling. Commerce and government should create the future rather than guess it and plan to achieve the guessed situation.

Airports, and in practice their terminal buildings rather than their runway systems, should be less determinist, built in smaller increments and more responsive to change. Most airport terminal developments have been incremental and adaptable, and therefore successful. Those which have not, such as Charles de Gaulle Airport Terminal 1, may have other qualities, but have been marked down as unsuccessful simply because their perceived problems have not been solvable by adaptation.

Radical concept designs have caught the eye in the form of taxi-through terminals and inclined runways, but high cost militates against experimentation.

Baggage handling

It is in the area of baggage provisions that the airport and aviation industry could be accused of projecting the past rather than creating the future. It is really an airline service matter: why do airlines have to cater for vast quantities of accompanied baggage? The answer has much to do with the fact that they have in the past, and because airport terminal handling systems are designed to solve the old baggage problem. Why do passengers expect the airlines to carry vast quantities of accompanied baggage? For the same reasons.

Russian peasants loading their own brown-paper-covered suitcases and packages into the holds of Ilyushin-86s on snow-covered aprons of Russian domestic airports do not demand fully automated baggage handling systems. Would it not be simpler if passengers kept their baggage with them, limited to what they can carry on to the aircraft and stow? Additional baggage should be treated as cargo and consigned accordingly. This, after all, is what used to happen on the British rail network. British Railways offered a passengers' luggage in advance (PLA) service for those travelling to and from boarding school and seaside holidays with cabin trunks and swimming trunks.

Technology in the service of air travel at airports

Just as some people could be forgiven today for thinking that the duty-free shop is the most important part of the airport, so others could be forgiven for wondering why baggage is better looked after than the passengers. It is ironic how well the baggage is served by technology, with automatic readers for optical coding on labels and tilt-trays (described in Chapter 20).

People-moving systems are limited in use to point-to-point trains on tracks, rather than multi-directional cars, and there are no signs yet of systems directed at the individual passenger. Therefore we look to information technology to take the strain out of the airport terminal. The smart cards and baggage labels referred to in Chapter 24 are simply the visible sign of an underlying information technology driving the terminal of the twenty-first century.

The real revolution will be in the hidden systems, the systems to manage and monitor the building and management activities. For example, when Manchester Terminal 2 opened in 1993, it was equipped with the latest technology for baggage and flight information handling, as well as a Terminal Management System (to plan, allocate and manage parking stands, staffing and equipment), a Building Management System (to report status on all equipment and to control fuel, heating and cooling, alarms, etc.) and notably a CHP plant, combined heat and power generators to ensure independence and economy in this vital and costly part of terminal operation.

Visualize the terminal manager of the future at his console. He sees a giant screen display of the layout plan of the landside concourse and flicks over to the airside concourse and then the apron. The plan is chequered with symbols each corresponding to the sensors and recording devices installed.

He flicks over to another display which shows the finishes on wall, floor and ceiling surfaces and their maintenance and cleaning systems and so on and so on. The hidden advantages to the traveller are reflected in reduced charges to airlines by the airport owner and by constant investment and improvement to facilities. The terminal building is energy-efficient and people-efficient, world-friendly and people-friendly.

Technology in the air

What lies in the future for air travellers in the way of aircraft technology? At the bottom end of the size/range scale are the predictions for growth in the number, and possibly types, of feeder aircraft (see Chapter 4). However, it is at the other end of the scale that the big questions lie. What is clear is that enormous sums of money are at stake in meeting the demand for aircraft and air space to carry tourists and business travellers, and that big money will be thrown at big aircraft and control systems.

The combined demands of airport congestion, market size, increased range and airliner economics have led Boeing to predict in their latest look into the future that after 1994 over 75 per cent of new aircraft delivered will have more than 240 seats and 46 per cent will have more than 350 seats. It is in the range of aircraft now populated by the wide-bodied Airbus A330 and A340, the McDonnell Douglas MD11 and notably the Boeing 747 and its new stable-mate the 777 that battles will be fought. It seems that the three giant manufacturers are concentrating on competing in a sub-Boeing 747 size range rather than thrusting ever bigger, but this could be set to change with initiatives from airlines like British Airways.

Apart from the actual aircraft it is in the field of engine design and economics, where the market is also dominated by three giants, Rolls-Royce, General Electric and Pratt and Whitney, and in air traffic control where the passenger will experience indirect benefits.

Technology in the service of designers

The signs are that the future will offer a means of seeing the future now, in the form of computer simulations of designs, both in the form of operational models and 3-dimensional visual models. By entering values for passenger arrival distribution, passenger/visitor ratio, service rates at check-in, security, immigration and customs and dwell times in certain areas a very valuable assessment of the performance of a design can be achieved even before the concept is developed.

Further reading: travel technology

King, R. (1992) Operational efficiency at airports. *Airport Forum*, **6**.

Reed, A. L. (1990) *Airline – the inside story of British Airways*, Chapter 12. London: BBC Publications.

Renaud, Y. (1992) Ithaca – a theoretical approach to airport design. *Airport Forum*, **6**.

Schwartz, A. C. (1992) 'Ecoport' would put terminal-parking in dome under inclined runways. *Airport Forum*, **6**.

Walmsley, P. (1978) Airports in the year 2000. *Airport Forum*, **4**.

Further reading: design technology

Fitzsimons, B. (1995) Pictures on a screen. *Airport Forum*, **1**.

Gethin, S. (1995) Modelling the future. *Airport Support*, March.

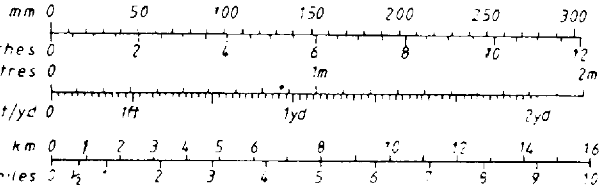
Conversion factors and tables

The system of measures used in this book is 'Système International d'Unités' known in all languages as SI units which are based on the following:

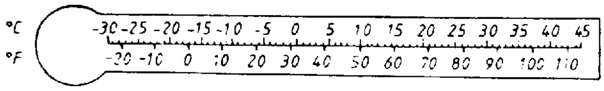
Quantity	*Name of unit*	*Unit symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin*	k
Luminous intensity	candela	cd

*The degree Celsius (°C) is used for all practical purposes.

Quantity	*Conversion factors*		
Length	1.0 mm	=	0.039 in
	25.4 mm (2.54 cm)	=	1 in
	304.8 mm (30.48 cm)	=	1 ft
	914.4 mm	=	1 yd
	1 000.0 mm (1.0 m)	=	1 yd 3.4 in (1.093 yd)
	20.117 m	=	1 chain
	1 000.0 m (1 km)	=	0.621 mile
	1 609.31 m	=	1 mile



Area	100 mm^2 (1.0 cm^2)	=	0.155in^2
	654.2 mm^2 (6.452 cm^2)	=	1 in^2
	929.03 cm^2 (0.093 m^2)	=	1 ft^2
	0.836 m^2	=	1 yd^2
	1.0 m^2	=	1.196 yd^2 (10.763 ft^2)
	0.405 ha (4046.9 m^2)	=	1 acre
	1.0 km^2	=	0.386 mile^2
	2.59 km^2 (259 ha)	=	1 mile^2
Temperature	X°C	=	($\frac{9}{5}$ X = 32)°F
	$\frac{5}{9} \times (X - 32)$°C	=	X°F



illumination	1 lx (1 lumen/m^2)	=	0.093 ft-candle (0.093 lumen/ft^2)
	10.764 lx	=	1.0 ft-candle (1 lumen/ft^2)

Quantity	*Conversion factors*		
Mass	1.0 g	=	0.035 oz (avoirdupois)
	28.35 g	=	1 oz (avoirdupois)
	454.0 g (0.454 kg)	=	1 lb
	1 000.0 g (1 kg)	=	2.205 lb
	45.36 kg	=	1 cwt US
	907.2 kg (0.907 t)	=	1 ton US
	1 000.0 kg (1.0 t)	=	1.102 ton US
Force	1.0 N	=	0.225 lbf
	1.0 kgf (9.807 N; 1.0 kilopond)	=	2.205 lbf
	4.448 kN	=	1.0 kipf (1000 lbf)
	8.897 kN	=	1 tonf US
Force per unit length	1.0 N/m	=	0.067 lbf/ft
	14.59 N/m	=	1.0 lbf/ft
	175.1 kN/m (175.1 N/mm)	=	1.0 lbf/ft

Tables

Length

mm ↔ in

mm		in	mm		in
25.4	1	0.04	254.0	10	0.39
50.8	2	0.08	508.0	20	0.79
76.2	3	0.12	762.0	30	1.18
101.6	4	0.16	1016.0	40	1.57
127.0	5	0.2	1270.0	50	1.97
152.4	6	0.24	1524.0	60	2.36
177.8	7	0.28	1778.0	70	2.76
203.2	8	0.31	2032.0	80	3.15
228.6	9	0.35	2286.0	90	3.54
			2540.0	100	3.93

m ↔ ft

m		ft	m		ft
0.3	1	3.28	3.05	10	32.8
0.61	2	6.56	6.1	20	65.62
0.91	3	9.84	9.14	30	98.43
1.22	4	13.12	12.19	40	131.23
1.52	5	16.4	15.24	50	164.04
1.83	6	19.69	18.29	60	196.85
2.13	7	22.97	21.24	70	229.66
2.44	8	26.25	24.38	80	262.47
2.74	9	29.53	27.43	90	295.28
			30.48	100	328.08

Area

m^2 ↔ in^2

m^2		ft^2	m^2		ft^2
0.093	1	10.76	0.93	10	107.64
0.19	2	21.53	1.86	20	215.28
0.28	3	32.29	2.79	30	322.92
0.37	4	43.06	3.72	40	430.56
0.46	5	53.82	4.65	50	538.2
0.56	6	64.58	5.57	60	645.84
0.65	7	75.35	6.5	70	753.47
0.74	8	86.11	7.43	80	861.11
0.84	9	96.88	8.36	90	968.75
			9.29	100	1076.39

Volume

m^3 ↔ ft^3

m^3		ft^3	m^3		ft^3
0.03	1	35.32	0.28	10	353.15
0.06	2	70.63	0.57	20	706.29
0.08	3	105.94	0.85	30	1059.44
0.11	4	141.26	1.13	40	1412.59
0.14	5	176.57	1.42	50	1765.73
0.17	6	211.89	1.7	60	2118.88
0.2	7	247.2	1.98	70	2472.03
0.23	8	282.52	2.27	80	2825.17
0.25	9	317.83	2.55	90	3178.32
			2.83	100	3531.47

Appendix: Aircraft dimensions

This listing is based on published data on the principal civil passenger airliner types current in 1993:

Narrow-bodied jet transport aircraft

The following 26 aircraft types account for over 13 000 civilian aircraft currently using the world's airports, ranging in size from the BAe 146 to the Douglas DC8. Note that sill heights specified are to the forward port door, with the range defined both by the types of aircraft in the grouped category (if more than one) and by maximum height (being with operating empty weight) and minimum height (being with maximum ramp weight).

Aerospatiale Caravelle
Nationality: French
Number manufactured: 282 (1955–72), approx. 65 in service 1991
Number of passengers: up to 110 (5 abreast)
Wingspan: 34.30 m (112 ft 6 in)
Length: 32.01 m - 36.22 m (105 ft 0 in–118 ft 10 in)
Height: 8.72 m (28 ft 7 in)
Sill height: 2.03 m–2.18 m (80–86 in)

Airbus A320-200
Nationality: European
Number manufactured: 810 orders by May 1993, 150 for stretched version 321
Number of passengers: up to 179 (6 abreast)
Wingspan: 33.91 m (111 ft 3 in)
Length: 37.57 m (123 ft 3 in) A321 is 44.51 m (146 ft 0 in)
Height: 11.80 m (38 ft 9 in)
Sill height: 3.41 m (134 in)

Boeing 720B
Nationality: USA
Number manufactured: 154
Number of passengers: up to 167 (6 abreast)
Wingspan: 39.87 m (130 ft 10 in)
Length: 41.68 m (136 ft 9 in)
Height: 12.67 m (41 ft 7 in)
Sill height: 3.02 m–3.25 m (119–128 in)

Boeing 707-320B and C and variants
Nationality: USA
Number manufactured: over 500 (215 still in use 1990) (last delivery 1982)
Number of passengers: up to 219 (6 abreast)
Wingspan: 44.42 m (145 ft 9 in)
Length: 46.61 m (152 ft 11 in)
Height: 12.94 m (42 ft 5 in)
Sill height: 3.02 m–3.25 m (119–128 in)

Boeing 727-100 and 200
Nationality: USA
Number manufactured: 1831 (last delivery 1984)
Number of passengers: up to 189 (6 abreast)
Wingspan: 32.92 m (108 ft 0 in)
Length: 46.69 m (153 ft 2 in) note 727-100 is shorter
Height: 10.36 m (34 ft 0 in)
Sill height: 2.44 m–3.07 m (96–121 in)

Boeing 737-100 and 200
Nationality: USA
Number manufactured: 1144 (30 100s) (last delivery August 1988)
Number of passengers: up to 130 (6 abreast)
Wingspan: 28.35 m (93 ft 0 in)
Length: 30.53 m (100 ft 2 in) note 737-100 is shorter
Height: 11.28 m (37 ft 0 in)
Sill height: 2.46 m–2.64 m (97–104 in)

Boeing 737-300
Nationality: USA
Number manufactured: 990 orders by May 1993
Number of passengers: up to 149 (6 abreast)
Wingspan: 28.91 m (94 ft 10 in)
Length: 33.40 m (109 ft 7 in)
Height: 11.13 m (36 ft 6 in)
Sill height: 2.62 m–2.77 m (103–109 in)

Boeing 737-400 (a stretched 737-300)
Nationality: USA
Number manufactured: 423 orders by May 1993
Number of passengers: up to 156 (6 abreast)
Wingspan: 28.91 m (94 ft 10 in)
Length: 36.45 m (119 ft 7 in)
Height: 11.13 m (36 ft 6 in)
Sill height: 2.62 m–2.77 m (103–109 in)

Boeing 737-500 (a short-body 737-300)
Nationality: USA
Number manufactured: 272 orders by May 1993
Number of passengers: up to 132 (6 abreast)
Wingspan: 28.91 m (94 ft 10 in)
Length: 31.01 m (101 ft 9 in)
Height: 11.13 m (36 ft 6 in)
Sill height: 2.62 m–2.77 m (103–109 in)

Boeing 757-200
Nationality: USA
Number manufactured: 822 orders by May 1993
Number of passengers: up to 239 (6 abreast)
Wingspan: 37.82 m (124 ft 6 in)
Length: 47.32 m (155 ft 3 in)
Height: 13.56 m (44 ft 6 in)
Sill height: 3.78 m–4.01 m (149–158 in)

British Aerospace BAe 146-100, -200 and -300, now renamed RJ series
Nationality: UK
Number manufactured: 209 sales up to early 1993
Number of passengers: up to 112 (6 abreast)
Wingspan: 26.34 m (86 ft 5 in)
Length: 30.99 m (101 ft 8 in) 146-100 and -200 are shorter
Height: 8.61 m (28 ft 3 in)
Sill height: 1.88 m (74 in)

British Aerospace (BAC) One-eleven-500
Nationality: UK
Number manufactured: 143 (smaller Srs 200–400) and 89 Srs 500
Number of passengers: up to 119 (5 abreast)
Wingspan: 28.50 m (93 ft 6 in)
Length: 32.61 m (107 ft 0 in)
Height: 7.47 m (24 ft 6 in)
Sill height: 1.68 m–1.91 m (66–75 in)

Canadair Regional Jet
Nationality: Canada
Number manufactured: 10 deliveries by May 1993
Number of passengers: up to 50 (4 abreast)
Wingspan: 21.21 m (69 ft 7 in)
Length: 26.77 m (87 ft 10 in)
Height: 6.22 m (20 ft 5 in)
Sill height: 1.61 m (63 in)

Fokker F28 and 100
Nationality: Dutch
Number manufactured: 241 F28 (pre-1986), and 245 Fokker 100 orders by May 1993
Number of passengers: up to 119 (5 abreast)
Wingspan: 28.08 m (92 ft 1 in) F28 is smaller span and length
Length: 35.31 m (115 ft 10 in)
Height: 8.60 m (27 ft 11 in)
Sill height: 1.63 m–1.93 m (64–76 in)

Ilyushin IL-62, -62M and -62MK
Nationality: Russia
Number manufactured: over 240
Number of passengers: up to 195 (6 abreast)
Wingspan: 43.20 m (141 ft 9 in)
Length: 53.12 m (174 ft 3 in)
Height: 12.35 m (40 ft 6 in)
Sill height: 3.55 m–3.93 m (140–155 in)

McDonnell Douglas DC-8 series 10 to 50
Nationality: USA
Number manufactured: 294
Number of passengers: up to 189 (6 abreast)
Wingspan: 43.41 m (142 ft 5 in)
Length: 45.87 m (150 ft 6 in)
Height: 13.21 m (43 ft 4 in)
Sill height: 3.23 m–3.40 m (127–134 in)

McDonnell Douglas DC-8 series 60 and 70
Nationality: USA
Number manufactured: 263
Number of passengers: up to 269 (6 abreast)
Wingspan: 45.24 m (148 ft 5 in)
Length: 57.12 m (187 ft 5 in)
Height: 13.10 m (43 ft 0 in)
Sill height: 3.23 m–3.40 m (127–144 in)

McDonnell Douglas DC-9 series 10, 20 and 30
Nationality: USA
Number manufactured: 767, excluding military versions
Number of passengers: up to 115 (5 abreast)
Wingspan: 28.47 m (93 ft 5 in)
Length: 36.37 m (119 ft 4 in) Srs 30 (Srs 10 and 20 are shorter)
Height: 8.38 m (27 ft 6 in)
Sill height: 2.18 m–*2.39 m (86–94 in)*

McDonnell Douglas DC-9 series 40 and 50
Nationality: USA
Number manufactured: 167
Number of passengers: up to 139 (5 abreast)
Wingspan: 28.47 m (93 ft 5 in)
Length: 40.72 m (133 ft 7 in) Srs 50 (Srs 40 is shorter)
Height: 8.53 m (28 ft 0 in)
Sill height: 2.18 m–*2.39 m (86–94 in)*

McDonnell Douglas MD-80 series (successor to DC-9)
Nationality: USA, also China (assembly agreement 1985)
Number manufactured: 1058 deliveries by 1992
Number of passengers: up to 172 (5 abreast)
Wingspan: 32.87 m (107 ft 10 in)
Length: 45.06 m (147 ft 10 in) MD-87 is short version, length 39.70 m (130 ft 5 in)
Height: 9.04 m (29 ft 8 in)
Sill height: 2.21 m–2.39 m (87–94 in)

McDonnell Douglas MD-90 (successor to MD-80)
Nationality: USA, also China (assembly agreement 1992)
Number manufactured: 179 orders up to March 1993
Number of passengers: up to 172 (5 abreast)
Wingspan: 32.87 m (107 ft 10 in)
Length: 46.51 m (152 ft 7 in)
Height: 9.33 (30 ft 7 in)
Sill height: 2.21 m–2.39 m (87–94 in)

Tupolev TU-134A and other versions
Nationality: Russia
Number manufactured: over 700
Number of passengers: up to 84 (4 abreast)
Wingspan: 29.00 m (95 ft 2 in)
Length: 37.05 m (121 ft 6 in)
Height: 9.14 m (30 ft 0 in)
Sill height: 2.41 m–2.51 m (95–101 in)

Tupolev TU-154
Nationality: Russia
Number manufactured: nearly 1000 by 1992
Number of passengers: up to 180 (6 abreast)
Wingspan: 37.55 m (123 ft 2 in)
Length: 47.90 m (157 ft 2 in)
Height: 11.40 m (37 ft 5 in)
Sill height: 3.02 m–3.50 m (119–138 in)

Tupolev TU-204 (counterpart of B-757)
Nationality: Russia
Number manufactured: in service 1994
Number of passengers: up to 214 (6 abreast)
Wingspan: 42.00 m (137 ft 9 in)
Length: 45.00 m (147 ft 8 in)
Height: 13.90 m (45 ft 7 in)

Yakovlev YAK-40
Nationality: USSR
Number manufactured: approx 1000
Number of passengers: up to 32 (4 abreast)
Wingspan: 25.00 m (82 ft 0 in)
Length: 20.36 m (66 ft 9 in)
Height: 6.50 m (21 ft 4 in)
Sill height: 1.74 m–1.95 m (68–77 in)

Yakovlev YAK-42
Nationality: USSR
Number manufactured: approx 100 by 1990
Number of passengers: 120 (6 abreast)
Wingspan: 34.88 m (114 ft 5 in)
Length: 36.38 m (119 ft 4 in)
Height: 9.83 m (32 ft 3 in)

Wide-bodied jet transport aircraft

The following aircraft types which each carry over 300 passengers accounted in 1993 for 3000 civilian aircraft using the world's airports. They range in size up to the new Boeing 747-400, with a wingspan of over 64 metres and a fuselage of over 70 metres. Note that sill heights specified are to the forward port door, with the range defined both by the types of aircraft in the grouped category (if more than one) and by maximum height (being with operating empty weight) and minimum height (being with maximum ramp weight).

Airliner: Airbus A300 various versions
Nationality: European
Number manufactured: 481 orders up to May 1993 (400 delivered)
Number of passengers: up to 344 (up to 9 abreast)
Wingspan: 44.84 m (147 ft 1 in)
Length: 54.08 m (177 ft 5 in)
Height: 16.62 m (54 ft 6 in)
Sill height: 4.42 m–4.67 m (174–184 in)
Size data for A300-600: note that 300B2 and 300B4 are shorter

Airliner: Airbus A310
Nationality: European
Number manufactured: 265 orders by May 1993 (231 delivered)
Number of passengers: up to 280 (up to 9 abreast)
Wingspan: 43.90 m (144 ft 0 in)
Length: 46.66 m (153 ft 1 in)
Height: 15.81 m (51 ft 10 in)
Sill height: 4.41 m–4.55 m (174–179 in)

Airbus A330-300 (2 engines) and A340-300 (4 engine version)
Nationality: European
Number manufactured: 243 orders for A330 and A340 by May 1993 (first deliveries March 1993)
Number of passengers: up to 440 (up to 9 abreast)
Wingspan: 60.03 m (197 ft 10 in)
Length: 63.65 m (208 ft 10 in)
Height: 16.74 m (54 ft 11 in)

Airbus A340-200 (longer range version of A340-300)
Nationality: European
Number manufactured: (first two deliveries March 1993)
Number of passengers: up to 303 (up to 9 abreast)
Wingspan: 60.03 m (197 ft 10 in)
Length: 59.39 m (194 ft 10 in)
Height: 16.74 m (54 ft 11 in)

Boeing 747-100, 200 and 300
Nationality: USA
Number manufactured: 724
Number of passengers: up to 516 (Srs–300 624) (10 abreast)
Wingspan: 59.64 m (195 ft 8 in)
Length: 70.67 m (231 ft 10 in)
Height: 19.30 m (63 ft 4 in)
Sill height: 4.65 m–5.36 m (183–211 in)

Boeing 747-400
Nationality: USA
Number manufactured: 464 orders by May 1993 (246 delivered)
Number of passengers: up to 660 (11 abreast)
Wingspan: 64.67 m (212 ft 2 in)
Length: 70.67 m (231 ft 10 in)
Height: 19.30 m (63 ft 4 in)
Sill height: 4.65 m–5.36 m (183–211 in)

Boeing 747SP
Nationality: USA
Number manufactured: 43
Number of passengers: up to 440 (11 abreast)
Wingspan: 59.64 m (195 ft 8 in)
Length: 56.31 m (184 ft 9 in)
Height: 19.94 m (65 ft 5 in)
Sill height: 4.78 m–4.98 m (188–196 in)

Boeing 767-200
Nationality: USA
Number manufactured: 218 orders by May 1993 (215 delivered)
Number of passengers: up to 290 (8 abreast)
Wingspan: 47.57 m (156 ft 1 in)
Length: 48.51 m (159 ft 2 in)
Height: 15.85 m (52 ft 0 in)
Sill height: 4.11 m–4.32 m (162–170 in)

Boeing 767-300
Nationality: USA
Number manufactured: 375 orders by May 1993 (264 delivered)
Number of passengers: up to 330 (8 abreast)
Wingspan: 47.57 m (156 ft 1 in)
Length: 54.94 m (180 ft 3 in)
Height: 15.85 m (52 ft 0 in)
Sill height: 4.11 m-4.32 m (162–170 in)

Boeing 777-200
Nationality: USA
Number manufactured: 118 orders by May 1993
Number of passengers: up to 440 (10 abreast)
Wingspan: 60.95 m (199 ft 11 in) note folding wing option reduces
Length: 63.73 m (209 ft 1 in)
Height: 18.45 m (60 ft 6 in)
Sill height: 4.71 m (15 ft 5 in)

Ilyushin IL-86
Nationality: Russia
Number manufactured: 97 by May 1993
Number of passengers: up to 350 (9 abreast)
Wingspan: 48.06 m (157 ft 8 in)
Length: 59.54 m (195 ft 4 in)
Height: 15.81 m (51 ft 10 in)
Sill height: 4.46 m–5.00 m (176–197 in)

Ilyushin IL-96–300
Nationality: Russia
Number manufactured: approx 65 ordered (first deliveries 1993)
Number of passengers: up to 300 (9 abreast)
Wingspan: 57.66 m (189 ft 2 in)
Length: 55.35 m (181 ft 7 in)
Height: 17.57 m (57 ft 8 in)
Sill height: 4.54 m (14 ft 10 in)

Lockheed L-1011–100 and 200 Tristar
Nationality: USA
Number manufactured: 249 (including 500 series) (last delivery 1984)
Number of passengers: up to 400 (10 abreast)
Wingspan: 47.34 m (155 ft 4 in)
Length: 54.17 m (177 ft 8 in)
Height: 16.87 m (55 ft 4 in)
Sill height: 4.62 m–4.72 m (182–186 in)

Lockheed L-1011–500 Tristar
Nationality: USA
Number manufactured: see 100 and 200 series data
Number of passengers: up to 330 (10 abreast)
Wingspan: 50.09 m (164 ft 4 in)
Length: 50.05 m (164 ft 2 in)
Height: 16.87 m (55 ft 4 in)
Sill height: 4.57 m–4.88 m (180–192 in)

McDonnell Douglas DC-10 series 30 (also series 10)
Nationality: USA
Number manufactured: 386 (last delivery 1989)
Number of passengers: up to 380 (10 abreast)
Wingspan: 50.40 m (165 ft 4 in) srs 10 is less
Length: 55.50 m (182 ft 1 in) srs 10 is 0.35 m longer
Height: 17.70 m (58 ft 1 in)
Sill height: 4.72 m–5.16 m (186–203 in)

McDonnell Douglas MD-11 (successor to DC-10)
Nationality: USA
Number manufactured: 100 deliveries by June 1993
Number of passengers: up to 405 (10 abreast)
Wingspan: 51.70 m (169 ft 6 in)
Length: 61.21 m (200 ft 10 in)
Height: 17.60 m (57 ft 9 in)

Supersonic jet transport aircraft

Aerospatiale/BAe Concorde
Nationality: Anglo-French
Number manufactured: 14
Number of passengers: 128–144 (4 abreast)
Wingspan: 25.56 m (83 ft 10 in)
Length: 62.17 m (203 ft 9 in)
Height: 11.40 m (37 ft 5 in)
Sill height: 4.55 m–4.88 m (179–192 in)

Turboprop transport aircraft

This range of aircraft types, 14 in number and with seats for up to 70 passengers, accounts for over 3000 civilian aircraft, excluding obsolete and fast-disappearing types.

Aerospatiale/Alenia ATR42
Nationality: Franco-Italian
Number manufactured: 273 orders by 1993 (238 delivered)
Number of passengers: up to 50 (4 abreast)
Wingspan: 24.57 m (80 ft 7 in)
Length: 22.67 m (74 ft 4 in)
Height: 7.59 m (24 ft 11 in)

Aerospatiale/Alenia ATR72
Nationality: Franco-Italian
Number manufactured: 203 orders by 1993 (77 delivered)
Number of passengers: up to 74 (4 abreast)
Wingspan: 27.05 m (88 ft 9 in)
Length: 27.17 m (89 ft 1 in)
Height: 7.65 m (25 ft 1 in)

Antonov AN-24 and XAC Y-7
Nationality: Ukraine and subsequently China
Number manufactured: over 1000 (pre 1978) and 83 (by 1993 in China)
Number of passengers: up to 50 (4 abreast)
Wingspan: 29.20 m (95 ft 9 in)
Length: 23.53 m (77 ft 2 in)
Height: 8.32 m (27 ft 3 in)

British Aerospace ATP and upgraded version named Jetstream 61
Nationality: UK
Number manufactured: 59 orders by 1993 (51 delivered)
Number of passengers: up to 72 (4 abreast)
Wingspan: 30.63 m (100 ft 6 in)
Length: 26.06 m (85 ft 4 in)
Height: 7.14 m (23 ft 5 in)

British Aerospace HS.748 series 2B
Nationality: UK
Number manufactured: 382 (1960–88), approx 160 in service 1991.
Number of passengers: 48–58 (4 abreast)
Wingspan: 31.24 m (102 ft 6 in)
Length: 20.42 m (67 ft 0 in)
Height: 7.57 m (24 ft 10 in)

De Havilland Canada Dash 7
Nationality: Canadian
Number manufactured: 111 (1975–88)
Number of passengers: up to 54 (4 abreast)
Wingspan: 28.35 m (93 ft 0 in)
Length: 24.54 m (80 ft 6 in)
Height: 7.98 m (26 ft 2 in)

De Havilland Canada Dash 8 Series 100 and 300
Nationality: Canadian
Number manufactured: 285/113 orders by June 1993 for 100/300 (257/84 delivered)
Number of passengers: up to 36 (srs100) or 56 (srs300) (4 abreast)
Wingspan: 27.43 m (90 ft 0 in) 100 is smaller span and length
Length: 25.68 m (84 ft 3 in)
Height: 7.49 m (24 ft 7 in)

Dornier 328
Nationality: German
Number manufactured: 45 orders by June 1993
Number of passengers: up to 39 (4 abreast)
Wingspan: 20.98 m (68 ft 10 in)
Length: 21.22 m (69 ft 8 in)
Height: 7.24 m (23 ft 9 in)

Embraer Brasilia
Nationality: Brazilian
Number manufactured: 323 orders by June 1993 (266 delivered)
Number of passengers: up to 30 (3 abreast)
Wingspan: 19.78 m (64 ft 11 in)
Length: 20.00 m (65 ft 7 in)
Height: 6.35 m (20 ft 10 in)

Fokker F27 and 50
Nationality: Dutch, also US version by Fairchild
Number manufactured: 786 F27 and 182 Fokker 50 orders by June 1993 (150 delivered)
Number of passengers: up to 60 (4 abreast)
Wingspan: 29.00 m (95 ft 2 in)
Length: 25.25 m (82 ft 10 in) F27 slightly smaller
Height: 8.60 m (28 ft 7 in)

Ilyushin IL-114
Nationality: Russia
Number manufactured: approx 350 planned (first deliveries 1993)
Number of passengers: up to 68 (4 abreast)
Wingspan: 30.00 m (98 ft 5 in)
Length: 26.31 m (86 ft 4 in)
Height: 9.32 m (30 ft 7 in)

Saab 340
Nationality: Swedish
Number manufactured: 398 orders by May 1993 (326 delivered)
Number of passengers: 35 (3 abreast)
Wingspan: 21.44 m (70 ft 4 in)
Length: 19.67 m (64 ft 6 in)
Height: 6.87 m (22 ft 6 in)

Saab 2000
Nationality: Swedish
Number manufactured: 46 orders by April 1993 (deliveries 1993)
Number of passengers: up to 58 (3 abreast)
Wingspan: 24.76 m (81 ft 3 in)
Length: 27.03 m (88 ft 8 in)
Height: 7.73 m (25 ft 4 in)

Shorts 330 and 360
Nationality: British
Number manufactured: 136 (330) and 164 (360) (last delivery 1992)
Number of passengers: up to 39 (3 abreast)
Wingspan: 22.81 m (74 ft 10 in)
Length: 21.59 m (70 ft 10 in) } data for 360; 330 is smaller
Height: 7.21 m (23 ft 8 in)

Bibliography

General references

Allen, R. (1983) *Major Airports of the World.* London: Ian Allan.

Ashford, N. J., Stanton, H. P. M. and Moore, C. A. (1984) *Airport Operations.* Revised by Pitman, 1991. New York: Wiley Interscience.

Ashford, N. J. and Moore, C. A. (1992) *Airport Finance.* New York: Van Nostrand-Rheinhold.

Ashford, N and Wright, P. H. (1992) *Airport Engineering* (3rd Edition). New York: Wiley Interscience.

Blankenship, E. C. (1974) *The Airport.* London: Pall Mall Press.

Civil Aviation Authority (1990) *CAP168 Licensing of Aerodromes* (4th edition). London: Civil Aviation Authority.

de Neufville, R. (1976) *Airport Systems Planning.* London: Macmillan.

Doganis, R. (1992) *The Airport Business.* London: Routledge.

Greif, M. (1979) *The Airport Book.* New York: Mayflower Books.

Hart, W. (1986) *The Airport Passenger Terminal.* New York: Wiley Interscience.

Horonjeff, R. and McKelvey, F. X. (1994) *Planning and Design of Airports* (4th edition). New York: McGraw-Hill.

Hudson, K. and Pettifer, J. (1979) *Diamonds in the Sky.* London: The Bodley Head and the British Broadcasting Corporation.

Hudson, M. G. (ed.) (1988) *Airport Technology International 1988.* London: Sterling Publications.

Hudson, M. G. (ed.) (1989) *Airport Technology International 1989/90.* London: Sterling Publications.

Hudson, M. G. (ed.) (1990) *Airport Technology International 1990/91.* London: Sterling Publications.

Hudson, M. G. (ed.) (1991) *Airport Technology International 1992.* London: Sterling Publications.

Institution of Civil Engineers (1976) *Proceedings of the 5th World Airports Conference, The Challenging Future* (London 1976). London: Thomas Telford.

Institution of Civil Engineers (1980) *Proceedings of the 6th World Airports Conference, Airports for the Community* (London 1979). London: Thomas Telford.

Institution of Civil Engineers (1984) *Proceedings of the 7th World Airports Conference, Economics of Air Transportation* (London 1983). London: Thomas Telford.

Institution of Civil Engineers (1988) *Proceedings of the 8th World Airports Conference, Airports for People* (London 1987). London: Thomas Telford.

Institution of Civil Engineers, edited by G. M. Crook (1992) *Proceedings of the 9th World Airports Conference, Airports and automation* (London 1991). London: Thomas Telford.

Institution of Civil Engineers (in preparation). *Proceedings of the 10th World Airports Conference, Airport Capacity and Development Funding* (Hong Kong 1994). London: Thomas Telford.

International Civil Aviation Organization (1985) *Aerodrome Planning Manual, Land Use and Environmental Control,* document 9184 pt 2 (2nd edition). Montreal: ICAO.

International Civil Aviation Organization (1987) *Aerodrome Planning Manual, Master Planning,* document 9184 pt 1 (2nd edition). Montreal: ICAO.

International Civil Aviation Organization (1990) *Aerodromes, Volume 1: Aerodrome design and Operations: International standards and recommended practices,* Annex 14 to the Convention on International Civil Aviation (1st edition). Montreal: ICAO.

International Civil Aviation Organization (1991) *Aerodrome Design Manual, Taxiways, Aprons and Holding Bays,* document 9157 pt 2 (3rd edition). Montreal: ICAO.

International Civil Aviation Organization (1992) *Outlook for Air Transport to the year 2001* (Circ. 237). Montreal: ICAO.

Papagiorcopulo, G. (ed.) (1992) *Airport Technology International 1993.* London: Sterling Publications.

Papagiorcopulo, G. (ed.) (1993) *Airport Technology International 1993/94.* London: Sterling Publications.

Papagiorcopulo, G. (ed.) (1994) *Airport Technology International 1994/95.* London: Sterling Publications.

Phipps, D. (1991) *The Management of Aviation Security.* London: Pitman.

Stroud, J. (1980) *Airports of the World.* London: Putnam Aeronautical Books (out of print).

Vulliamy, J. (1985) *Airport passenger and cargo terminals*. In *Planning* (10th edition) (edited by E. D. Mills). Oxford: Butterworth-Heinemann.
Wells, A. T. (1992) *Airport Planning and Management* (2nd edition). Blue Ridge Summit, PA, USA: McGraw-Hill.
Woolley, D. (ed.) (1987) *Airport Technology International 1987*. London: Sterling Publications.
Wright, A. J. (1989) *European Airports*. London: Ian Allan.
Wright, A. J. (1991) *British Airports* (4th edition). London: Ian Allan.
Wright, A. J. (1992) *World Airports*, London: Ian Allan.

Magazines

Airport Business Management & Development, published ten times a year by Euromoney Plc, Nestor House, Playhouse Yard, London EC4V 5EX.
Airport Forum, published six times a year by Vereinigte Motor-Verlage GmbH, Leuschnerstrasse 1, PO Box 10 60 36, D-70162, Stuttgart, Germany. In English.
Airports International, published ten times a year by SKC Communications Ltd, Southfields, South View Road, Wadhurst, East Sussex TN5 6TP.
Jane's Airport Review, published ten times a year by Jane's Information Group, Sentinel House, 163 Brighton Road, Coulsdon, Surrey CR5 2NH.

Trade handbooks

British Airport Equipment Catalogue 1994–1995 (6th edition). Combined Services Publications Ltd, PO Box 4, Farnborough, Hants GU14 7LR.
Jane's Airports, Equipment and Services 1994–95 (13th edition). Special sections on Terminal Operations (Passenger handling) and Apron Equipment (Passenger handling). Jane's Information Group, Sentinel House, 163 Brighton Road, Coulsdon, Surrey CR5 2NH.

Other periodicals

AIA Journal, American Institute of Architects, NY.
Architects' Journal, Emap Business Communications Ltd, London.
Architectural Design, Academy Group, London.
Architectural Record, McGraw-Hill Publications, Maidenhead, UK.
Architectural Review, Emap Business Communications Ltd, London.
Architecture Today, Architecture Today plc, London.
Building, The Builder Group, London.
Building Design, Miller Freeman Publishers Ltd, London.
Building Services, The Builder Group, London.
Designers' Journal, Emap Business Communications Ltd, London.
Journal of Air Transport Management, Elsevier Science Ltd, Oxford, UK.
New Builder, Thomas Telford Ltd, London.
Public Transportation, The Bloomsbury Partnership, London.
RIBA Journal, the journal of the Royal Institute of British Architects, The Builder Group, London.
Surveyor, Reed Business Publishing Group, Sutton, UK.
Transportation Planning and Technology, Gordon and Breach Science Publishers, Kingston, UK.

Computer models, related to terminal design

CAPASS, Airport Terminal Capacity Programme, designed by the International Air Transport Association to assist airport planners and managers to determine sizes of various major functional elements to handle a given passenger throughput, or conversely, to determine the passenger throughput capability of existing or proposed facilities.
Details from: IATA, 2000 Peel St, Montreal, Canada, H3A 2R4. Fax: (514) 8446727.

TMS, designed by The Preston Group Pty Ltd, to help airport authorities and airline companies manage their airport terminal resources and facilities. Individual modules relate to apron bays, stands and gates, check-in counters, gate lounges, baggage resources, airside buses and passenger flow simulation. Other products include TAAM, Total Airspace and Airport Modeller, which enables aviation authorities, airports and airlines to find solutions to problems with airspace and airport congestion.
Details from: The Preston Group.
Head office: 488 Victoria St, Richmond, Victoria 3121, Australia. Fax: (61) 3-4271969.
European office: 4th Flr, Bechtel Ho., 245 Hammersmith Rd, London, W6 8PW. Fax: (44) 181-8951150.

ARCTERM, designed by Aviation Research Corporation, to assist planning, evaluating staffing, analysing stand allocation strategies, and much more. It offers complete animation of people movement.
Details from: Aviation Research Corporation, 515 Chemin de L'Anse, Vaudreuil, Montreal, Canada, J7V 8P3. Fax: (514) 4552242.

PAXPORT, designed by Halcrow Fox for BAA plc, is a model which simulates the movement of people throughout airport terminals, helping to identify congestion and levels of service. Aspects of an airport which can be modelled interactively include: check-in; baggage retrieval; baggage screening; information and ticket desks; passport control; use of commercial facilities; rail/transit interaction.
Details from: Halcrow Fox, Vineyard House, 44 Brook Green, Hammersmith, London W6 7BY. Fax (44) 171-6035783.

Glossary

This list is not exhaustive but is a useful series of definitions and abbreviations, especially where words have a special meaning in the context of airport passenger terminals.

Airside: That area of the airport under jurisdiction of government control authorities or, where this does not apply, that area with immediate access to the apron.
Apron: The area on the airside of the terminal where aircraft manoeuvre and park.
APU: Auxiliary power unit.
Arrivals: Passengers arriving by air, whether terminating, transferring or transiting.
ATB: Automated ticketing and boarding pass issuing.
Baggage make-up: The assembly of flightloads of baggage.
Check-in: Where passengers present their tickets and such baggage as they wish to be carried in the hold of the aircraft.
CIP: commercially important passengers – those travelling business or first class.
Common check-in: Where all check-in facilities are operated by one airline or agent.
Contact stands: Aircraft parking positions served by direct bridges to and from the terminal.
CUTE: Common-user terminal equipment (at the check-in desk).
DCV: Destination-coded vehicle.
Departures: Passengers departing by air whether originating, transferring or transiting.
Design year: The year chosen as a basis for design.
Gate: The point of passenger access to the aircraft or apron and vice versa.
Gate lounge/hold room: Area adjacent to the gate for assembling departing passengers.
FIDS: Flight information display system.
Hand baggage or cabin baggage: Carried on to the aircraft by passengers.
Handling agent: Company providing services to airlines for check-in, baggage, etc.
Hold baggage: Checked in for carriage in the hold of the aircraft.
Landside: The area of the terminal to which the public has access.
Loading bridge: Adjustable enclosed bridge linking aircraft and terminal.
Pax: Passengers.
Peak hour: Defined period when highest traffic activity occurs or is predicted to occur.
Ramp: Apron.
Remote stand: Aircraft parking position not served by direct bridge.
Security/screening: Screening of passengers and baggage to check that no prohibited items are carried into the secure areas of the terminal or on to aircraft.
Segregation: Separation of arriving passengers and departing passengers in airside areas for reasons of security and avoidance of cross flow.
Taxilane: Part of an apron designated as a taxiway and providing access to aircraft stands only.
Taxiway: Defined path for movement of aircraft from one part of airfield to another.
Transfers: Passengers arriving by one flight and continuing journey by another.
Transits: Passengers arriving and departing by the same flight.
ULD: Unit load device or baggage container.

Index

Illustrations are indicated by page numbers in italics

In the five years since publication of the first edition, many new airport terminals and facilities have been completed, including those at Kansai, Denver Colorado, Munich, Macau, Chicago, Southampton, Amsterdam, Frankfurt, Manchester, Birmingham Eurohub, Gatwick North, amongst others. There have been new designs for Moscow, Hong Kong, Heathrow, Bangkok and Kuala Lumpur. These last five years have also seen improvements in baggage security, privatization, more plans for the NLA, the arrival of the B3777 and sub-apron services at Stockholm Arlanda. All these new terminals and improvements are included in this updated edition of Chris Blow's book.

Airport passenger terminals have developed to be a major new public building-type representing transportation in the late twentieth century. The functional planning of facilities for aircraft and people, and the architectural forms to accommodate them, are of great interest to designers and the myriad of people who work in, and visit, airports. The book is a discourse rather than a design guide. It is written for an international readership and illustrated from the author's experience. The reader is first given a review of airport design principles as they affect the design of terminal buildings. This is supported by features on London Gatwick's original 1934 'beehive' terminal and hub terminals, designed for airlines to cater for passengers transferring between their flights, come in for special mention. The author recognizes the organic nature of modern technologically-derived buildings with a taxonomy of recent airport terminals of seven principal forms, showing how these forms are each responsive to the scale of the relevant operation and the demands of aircraft movement and passenger circulation.

Knowing that the airport terminal sits between ground transport and air transport, the author gives detailed descriptions of ground transport's needs at the terminal, the terminal building itself and the air transport's needs when on the ground at the terminal. There is a series of features on the re-development of existing airport terminals, a pointer to the future facing many designs and new technology and larger aircraft.

Christopher Blow is a director of Scott Brownrigg & Turner Ltd, architects with wide experience over twenty years of the design of airport facilities. He has personally been involved in projects throughout the UK, Europe, the Middle East, the Far East and Africa.

Architectural Press
An imprint of Butterworth-Heinemann
http://www.bh.com

ISBN 0-7506-2585-6
9 780750 625852